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Because we are here: a new approach to the history of the anthropic principle

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**Because we are here:
a new approach to the history of the anthropic principle**

by

Blair Robert-Wilton Williams

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

Major: History of Technology and Science

Program of Study Committee:
Matthew Stanley, Major Professor
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Ames, Iowa

2007

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Preface

Physicist John Archibald Wheeler once wrote that “it is not necessary to understand every point about the quantum principle in order to understand something about it.”¹ With great appreciation of this spirit, I present the history of the anthropic principle. Few humans—whether scientist, philosopher, or historian—would dare admit they understand the astute complexity of life and its place in the universe, but nonetheless careers have been made and lost on these very arguments. Though I lack the skills in mathematics and physical science to participate in the current debate on the anthropic principle, I possess ample historical skills to comment on its development.

The danger in addressing an ongoing issue lies in the confusion of analysis and argumentation. I will neither glorify nor assault the anthropic principle. The role of the historian is to present arguments both elegant and dross, to *illuminate* the means by which the world works while not *defeating* the very subject at hand. I do not wish to be involved in the debate over the anthropic principle, but rather to analyze and comment on its development.

This paper has been a labor of love, in more ways than one. Since walking into Matt Stanley’s office on March 4, 2006 and choosing this topic over all others, the paper and my life have changed beyond my wildest imaginations. Over the past year I have lived in six different places, seen my family through illness and

¹ John Archibald Wheeler, “Observer Created Reality,” *The Tests of Time: Readings in the Development of Physical Theory*, eds. Lisa Dolling, Arthur Gianelli, Glenn Statile, (Princeton: Princeton University Press, 2003), 492.

unemployment, and had my girlfriend become a best friend. As this all happened, the thesis changed from a simple catalog of historical events into three unique historical claims, something I never foresaw a year ago. A year later, almost to the day, I am happy to say the thesis, and I, survived.

I would like to acknowledge many people for their help in producing this paper. To all the coffee shops I sat in for hours and bought only a small soda: I apologize. Your internet was much appreciated. To my advising professors and colleagues I send my thanks for a helpful and patient ear. Matt Stanley, in particular, deserves many thanks for reading and commenting on numerous drafts. To Meghan I credit all my smiles—the best gift she ever gave me. To my dad I give infinite gratitude for all his hard work; if it wasn't for his lessons I would still be making minimum wage at the bookstore. And no words represent my gratitude to my mother. She taught me love is just too valuable to feel for even a second without it. Her courage is my courage.

And to those debating the anthropic principle—may you one day find an answer. If it really is the accidental universe, then the writing of this paper is just a cosmic coincidence.

Introduction

Coined in 1973 by theoretical physicist Brandon Carter, the anthropic principle argues, to varying degrees, that life and the universe are intimately connected. Generally limited to the field of cosmology, to this day it remains a tantalizing yet extremely controversial subject. Much of the scientific debate surrounds the principle's explanatory power—can humans use their own existence to recognize limits on the physical laws of the cosmos? Despite having supporters that count as 'super-stars' of cosmology—Stephen Hawking, Martin Rees, Paul Davies, among others—the anthropic principle may be the scientific tenet least understood by historians. In fact, no historian has given significant coverage to the principle's development or dissemination. The treatment provided by philosophers and scientists is admittedly excellent, but tends to gravitate toward the principle's validity, and neglects the very interesting discussion of the scientific milieu into which the anthropic principle was born. This thesis argues the anthropic principle is a product of twentieth century science and scientists, the result of cosmologists trying to understand the place and role of humankind in the cosmos.

The fashionable account of the anthropic principle, told in so many popular science books, goes like this: the universe is big. Very big. And old. In fact, the universe is so big and old that its basic elements of quarks and photons had enough time to coalesce into mostly hydrogen and some helium and then into billions of stars collected into billions of galaxies. After a few million years these first stars died by means of a massive explosion known as a supernova, and cast off the products of its

stellar furnace, complex elements like carbon and iron. New stars formed from this cosmic flotsam and congregated into new galaxies. After thirteen billion years, at least one star in this vast, practically empty space found itself the owner of a planet teeming with life. Among this life was a group of men and women who called themselves astronomers, curious folks who watched the stars and asked how they arrived on this small planet. Eventually some of them questioned if their own existence could reveal any fundamental rules about the universe they called home. Some astronomers said the existence of humans could help in understanding some very complex laws of the universe, while others explored the possibility that every vast stretch of the cosmos and every burning star conspired to produce life on exactly one planet: the earth. Despite the different intentions and explanations and even disagreements on whether there was a designer of the universe or a great cosmic contingency, when they spoke of their ideas they called it the *anthropic principle*.

Hopefully it is clear that the ambiguity of the term ‘anthropic principle’ needs to be addressed first. Scientists supporting the anthropic principle tend to pick a favorite flavor while retaining the original trope, resulting in over thirty different definitions.² Not only does this endanger an historical account through imprecise terms, it leaves the reader fearing that the anthropic principle is really a sort of scientific street slang! By the 1980s, Carter lamented his misnomer and admitted he should have instead used *self-selection principle*, for it referenced not humans but

² Nick Bostrom, *Anthropic Bias: Observation Selection Effects in Science and Philosophy* (New York: Routledge, 2002), 6.

intelligent life in general.³ The ‘anthropic principle’ label persists today for many reasons, chief among them popular familiarity. Before declaring this paper’s definition of the anthropic principle, it would do well to familiarize the reader with its structural components and then explain its more popular versions.

The anthropic principle is an instance of an ‘observation selection effect.’⁴ This is a recent philosophical categorization largely absent from the initial publications, but it aids in understanding the historical development. To begin, a selection effect is a distorted interpretation of statistical analysis stemming from the methodology of collecting data, perhaps best illustrated in a famous fishing story by the astronomer Arthur Eddington. If the fisherman, upon reeling in his net, realizes he has collected no fish less than two inches long, is it safe to say there are no tiny fish in the lake? Well, not if the net is made of three-inch wide gaps—smaller fish would swim right through and never be collected. In the case of the anthropic principle, the selection effect is that humankind is the only known intelligent life form, so any anthropic arguments need to at least satisfy the existence of humans. That assertion is grounds for some of the most heated debates surrounding the anthropic principle and has been covered in numerous volumes elsewhere.⁵ An observation effect is the act of making the measurement and as a result modifying the sample, which for the

³ Brandon Carter and W.H. McCrea, “The Anthropic Principle and its Implications for Biological Evolution,” *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences* 310, No. 1512, The Constants of Physics, (Dec 20, 1983), 348

⁴ This is covered thoroughly throughout Bostrom, *Anthropic Bias*.

⁵ Maybe the best example is John Barrow and Frank Tipler, *The Anthropic Cosmological Principle*, (Oxford: Clarendon Press, 1986), where they are adamant that humanity is the only kind of life possible in the universe. Maybe the most famous response comes from Martin Gardner, “WAP, SAP, PAP, & FAP” *The New York Review of Books* 33, no. 8 (May 8, 1986): 22-25. Here, Gardner responds to Barrow and Tipler’s denial of extraterrestrial life by recommending the CRAP—“the Completely Ridiculous Anthropic Principle.”

anthropic principle means that an observer reveals details of its environment.

Therefore, the observation selection effect of the anthropic principle is the impact made on statistical data brought about by the fact that humans are making the observation. Controversy develops when scientists explain particular properties of the universe solely by appeal to humans.

Much of the debate surrounds what many consider to be the canonical book on the subject: *The Anthropic Cosmological Principle* by John Barrow and Frank Tipler. It is a multi-faceted text, acting both as an introduction and defense of the anthropic principle. The authors present two hundred pages of history spanning from ancient Greece to modern teleological movements, four different interpretations of the principle, and propose some controversial arguments for the sustainability of life throughout the universe. Before discussing the book's historiographical role, I will explain the distinction between the original anthropic principle and Barrow and Tipler's version. The differences between the principles are subtle but discernable, and covered at length in chapter two of this thesis.

Brandon Carter introduced two anthropic principles in 1973: the *weak* and the *strong*. The weak anthropic principle argued that the location in which intelligent life resided in space and time must be compatible with its existence. As an example, he explained humanity could not inhabit a universe filled with very hot stars or very cold stars. This argument limited itself to explaining why humanity does not live in a random corner of the universe at any given time, but rather at a somewhat 'privileged' location and time—on the earth approximately 13 billion years after the Big Bang. The strong anthropic principle took that argument beyond location and

claimed that the universe “must be such as to admit the creation of observers within it at some stage.”⁶ Here is how Carter saw the difference between the two: 1) the weak anthropic principle applied to the current layout of the universe—since life existed, any proposed cosmological model must agree with that fact; 2) the strong anthropic principle applied to the fundamental parameters at the beginning of the universe—given that life now exists, the fundamental parameters must form a universe that will eventually produce life. Of all statements, the strong anthropic principle was the most misinterpreted. Carter did not mean that the universe was set-up or designed for the purposes of creating human life; rather, he meant when scientists discussed problems on the fundamental parameters of the universe—a common topic in cosmology—the obvious existence of man precluded any theory which would create an uninhabitable universe. This is explained in detail in chapter two.

Barrow and Tipler, however, interpret the anthropic principle to mean that the universe is ‘designed’—not necessarily in the sense that it is done by an omniscient being, but in the sense that the universe is set-up for human life. Their weak anthropic principle requires life to be in a specific location suitable for its development, and their strong anthropic principle states: “The Universe must have those properties which allow life to develop within it at some stage in its history.”⁷ This difference in interpretation then explains why the two realms of anthropic principles are *very* different in nature. Carter’s principles are tautological, in the sense that since humans

⁶ Brandon Carter, “Large Number Coincidences and The Anthropic Principle in Cosmology,” *Confrontation of Cosmological Theories With Observational Data*, ed. M.S. Longair (Dordrecht, Holland: D. Reidel Publishing Co., 1974) [Symposium No. 63 (Copernicus Symposium II) Held in Cracow, Poland, 10-12 September 1973], 294.

⁷ Barrow and Tipler, 21.

exist, they must do so in a universe generally compatible with their existence. In this case, scientists should use the existence of humans as a way to rule out cosmological theories incongruent with the observed existence of life. Comparatively, Barrow and Tipler's principles are teleological, in the sense that they assume the universe to be organized for the eventual development and subsistence of intelligent life. In this case, scientists should expect to find the fundamental parameters of nature very 'fine-tuned' for the existence of life. This subtle difference in interpretations—the winnowing of cosmological theories vs. fine-tuning—is almost always overlooked and leads to the confusion of tautology vs. teleology. Chapter three of this thesis will address the development of the gap between forms of the anthropic principle.

This difference in interpretation then places the historiographical role of Barrow and Tipler on shaky ground. While certainly not intended to be a duplicitous history of the anthropic principle, their history of teleology in science has very little to do with Carter's original development of the anthropic principle. Their account is very much a practitioner history and lends itself to the feeling that the anthropic principle has always been around and just needed somebody to name it. The authors have their right to make this claim, but it paints an incomplete picture of the scientific milieu surrounding the development of modern selection effects and the development of the anthropic principle.

Barrow and Tipler do an excellent service in developing a linear progression of every possible equation and observation that could possibly develop into an anthropic explanation. No reader could digest their history without grasping the broad context from which anthropic explanations developed. Their book is responsible for

encapsulating the anthropic principle as a cogent idea and presenting it to a mass audience. It is also, however, responsible for instigating the confusion of principles. As for the first use of the anthropic principle, they bestow that honor upon physicist Robert Dicke from 1957-1961. In this case, Dicke published several articles refuting physicist Paul Dirac's time-dependent gravitational theory by arguing that humans must live in a very specific time in the universe. As far as a scientific account goes, one could ask for no better work than Barrow and Tipler's.

However, their history underestimates the role that the nascent field of cosmology played in permitting non-traditional explanations to flourish. As an environment catering to wide interests, cosmologists entertained legitimate philosophical arguments in addition to observational evidence. By rearranging the historical development to view cosmology as a field for growing new ideas, it is easier to trace the trends that would develop into the anthropic principle. The history then focuses on the growing use of 'metascientific' principles, arguments that make scientific claims without observational evidence, such as Mach's principle and the Copernican principle.

The historian must then recognize that the development of the anthropic principle is epiphenomenal to the development of cosmology. Its intellectual roots are then shifted from the 1960s to the early days of cosmology in the 1920s and 1930s. An historian should understand the corresponding influences behind Brandon Carter and Robert Dicke, which are Arthur Eddington and Paul Dirac. Although present in Barrow and Tipler's history, these figures act as steps toward more fruitful

explanations. A closer examination will reveal that anthropic-like arguments existed in the discourse of cosmology as early as Arthur Eddington.

By refocusing on cosmology as the scientific background for the use of these metascientific principles, the development of the anthropic principle no longer seems like an inevitable outcome dependent to the gradual collection of data. Eddington believed that physical laws could exist only so far as the mind could comprehend them. This he called 'selective subjectivism,' in that the mind acted as the selection effect to understanding the universe. Then as scientists proposed and debated the Big Bang model and the Steady-State model, they disagreed over the significance of the Copernican principle and Mach's principle. The former asserted that no place in a homogeneous universe was privileged in terms of location; while the latter argued against the Newtonian absolute frame reference by saying motion was meaningless without reference to an object's interaction with the entire universe. These principles made science-like explanations by asserting that the universe must be a certain way, but until the 1950s were generally considered philosophy incompatible with observational evidence. As the discipline of cosmology developed, it became more receptive to utilizing these metascientific principles alongside observational evidence. The best example would be Dicke's 1961 article arguing that the laws of the universe must be somewhat limited through appeal to Mach's principle: that whatever the mass distribution of the universe, it must be distributed so as to allow for the existence of the physicists that observe it.⁸

⁸ Dicke, "Dirac's Cosmology and Mach's Principle," 440-441.

As an evolution of scientific discourse, then, an historical understanding of the anthropic principle should consider it as a cosmological model in reaction to and superceding Mach's principle and the Copernican principle. Specifically, it rejects the Copernican principle and presents a neo-Machian principle: in place of motion, the anthropic principle presents human observation as meaningless without reference to the remaining universe.⁹ Under this direction, historians can then understand the principle as existing in two distinct forms: the first being Brandon Carter's metascientific principle, and the second being the more explanatory Barrow and Tipler model.

It should be clarified that this paper intends to avoid the obvious temptation for anachronism. There is an enormous allure to place the anthropic principle as beginning at almost any moment in history, which is the path chosen by Barrow and Tipler. Historians would do well to admit that many anthropic-like arguments existed in the past, but that the specific lineage of the modern principle began with the new field of cosmology in the early 1920s.

The first chapter will propose Sir Arthur Stanley Eddington as the doyen of modern anthropic arguments through his interest in selection effects. His work from the 1920s to the 1930s demonstrates his struggle to build a unified theory of the universe featuring the theories of relativity and quantum mechanics. Demanding these

⁹ This conclusion is inspired in part by an argument from Steady-State theory taken out of context: "Our observations of the universe depend on the interactions between the rest of the universe and ourselves." Here, Hermann Bondi and Thomas Gold intended to demonstrate the importance of Mach's principle to understanding laboratory experiments, but they were likewise speaking of mankind and its place in time as a selection effect. Cited from Hermann Bondi and Thomas Gold, "The Steady-State Theory of the Expanding Universe," *Monthly Notices of the Royal Astronomical Society* 8, no. 5 (Oct. 8, 1948): 259.

conflicting theories of physics agree, Eddington's struggle to produce his grand opus the *Fundamental Theory*, can be viewed as a scientist approaching a difficult problem through non-traditional means. Vital to his argument was that the number of particles in the universe seemed mathematically related to the elementary forces. Unique to Eddington at the time was his insistence on a connection between the mind and the laws of the universe—the existence of the mind permitted the laws of physics. His reasoning is remarkably similar to the strong anthropic principle, but thirty years before Carter's version.

The second chapter will elucidate the development of metascientific principles into the anthropic principle. The utilization of philosophy in cosmological models, like the Steady-State theory, developed cosmology into a field that could discuss gravity and homogeneity with non-mathematical models. For example, Robert Dicke used Mach's principle to refute Paul Dirac's time-dependent gravity. This now acceptable use of language and philosophy, which was almost always accompanied with some token mathematics, would act as the background for the anthropic principle. I will also address the realization of 'fine-tuned' properties of the universe. While a staple of modern anthropic explanations, at the time they played almost no role in the development of the anthropic principle. In regards to any evidence of narrowly constrained fundamental parameters, in 1973 Carter preferred a mathematical explanation if possible, but admitted that if none could be found then anthropic principle had surprising merit.¹⁰

¹⁰ Carter, "Large Number Coincidences," 298.

The third and last chapter will take an entirely new approach to the anthropic principle by focusing on the role of social networks in the development and dissemination of the anthropic principle. Using Cambridge as a locus for the development of the anthropic principle, I will analyze the development of the Carter anthropic principle through his interaction with mentor Dennis Sciama and his fellow students. Then I will address how this community propagated the anthropic principle and the slight alterations made over time that resulted in the Barrow and Tipler model. By addressing the plurality of anthropic principles, it is my hope that this analysis will persuade historians and philosophers to entertain such historical approaches, and that scientists will recognize the plurality of anthropic principles.

Furthermore, this history feigns no pretense to cover the entire history of anthropic arguments. The focus is on the transition from Arthur Eddington's selective subjectivism to the metascientific principles that developed into the modern anthropic principle. In other words, I am presenting a 'pre-history' of the elements that lead to the anthropic principle. No determined effort will be made to address the most recent forms, which often associate themselves with the technicalities of string theory. When I speak of a generalized anthropic principle, I am not trying to promote one over another. I will use specific terminology when addressing specific anthropic principles. Other terms, like 'anthropic explanations,' are typically used to describe the pre-Carter and Dicke era. Such explanations might fall along the same lines as the anthropic principle, but it would be anachronistic to associate them with terminology that did not yet exist.

Chapter One

The Historiography of the Anthropic Principle

The historical development of the anthropic principle presents to scholars an elusive façade, maybe more so than any idea in the lexicon of twentieth century scientists and philosophers. It is anathema to historians of science to constrain the development of a scientific principle to the hands of an isolated actor; some ideas are so prevalent throughout cultures, it would be irresponsibly reductionist to winnow the list of actors to a select few. Traditionally, this impasse characterizes the confusion over the historical origins of the anthropic principle: if mankind has always possessed a burning question as to its place in the universe, how could one scientist, Brandon Carter, be singled out as the first man to possess a scientific grasp of this information? Viewing the anthropic principle in this fashion leads to an infinite regress and masks the authentic modern influences. Beginning with Arthur Eddington and continuing with the work of Paul Dirac, this chapter follows a line of thought that carried through the early years of cosmology and would be fundamental to the inception of the anthropic principle.

As noted, there could be two ways to go about doing this history: the first being an analysis of every possible influence present in the twentieth century; the second being the pursuit of a certain line of thought and tracing its path over time. Heeding the words of mathematician Hermann Bondi, I will follow the latter path: “It

is only when [the historian] has made his choice of what is important that he can look at the question of causality in history. It depends on where you draw the line as to how far you can follow any causal links.”¹¹ This stance then implies that the anthropic principle has *not* always been in existence, but instead is a very modern explanation of the universe. The former approach—which considers relevant any argument that includes an appeal to the existence to humans—assumes the anthropic principle has always been in existence. It is this stance which dominates the historiography. It is also based around one canonical text, to which I now turn.

In 1986, John Barrow and Frank Tipler published *The Anthropic Cosmological Principle*. A veritable encyclopedia of science and philosophy, it weighed in at over 700 pages and included over a thousand footnotes. As it was the first publication to treat the anthropic principle in a greater historical context, it set the tone by which all other accounts of the anthropic principle would be judged. The authors admitted in the preface that they derived their vast array of eclectic information from general public bewilderment at these novel arguments. “For this reason,” they said, “it is important to display the anthropic principle in a historical perspective as a modern manifestation of a certain tradition in the history of ideas that has a long and fascinating history involving, at one time or another, many of the great figures of human thought and speculation.”¹² In other words, their underlying thesis

¹¹ Hermann Bondi, “Is Science Human?” *Physics, Logic, and History: Based on the First International Colloquium held at the University of Denver, May 16-20, 1966*, Ed. Wolfgang Yourgrau and Allen D. Breck (New York: Plenum Press, 1970), 324.

¹² Barrow and Tipler, xi.

was that a form of the anthropic principle had been ever-present in human thought, and their book was an effort to catalog these insights.

Just ten pages after they offered an historical background, however, Barrow and Tipler reveled in their ahistorical approach. Suddenly they announced, “Our primary purpose in this book is not to write history. It is to describe the modern anthropic principle.”¹³ To do this, they adhered to the “shameful mark of an amateur” historian: the practice of Whig history.¹⁴ Their reasons for doing so were four-fold: 1) to interpret past ideas in terms that a modern scientist could understand, such as Fichte’s absolute idealism in the language of computer science; 2) to interpret present ideas in terms that a theologian or a philosopher could understand, so that those lacking mathematical ability could still grasp the message; 3) the intentional passing of judgment on past scientists to learn from their “mistakes and successes,” and demonstrate the usefulness of teleology in science; and 4) the acceptance of recurring themes throughout history, and their refusal “to distort history to fit the current fad of historiography.”¹⁵ The historicity of their work, then, was markedly ‘unfashionable’ to modern historians. Put another way, they assumed the objectivity of scientific ideas and discoveries, and because of this, the present way of understanding the universe could be overlaid on the past.

This thesis aims to change that historical account. Barrow and Tipler reserve their right to produce Whiggish history, but that cannot stand for modern historians of science. Regardless of whether an idea has been present in the distant past, that fact is

¹³ Ibid., 10.

¹⁴ Ibid.

¹⁵ Ibid., 10-11.

generally subordinate to the immediate influences surrounding the production of useful scientific tools. Take Isaac Newton and gravity for example. Certainly gravity had been causing apples to fall from trees and keep the planets orbiting ages before Newton, so in that way Newton cannot be said to be the ‘discoverer’ of gravity. His contribution, however, had been a new understanding of gravity given the contemporary discussions of action at a distance. This is analogous to the anthropic principle. Probably since the inception of cognition, mankind has questioned its place in the universe. This fact, however, is subordinate to the immediate scientific milieu into which the anthropic principle was born. That is not to say the anthropic principle arrives in an ‘eureka’ moment of discovery. Rather, there is a recognizable line of thought connecting scientists that can be approached and understood through modern historical methods, and this is a paper about that.

The question then becomes that if the idea is so ubiquitous, where and when should a practical history start? Barrow and Tipler recognize this predicament almost immediately in their defense of a Whiggish approach: “Every historian must always select a finite part of the infinitely-detailed past to write about. This selection is necessarily determined by the interests of the people in the present, the modern historian if no one else.”¹⁶ The modern historian cannot be this pessimistic, though.

The anthropic principle begins in 1973 when Brandon Carter names it, defines it, and demonstrates its explanatory power. His inspiration came from two scientists: Robert Dicke and Hermann Bondi, who will be the focus of chapter two. The historian should then take one step further to recognize the relevant influences behind

¹⁶ Ibid., 10. The authors, of course, begin their history at the dawn of human existence.

Dicke and Bondi, namely Arthur Eddington and Paul Dirac, the subjects of this present chapter.

At first glance, all these scientists seem awkwardly disconnected: they work in different times, places, and in many cases their findings opposed one another. Their connection with each other and the anthropic principle, however, was the theme of ‘large numbers,’ or the ratios of fundamental physical constants of the universe. The mysterious convergence of large numbers around 10^{40} incited these scientists to meticulously explain the universe in non-traditional ways. Their interactions, their discourse, and their new synthesized knowledge all played a role in the formation of the modern anthropic principle. Because the large number coincidences began with Eddington (and also because of a particular mode of thought he possessed), he should be considered the first causal link in the development of the anthropic principle.

With this delineation in mind, it should be clarified that this paper presents the history of a different anthropic principle than the Barrow and Tipler history. This paper illuminates the transition of ideas from Eddington until Carter’s 1973 proposal. After that, the principle somehow changed meanings, and the modified teleological version would appear in Barrow and Tipler’s account with Carter maintaining ownership of the principle that no longer contained his words. In addressing the historical development of the Carter anthropic principle, this paper calls for historians of science to reanalyze the Whiggish subject matter. Perhaps the anachronistic exchange of ideas is the best way to *comprehend* the anthropic principle, but this method obfuscates a tantalizing and complex history that demonstrates the anthropic principle to be a pragmatic explanation for perplexing scientific issues.

Arthur Eddington and Paul Dirac are then the subjects of this first chapter. While their lifework spanned distances across the realms of cosmology and physics, I will now focus on their concern over the role of large numbers in the cosmos. Barrow and Tipler follow this same focus throughout the modern history of the anthropic principle, and state, “The Holy Grail of modern physics is to explain why these numerical constants...have the particular numerical values that they do.”¹⁷ Their account, however, lacks analysis of the contemporary significance of these numbers to the scientists. Instead, they claim that, “Most of the early work of Eddington and others on the large number coincidences has been largely forgotten. It has little point of contact with ideas in modern physics and is now regarded as a mere curiosity in the history of ideas.”¹⁸ My account will take a converse approach and consider the large numbers in respect to their own timeframe, where they were considered as enticing as they were suspicious, and very much a problem to be addressed.

Arthur Eddington: Large Numbers, Selective Subjectivism, and the Fundamental Theory

I: Life and Times

Born to a family of Quakers in 1882, Arthur Eddington’s scientific success brought him adventure and renown that few scientists had experienced. He was active in clubs and academics throughout his college years at Cambridge, being the first second-year student to take top honors on the mathematical exams and be named the Senior Wrangler. His success earned him an invitation to be the Chief Assistant at

¹⁷ Ibid., 5.

¹⁸ Ibid., 231.

Greenwich Observatory, which gave him the opportunity to study stars and travel the world aiding other observatories. In 1913, Cambridge hired him as the Plumian Professor of Astronomy, one of two esteemed chairs in the Astronomy Department. His most well-known contribution to science came in 1919, when he sailed to Príncipe, an island off the coast of West Africa. Here he led a team that took pictures of an eclipse to test Albert Einstein's prediction that light would bend around a massive body like the sun. Eddington's work verified this claim, and Einstein received international adulation. In the next twenty years, Eddington continued his research at the Cambridge Observatory and participated in developing early models of the expanding universe and popularizing science.¹⁹

I now turn to one of Eddington's biggest 'failures:' the Fundamental Theory. This capstone to Eddington's career sought to unite the early twentieth century's two innovative models of physics: general relativity and quantum mechanics. Relativity reframed concepts of space—there was no absolute grid against which objects moved, but instead objects moved in relation to each other. Then throughout the 1920s, an international *mélange* of physicists tackled the equations of quantum mechanics that undermined the supposed regularity of reality; if true, particles could only be said to be 'probably' somewhere until observed. Together, relativity and quantum mechanics were diametrical views of the universe: in relativity, nothing could move faster than light, while in quantum mechanics, particles could interact instantaneously over,

¹⁹ For more on Eddington, please consult A. Vibert Douglas, *The Life of Arthur Stanley Eddington* (London: Thomas Nelson and Sons, Ltd., 1956)

theoretically, unlimited distances. This conflict puzzled scientists, and inspired some to try their hand at fashioning a unified solution.

In the late 1920s, Eddington found himself in a peculiar situation among these theories—among scientists he was the top at his field in relativity, but young scientists dominated the debate over quantum mechanics. Using an interpretation of quantum mechanics developed by his student Paul Dirac, Eddington spent the next decade trying to unite these opposed models of the universe—infusing his own philosophy along the way—resulting in the posthumous publication of his *Fundamental Theory*.²⁰

Although seen as trite by his contemporaries, two core topics in Eddington's Fundamental Theory formed the groundwork from which the anthropic principle would grow: his personal philosophy of 'subjective selectivism,' and his fascination with large numbers.²¹ For the best comprehension, these subjects need to be separated for now, although this forces them into a somewhat anachronistic presentation. This is justifiable for two reasons: first, Eddington's reasons for pursuing the large numbers are unclear without a grasp of his selective subjectivism. Second, Eddington presented these topics to completely different audiences—usually he reserved his philosophy for speeches and semi-popular publication, whereas his technical documents hid most of these insights. In a similar fashion, I will discuss the realms of his philosophy and science in different sections. The emphasis here is not the

²⁰ For clarification, the italicized *Fundamental Theory* represents the book, and the capitalized Fundamental Theory represents the theory in general.

²¹ It should be noted that while Einstein also sought a unified theory, he went about it in a much different manner than Eddington. Perhaps future work could elaborate on the differences between the two, and why Einstein is never considered a contributor to the anthropic principle.

particulars of when Eddington thought of this or that, but to provide an overall framework of how he formulated his Fundamental Theory and show how its influence as a mode of explaining the universe. I will therefore describe Eddington's selective subjectivism first, and follow-up with his technical approach to his Fundamental Theory.

II: Selective Subjectivism

Throughout Eddington's life, he developed an epistemology that was reminiscent of Kant, but broadened it to the entire application of science. With Eddington's selective subjectivism, he proposed that the mind acted as a filter that sorted all experience. In his words,

If we take observation as the basis of physical science, and insist that its assertions must be verifiable by observation, we impose a selective test on the knowledge which is admitted as physical. The selection is subjective, because it depends on the sensory and intellectual equipment which is our means of acquiring observational knowledge.²²

As he saw it, everything filtered through the mind, and science just gave order to those perceptions. Perhaps Eddington's fisherman story best illustrated this view, which I will now revisit.

After every long day of fishing, a fisherman returns home and counts the fish from his net. Day in and day out, the fisherman never collects fish less than two inches in length. From this observational experience, can the fisherman rightly say there are no tiny fish in the lake? Eddington says no: if the fisherman's net is

²² Arthur Stanley Eddington, *The Philosophy of Physical Science* (New York: The Macmillan Co., 1939), 17.

composed of two-inch gaps, then all the small fish will swim right through. The fisherman's estimate of the fish population is limited by his measuring apparatus—the net.²³

Eddington's selective subjectivism then expands this analogy to the mind and the universe. All observations and sensations are data processed by the mind. The mind then acts as the selector; it can only perceive so much. What the mind can comprehend—that is, what observations it can process and put into order—is then turned into 'science.' Perceived reality is then just what the human mind can make of it. The reality of atoms and electrons can be determined experimentally, but unseen objects like these evince a world that is unperceived to the human mind. Yet these microscopic elements form a universe which is very comprehensible to humans. Therefore, there are fundamental requirements that the unperceived realm must meet for the human mind to comprehend the perceptible realm. Without the human mind, then, cosmic laws would have never existed. This line of thought places humanity at the center of the cosmological debate, and has much in common with the later strong anthropic principle—instead of saying the universe must be set up for the existence of humanity, it says that cosmic laws must be comprehensible. In the discussion of large numbers, it will be shown how Eddington took this belief that the universe must be comprehensible to show a particular large number as being fundamental. Before going there, however, an important qualification must be made to the selective subjectivism discussion.

²³ Ibid.

Since Eddington was a pious Quaker, it might be argued that he sought a holistic and scientific view of design. While he did admit the existence of a Creator and the role of his hand in shaping the universe, mankind had no way of understanding this design. This was because he believed in the separation of scientific knowledge from theology.²⁴ In his view, most people possessed the attributes of reason and ‘mysticism,’ or the belief of some type of spiritual nature. He described the development of two channels of knowledge:

For the most part our inquiry into the problem of experience ends in a veil of symbols, there is an immediate knowledge in the minds of conscious beings which lifts the veil in places; and what we discern through these openings is of mental and spiritual nature.²⁵

To make sense of this, Eddington divided the two channels into the objective world of theology and the subjective world of analytical reason and quantifiability. His idiosyncratic use of ‘objective’ and ‘subjective’ should be noted and kept in mind. In his 1938 Tarner Lectures, he observed: “I have often found an impression that to explain away the laws of nature as wholly subjective is the same thing as to explain away the physical universe as wholly subjective.”²⁶ He denied this position on grounds of his epistemological division: “The purely objective sources... in our observational knowledge... are *life, consciousness, spirit*.... The purely objective world is the spiritual world; and the material world is subjective in the sense of

²⁴ David B. Wilson, “On the Importance of Eliminating *Science* and *Religion* from the History of Science and Religion: The Cases of Oliver Lodge, J.H. Jeans, and A.S. Eddington,” *Facets of Faith and Science: Historiography and Modes of Interaction*, vol. 1. ed. Jitse M. van der Meer, (New York: University Press of America, 1996), 39.

²⁵ Arthur Stanley Eddington, *New Pathways in Science* (New York: The MacMillan Co., 1935), 322.

²⁶ Eddington, *Philosophy of Physical Sciences*, 15.

selective subjectivism.”²⁷ Therefore, the quantifiable material world, the world of science, was to be examined and understood in terms of selective subjectivism—that was, in terms of the existence of the mind. God transcended every explanation.

How was physical reality to be understood then? Eddington divided reality into two categories: fundamental laws of nature and “special facts.”²⁸ Fundamental laws stood for the “laws and constants of physics [that] can be deduced unambiguously from *a priori* considerations, and are therefore wholly subjective.”²⁹ They are laws that when put together comprise the basic workings of the universe—relativity, quantum mechanics, entropy, et cetera. Special facts were those properties of the universe that the laws act upon. These facts could have varied, which for the purpose of argument Eddington used as an example the number and distribution of protons and electrons in the universe. This example will be revisited in the next section.

Given this split between fundamental laws and special facts—to which Eddington denied being the original author but liked the terminology—he realized a major conflict in his theory: if man cannot know objectivity through reason, then how could man formulate these laws of nature through observation and experience? He determined there must be another truly objective level of nature beyond the former ‘fundamental’ level. He raised this question: “Have we any reason to believe that if a law of Nature—a generalization about the objective world—were to become known

²⁷ Ibid., 69. The omitted parts are Eddington’s redundant explanations of the body as observational apparatus.

²⁸ Ibid., 63.

²⁹ Ibid., 62.

to us, it would be accepted by current physics as a law of nature?”³⁰ Essentially, if one were to discover a true transcendent law of physics, it would be “outside physics,” and “that there is no particular reason to expect that it will be called physics.”³¹ As noted, the objective sources of knowledge in observation were life, consciousness, and spirit. If a method existed to understand the level beyond perceived observational reality, then it existed through the study of one of these realms. The realm of physics held such a lead—in the study of large numbers.

In summary, Eddington’s selective subjectivism had much in common with the strong anthropic principle. Eddington’s mind imposed a structure on both the sensory (or ‘subjective’) world and the unseen (or ‘objective’) world. The regular laws of physics handled the realm of sensory experience while God’s transcendental laws commanded the real workings of reality. Eddington believed the discovery of the large numbers permitted a peek into the unseen workings of the cosmos, and in this he realized that a slight change in the fundamental makeup of the universe would imply an unrecognizable universe. Eddington’s philosophy is much stronger than Carter’s anthropic principle, but it lacks the implication of design to which Barrow and Tipler adhere. This philosophical line of thought will be vital to follow over time. Next, I will illustrate Eddington’s effort to understand the ‘true’ objective reality by analyzing his work with large numbers.

III: The Fundamental Theory and the Large Number Coincidences

³⁰ Ibid., 67.

³¹ Ibid., 68.

Eddington's *Fundamental Theory*, published posthumously in 1946, showed a man struggling to understand the universe on near-transcendental level. Despite the efforts to work through relativity and quantum mechanics, there seemed no apparent relation between these models of the universe. This discrepancy haunted many physicists and astronomers, but as Eddington's former student Clive Kilmister noted, Eddington's *Fundamental Theory* "serves to challenge that consensus."³² To Eddington, relativity and quantum mechanics were patterns recognized in the human mind. He believed that taking certain subjective data, in this case large numbers, and applying them to these patterns, he could gain a glimpse into the true objective world. When he noticed a group of these large numbers had the magnitude of 10^{40} , he realized that he had hit on an unperceived unity in nature. This section details his efforts to explain that coincidence.

As early as 1920, Eddington believed the theory of relativity only partially described the world. He remarked in his popular book *Space, Time, and Gravitation*,

The theory of relativity has passed in review the whole subject-matter of physics. It has unified the great laws....And yet, in regard to the nature of things, this knowledge is only an empty shell—a form of symbols. It is knowledge of structural form, and not knowledge of content. All through the physical world runs that unknown content, which must surely be the stuff of our consciousness. Here is a hint of aspects deep within the world of physics, and yet unattainable by the methods of physics.³³

In this view that pre-dated quantum mechanics, he found reality fairly deterministic:

“The thing that has been identified with matter is permanent, and because of its

³² C.W. Kilmister, *Eddington's Search For a Fundamental Theory: A Key to the Universe* (Cambridge, UK: Cambridge University Press, 1994), 1.

³³ Arthur Eddington, *Space, Time, and Gravitation: An Outline of the General Theory of Relativity* (Cambridge, UK: Cambridge University Press, 1920), 200-201.

permanence it must be for mind the substance of the world. Practically no other choice is possible.”³⁴ Had quantum mechanics never been developed in his lifetime, Eddington certainly would not have proceeded with his Fundamental Theory and perhaps the anthropic principle would have never been developed. But quantum mechanics had been elucidated in 1925-1926, and this markedly changed Eddington’s view of the world.

At the crux of quantum mechanics was ‘indeterminism,’ or the possibility that events could be, at most, probable at the quantum level. As a religious-minded scientist, Eddington noticed the controversy indeterminism brought to philosophy—perhaps science now possessed an explanation for free will. In a very famous passage from his 1927 Gifford lectures, he remarked,

It will perhaps be said that the conclusion to be drawn from these arguments from modern science, is that religion first became possible for a reasonable scientific man about the year 1927....But seeing that before this enlightened era men managed to persuade themselves that they had to mould their own material future notwithstanding the yoke of strict causality, they might well use the same *modus vivendi* in religion.³⁵

In other words, scientists believed they had free will long before quantum mechanics, and the theory’s elucidation was unlikely to change this discussion much.³⁶ But for Eddington’s conception of a truly objective reality, indeterminism had very different repercussions.

³⁴ Ibid., 196.

³⁵ Arthur Eddington, *The Nature of the Physical World* [Reprint] (Ann Arbor, Michigan: University of Michigan Press, 1963), 208-210. These are a collection of the Gifford Lectures originally given at the University of Edinburgh in 1927.

³⁶ Alan Battan, “What Eddington Did Not Say,” *Isis* 94, no. 4 (December 2003): 656-660.

Given that fundamental laws supposedly formed the rules of the game and the special facts were the players, Eddington then applied quantum indeterminacy to this setup and discovered he needed to reevaluate the entirety of his philosophy. In a classical deterministic system (including relativity), the fundamental laws had predictive power—acceleration equals force over mass, and after such a time an object will have moved so far. To Eddington, this type of predictive power differentiated fundamental laws from any law that might govern special facts.³⁷ But this distinction broke down once quantum mechanics came into play, as he said, “In the current indeterministic system of physics, there is no corresponding demarcation between the laws and the special facts of nature.”³⁸ Now, the special facts had a very different role: “The special facts, which distinguish the actual universe from all other possible universes obeying the same laws, are not given once for all at some past epoch, but are being born continually as the universe follows its unpredictable course.”³⁹ Essentially, the players in the game were not static entities—they developed as the game went on. Since this eliminated the ability of the ‘fundamental laws’ to predict special facts, they were not truly objective. The truly objective laws were then transcendental like God; pattern-like laws still existed, and they must be understood through selective subjectivity.

The way Eddington chose to understand these laws was very roundabout. When he introduced his special facts, he used as an example the number and

³⁷ Eddington, *Philosophy of Physical Sciences*, 63.

³⁸ Ibid.

³⁹ Ibid., 64. It should be noted his discussion of limiting the possibility of universes, another common theme in the anthropic principle.

distribution of protons and electrons in the universe. In his opinion, cosmologists generally accepted this number as a randomly determined fundamental parameter: “A universe could be made with any number of particles; and, so far as physics is concerned, we must just accept the number allotted to our universe as an accident or as a whim of the Creator.”⁴⁰ But Eddington had a system in place to determine the number of particles in the universe, and he was going to show that the number of particles in the universe had to be a very specific number, or else the rules by which the mind understood the cosmos would have been violated.

In his 1938 Turner lectures, Eddington announced to the audience, “I believe there are

15,747,724,136,275,002,577,605,653,961,181,555,468,044,717,914,527,116,
709,366, 232,425,076,185,631,031,296 protons in the universe, and the same
number of electrons.⁴¹

His brazen rhetoric was to introduce a very specific argument. In the classical determinist world, one really could have counted all those particles; in the quantum mechanical indeterminist world, any attempt to count a particle (and they all looked alike) would result in an increasing difficulty in tracing its future movement and separating it from the next indistinguishable electron. Yet despite this hopeless practice, it was commonplace for physicists to say a gram of hydrogen contained 6×10^{23} electrons.⁴² Eddington admitted specificity like this could be achieved through indirect manners, and he believed he could do this to determine the number of particles in the

⁴⁰ Ibid., 65.

⁴¹ Eddington, *Philosophy of Physical Science*, 170.

⁴² Ibid., 172.

universe. What follows is a short discussion of how Eddington arrived at his conclusion that the universe must have 10^{79} protons and electrons.

In 1927, the same year that Werner Heisenberg introduced the uncertainty principle that provoked Eddington to comment on free will and religion, Paul Dirac introduced a different equation. Dirac, an ardent adherent of relativity, opted to develop an interpretation of the uncertainty principle that put relativity into quantum mechanics. Having studied somewhat under Eddington, Dirac did not inherit any of his teacher's lucidity. Because it combined relativity and quantum mechanics, Eddington grew interested in Dirac's "mystic formula," but translated its mathematics into tensor calculus, the same mathematics used by relativity.⁴³

Eddington then began his Fundamental Theory with an altered version of the uncertainty principle, translated into classical terms: $qp-pq=ih/2\pi$.⁴⁴ This is a straightforward equation: p represents momenta, q represents coordinates, h is the action of the atom, i is the square root of -1, and 2 and π are familiar terms. The specific meanings of these terms are unimportant right now, as Eddington wanted to focus on the general ambiguity of p and q . He called these variables "baffling," because general arithmetic said they should commute and equal 0, but nothing could "explain why qp is so ill-behaved as to be unequal to pq ."⁴⁵ At the time, Schrödinger held that p was an operator while Dirac held that p was a non-real number. Dirac's method attracted Eddington because that non-real number would be another inspection of the unseen world:

⁴³ Eddington, *Nature of the Physical World*, 207.

⁴⁴ *Ibid.*, 208-210.

⁴⁵ *Ibid.*, 208

The idea is that in digging deeper and deeper into that which lies at the base of physical phenomena we must be prepared to come to entities which, like many things in our conscious experience, are not measurable by numbers in any way; and further it suggests how exact science, that is to say the science of phenomena correlated to measure-numbers, can be founded on such a basis.⁴⁶

While other scientists continued with the work of Heisenberg and Schrödinger, Eddington pursued Dirac's method, and it became the basis behind his Fundamental Theory.

Eddington then departed from standard models of the uncertainty principle by viewing the particle as a connected entity. Whereas other models tried to understand the particle in isolation, Eddington claimed this was implausible given that objects do not act alone in a relativistic space.⁴⁷ First, he redefined the consideration of the solo atom—it needed to treat the nucleus and electron as separate interacting entities. And then because of his relativistic approach, Eddington added a second “companion” particle to the equation. Therefore, four elements entered the equation. Then Eddington claimed p and q —the transcendental momenta and the location—gave the atom 16 “degrees of freedom,” or the ability to move or rotate in any of sixteen different ways—up, down, left, right, vibration, and so on. So there were $16 \times 16 = 256$ degrees of freedom. Now running through the equation, Eddington arrived at this answer: the particle in question had $10^2 + 6^2 = 136$ degrees of freedom (nucleus compared to the electron, respectively), and so by arithmetic the companion particle

⁴⁶ Ibid., 209.

⁴⁷ Kilmister, 112.

had 120 degrees of freedom. These numbers, particularly 136 and 256, had been appearing in his other work, and drove him to strengthen the connection.⁴⁸

Next, Eddington approached the “fine-structure constant,” a fundamental constant of the universe that measured the force of electromagnetic interaction. It was among a larger group of numbers called “dimensionless” because all measuring mechanisms—like feet or pounds or ounces—cancelled and left only a number. In Eddington’s time its measured value was very near 1/137. Building on his claim of the 136 degrees of freedom, he thought to expand his research by universalizing his number, and in 1929 argued that the fine structure constant was exactly 1/136.⁴⁹ The scientific community scoffed. The Swedish physicist Oskar Klein complained, “I now regard the Eddington ‘136-work’ as complete nonsense; more precisely, as romantic poetry, not as physics.”⁵⁰ The next year Eddington published a correction and admitted the value to be 137; “The mistake,” he said, was “in not recognizing [his theory’s] distinctness from the others.”⁵¹ This work, and the numbers that continued to appear in equations, gave him a background to formulate his most famous number.

Eddington’s determination of the number of protons and electrons in the universe came from dividing the estimate of mass in the universe by the mass of the

⁴⁸ Ibid., 113.

⁴⁹ Arthur Eddington, “The Charge of an Electron,” *Proceedings of the Royal Society of London A* 122, no. 789 (Jan. 1, 1929): 358-369.

⁵⁰ Quoted in Kilmister, 116.

⁵¹ Arthur Eddington, “The Interaction of Electric Charges,” *Proceedings of the Royal Society of London* 126, no. 803 (Mar. 3, 1930): 696.

hydrogen atom.⁵² He then took this and applied it to a certain sequence,

$N_r = n_r(n_r + 1)2^{n^2/r}$, as $r=1,2,3,\dots$ ⁵³ It gave the following sequences:⁵⁴

$$N_1 = 2 \times 3 \times 2^4 = 96$$

$$N_2 = 4 \times 5 \times 2^{16} = 1,310,720$$

$$N_3 = 16 \times 17 \times 2^{256} = 2 \times 136 \times 2^{256} = 10^{79}$$

He determined the third sequence to be the best option because, “The number 136 is characteristic of the group structure of the quadruple existence symbols; and for that reason it also turns up in the theory of the other numerical constants of nature (the fine-structure constant and the mass-ratio).”⁵⁵ He called it N, and it became known as Eddington’s number: 10^{79} . The importance of this number swelled as Eddington realized its connection to other realms of physics.

Eddington’s number could reevaluate Einstein’s controversial ‘cosmical constant.’ To Einstein, who believed in a static universe, this mysterious expansive force opposed gravity and kept the universe from collapsing on itself. After Georges LeMâitre proposed an expanding relativistic cosmology in 1927 (the forerunner to the Big Bang), many cosmologists saw the cosmical constant as the active force which caused the expansion of the universe. To Eddington, this meant it was the force responsible for moving all protons and electrons apart. In his equations, these subatomic particles were subject to the larger rules of relativity, and he argued that the mass of an electron could be determined *a priori* through the cosmical constant.⁵⁶

In relativity, space is curved where mass is present, like the fabric of a trampoline

⁵² Kilmister, 200.

⁵³ Ibid.

⁵⁴ Ibid.

⁵⁵ Eddington, *Philosophy of the Physical Sciences*, 176.

⁵⁶ Arthur Eddington, “On the Value of the Cosmical Constant,” *Proceedings of the Royal Society of London A* 133, no. 822 (Oct 1, 1931): 605-615.

when a child stands on it. Eddington understood that this curvature gave particles their mass. Therefore, for his equation he needed the radius of space R (10^{22} cm), the number of electrons in the universe N (10^{79}), and then energy and the speed of light constants (from $e=mc^2$). To find the mass of the electron m_e , he then needed the equation $m_e c^2 = R/\sqrt{N}$.⁵⁷ But wanting to find *a priori* values, Eddington changed the “quantum mechanical units” to his own value for the electrical charge of a particle: $136m_e = R/\sqrt{N}$.⁵⁸ His answer was 1847.6, within 0.3% accurate to the contemporary estimate.⁵⁹

Realizing the utility of the numbers 136, 256, and 10^{79} , Eddington felt that he was on to something. He compared these numbers to other ratios that had been determined by other scientists and realized they had a remarkable relationship: their values were all very near 10^{40} . Here was the list that he used,⁶⁰ and it should be noted that later scientists added more numbers to this list:

- 1) M/m =the mass-ratio of the proton and electron=1840
- 2) $hc/2\pi e^2$ =fine-structure constant=1/137
- 3) e^2/GMm =ratio of the electrical force between an electron and proton to the gravitational force between them= 2.3×10^{39}
- 4) $(2\pi c/h) \sqrt{(Mm/\lambda)}$ =ratio of the radius of the curvature of spacetime to mean length of a Schrödinger wave= 1.2×10^{39}
- 5) $2 \times 136 \times 2^{256}$ =the number of protons and electrons in the universe= 10^{79} , of which the square root is near 10^{39}

⁵⁷ Kilmister, 158.

⁵⁸ Ibid.

⁵⁹ Arthur Eddington, “On the Mass of the Proton,” *Proceedings of the Royal Society of London A* 134, no. 824, (Dec. 2, 1931): 531.

⁶⁰ Eddington, *New Pathways in Science*, 232.

Going back to his Turner lectures and that very specific determination of the number of protons and electrons, Eddington had two arguments: either the universe could have 10^{79} particles or the search was utterly hopeless. As he framed the predicament, “To put it crudely, we have *debunked N*...Is it any longer of interest?”⁶¹ According to Eddington, it must be: “The number is scientifically important because it keeps cropping up in more prosaic problems.”⁶² Furthermore, the unity it displayed among other physical constants showed the glimpse of true objectivity that Eddington had been searching for. Looking back, if N had been different, the ratio of masses between the proton and the electron would have been different (equation 1), and in turn if this ratio was different it would have thrown off numbers (3) and (4) above. The unity of this number, then, demanded it be a fundamental law. It is only now that we can understand why Eddington said,

A universe cannot be made with a different number of elementary particles—consistently with the scheme of definitions by which the ‘number of particles’ is assigned to a system in wave-mechanics. We must therefore no longer look on it as a special fact about the universe, but as a parameter occurring in the laws of nature, and, as such, part of the laws of nature.⁶³

In summary, Eddington’s Fundamental Theory used selective subjectivism to narrow the search for physical clues that revealed transcendental mysteries of the universe. This approach, which predicated a relationship between the perceiving mind and the laws of the cosmos, determined, at least in Eddington’s mind, that some physical laws needed to be such as to permit the integrity of a logical universe. Placed in this context, Eddington acts as very much more a contributor to the anthropic

⁶¹ Eddington, *Philosophy of the Physical Sciences*, 177.

⁶² *Ibid.*

⁶³ *Ibid.*, 65.

principle than a “mere curiosity in the history of ideas.”⁶⁴ Despite this work, his contribution is overshadowed by the even more scientifically controversial work of Paul Dirac, whose work will now be in focus.

Paul Dirac and the Large Number Hypothesis

Born in 1902, Paul Dirac finished his undergraduate work in engineering and mathematics at the University of Bristol before completing his doctorate at Cambridge. Here, he approached Eddington freely and discussed the professor’s technical book *The Mathematical Theory of Relativity*.⁶⁵ His graduate work focused largely on quantum mechanics, though, and in 1928 he proposed his interpretation of the uncertainty principle that diverged greatly from the other interpretations. In 1930 he would publish a landmark textbook, *Principles of Quantum Mechanics*. It was a salute to rigor, containing two pages of preface followed by two hundred pages of complex mathematical theory. Eddington took this work in a different direction and produced his Fundamental Theory. Dirac, however, resented his mentor’s approach, saying Eddington “occasionally makes use of concepts which have no place there.”⁶⁶ While most well-known for his contributions to atomic theory, he would spend a significant amount of his later years defending a tenuous position that claimed the force of gravity changed over time. An argument based on an interpretation of Eddington’s large number coincidences, it would be attacked by Hermann Bondi and

⁶⁴ Barrow and Tipler, 231.

⁶⁵ Helge Kragh, *Dirac: A Scientific Biography* (Cambridge, UK: Cambridge University Press, 1990), 9. For more on Dirac, please see this book.

⁶⁶ *Ibid.*, 226-227.

Robert Dicke along the lines of anthropic reasoning. Dirac should then be seen as a transition figure in the early history of the anthropic principle.

In 1937, Dirac wrote a letter to the editor of *Nature* summarizing his position on Eddington's large numbers. While he admits their significance had drawn a lot of attention, he lamented, "Eddington's arguments are not always rigorous, and while they give one the feeling that they are probably substantially correct in the case of the smaller numbers...the larger numbers...are so enormous as to make one think that some entirely different type of explanation is needed for them."⁶⁷ Whereas Eddington founded his argument on the belief of the connection between the mind and the cosmos, Dirac approached the situation from a very different point of view.

He explained the large numbers beginning with the age of the universe. At the time, scientists believed the universe to be about 2 billion years old. Translated into units of Planck time (10^{-44} seconds), the age of the universe was about 10^{39} .⁶⁸ "This suggests," Dirac said, "that the above-mentioned large numbers are to be regarded, not as constants, but as simple functions of our present epoch."⁶⁹ Here he had translated the large realm of years into the smaller realm of atomic time and come across another coincidental large number. Only now, this number would change as time went on; it would remain at 10^{39} for only a specific time in history before rising. This number was not *a priori*, like Eddington would prefer; instead, it was an effect of a deeper underlying cosmic phenomenon. The next year, Dirac proposed a very controversial explanation for this coincidence.

⁶⁷ Paul Dirac, "The Cosmological Constants," *Nature* 139, no. 3512 (Feb. 20, 1937): 323.

⁶⁸ *Ibid.*

⁶⁹ *Ibid.*

He began by strengthening the relationship between the large numbers: “Any two of the very large dimensionless numbers occurring in Nature are connected by a simple mathematical relation, in which the coefficients are of the order of magnitude unity.”⁷⁰ Essentially, because their values were near 10^{39} , he linked the ratio of the electrical to the gravitational force between an electron and a proton to the age of the universe expressed in atomic time. Believing this relationship “a coincidence we may presume is due to some deep connection in Nature between cosmology and atomic theory,” he connected the numbers by a mathematical relationship.⁷¹ Therefore, as the universe aged and as this number went to 10^{50} , the ratio of the electrical to the gravitational force would also increase toward 10^{50} . What Dirac implied here was that the force of gravity *changed* over time, and his proof was this underlying unity.

While time-dependent gravity would be a major theme over the next twenty years, Dirac also advocated matter creation for a short time.⁷² While this entirely contradicted Eddington’s number and the laws of thermodynamics, Dirac believed experiments “were much too imperfect to be able to assert that such an increase cannot occur...”⁷³ This irked many scientists—not only did they have to deal with rising political tensions at home, they had to deal with the Nobel prize winner Dirac, who argued that all of science since Galileo needed to be overturned based on an elegant mathematical relation. Many scientists looked on in embarrassment.⁷⁴ The

⁷⁰ Paul Dirac, “A New Basis for Cosmology,” *Proceedings of the Royal Society of London A* 165, No. 921 (Apr. 5, 1938): 201.

⁷¹ *Ibid.*

⁷² Dirac, “The Cosmological Constants,” 323.

⁷³ *Ibid.*

⁷⁴ Helge Kragh, *Quantum Generations: A History of Physics in the Twentieth Century* (Princeton: Princeton University Press, 1999), 227.

next year, Dirac would squeamishly admit spontaneous matter creation might not occur, but only on the grounds that it did not affect the outcome of his cosmological model.⁷⁵

When he combined matter creation and a time-dependent gravity, it was called his ‘large number hypothesis,’ and as Dirac said, experimental evidence could not disprove it at the time. The first attempt to refute Dirac’s hypothesis came with Edward Teller in 1948, and foreshadowed the new techniques cosmologists would need to address such abstruse cosmologies. In two pages, Teller pointed out that if gravity weakened over time, it must have been very strong in the past, making the sun hotter. Given the time-scales known at the time, Teller argues that a stronger gravity would have made the oceans boil at the times when man was known to be walking the earth. He admitted, though, that Dirac’s hypothesis still had some merit, “because of the nature of the subject matter, [it is] vague and difficult to disprove.”⁷⁶ The next scientist to seriously confront Dirac’s equations would be Robert Dicke from 1957-1961, and his explanations along the line of the anthropic principle is covered at length in the next chapter.

Conclusion:

The anthropic principle can trace its early history to the work of Arthur Eddington and Paul Dirac. A non-Whiggish history needs to limit the actors involved, and given the scope of the Fundamental Theory and the large number hypothesis and

⁷⁵ Dirac, “A New Basis for Cosmology,” 204.

⁷⁶ Edward Teller, “On the Change of Physical Constants,” *Physical Review* 73, no. 7 (April 1, 1948): 802.

their methods of argumentation, it is possible to trace a clear path from a few local actors to a broader community. For now, the explicit role of these figures and theories in the development of the anthropic principle is probably unclear, because there is a significant amount of work from 1948-1973 that has yet to be covered. It is best to keep in mind that going into this time period, two significant astronomical figures had been publishing and advocating cosmological theories that were 1) philosophical, 2) to a certain degree centered on man, and 3) contrary to the status quo. Now, the focus turns toward the debate between the Steady-State theory and the Big Bang, Robert Dicke's efforts to refute Paul Dirac, and the introduction of the anthropic principle.

Chapter Two

Reanalyzing the Modern Development of the Anthropic Principle

Tracking the maturation of an idea from its infancy to adulthood is no small task, especially in the case of the anthropic principle. The first chapter established the presence of anthropic selection effects playing roles in the early cosmologies of Arthur Eddington and maturing through the work of his student Paul Dirac. The field of British cosmology from the post-War period to around 1960 lent itself to innovative methods of argumentation, perhaps most notably in a cosmological system developed by Cambridge associates Hermann Bondi, Thomas Gold, and Fred Hoyle: the Steady-State theory. Whereas Eddington attempted to unite the realms of quantum mechanics and general relativity to demonstrate the laws of physics as dependent on the human mind, the Steady-State scientists proposed through “speculative” cosmological principles that the universe must be ordered in such a way to guarantee uniform repeatability of experiments.⁷⁷ This chapter will argue the development of Steady-State cosmology pushed British cosmologists to develop innovative methods of argument that eventually led to Brandon Carter’s proposal of the anthropic principle.

⁷⁷ Hermann Bondi, a developer of the Steady-State Theory, often plays with the irony of what he calls “speculative” theories playing a role in cosmology. He splits cosmology into two methodologies—empirical and deductive. “Speculative” theories are characteristic of the later category. For more on this, see Hermann Bondi, *Cosmology* 2nd Ed. (Cambridge, UK: Cambridge University Press, 1961).

The relationship between the Steady-State theory and the anthropic principle is often misunderstood and neglected. At its most basic, the Steady-State theory proposes that the universe is uniform and homogeneous over all of time and space, or the universe looks exactly the same no matter where or when the observer is situated. This guarantees the laws of physics will be consistent over time, a refutation of Dirac and the Big Bang scientists. Specifically, Bondi called the large number hypothesis a “council of despair,” a shot-in-the-dark theory that actually bolstered Steady-State theory by revealing “how limitless the variations are that may be imagined to arise in a changing universe.”⁷⁸ These ideas conform to the Copernican principle, an argument stating that man occupies a non-privileged place in the universe. The anthropic principle is a diametrical opposite claim: that observers should be located in a position suitable with their existence. Barrow and Tipler expand this point to say, “The Anthropic Principle can be used to rule out virtually any type of Steady-State theory.”⁷⁹ This statement should not be taken at face value, though, but instead act as a call for historical attention. The anthropic principle, that is to say the belief that man has a ‘necessarily privileged’ place in the cosmos, develops as a reaction against the Steady-State theory, where man has no special place.

However, actually *seeing* this historical development requires analysis beyond the typical accounts of observational evidence. This is because from 1950-1965, there

⁷⁸ Bondi, *Cosmology*, 160.

⁷⁹ Barrow and Tipler, 602. Their argument is that any Steady-State universe cannot ‘evolve’ beings, so they must be created at the beginning. Then, if many beings had existed for a near eternity, it would hold that many of them had developed technologies to expand beyond their solar systems. Since humans do not see signs of life teeming in the universe, it stands that the previous cannot be true, and that any cosmology based on the perfect cosmological principle is, as far as the anthropic principle can demonstrate, false. Aside from this seven-page argument, Barrow and Tipler have about four more pages in their seven-hundred page book discussing the Steady-State theory.

was no way to observationally refute the Steady-State theory. Martin Ryle's radio telescope did not arrive until the late-50s and the cosmic background radiation was not discovered until 1965. The way to understand the relationship between the Steady-State theory and the anthropic principle, then, is to understand how the cosmologists changed their mode of communication. At this time, the Big Bang cosmologists realized the only way to address a 'metascientific' cosmology like the Steady-State theory was to use the same metascientific principles in lieu of customary scientific arguments. This effect is best evinced by Robert Dicke's first 'anthropic explanations' from 1957-1961, in which he opposed Dirac's time-dependent gravity by using Mach's principle instead of observational evidence. Similarly, in 1973, Carter founded his anthropic principle based on his reticence toward Bondi's 1959 textbook *Cosmology* and its approach to the large number coincidences and the Copernican principle. By this method, the anthropic principle develops historically as a pragmatic explanation—a sort of discursive tool—that developed from the new mode of communication between certain groups of cosmologists in the 1950s and 1960s.

In historical methodology, this new tool of scientific discourse should be familiar. Take Thomas Kuhn's assertion that it was "particularly in periods of acknowledged crisis that scientists have turned to philosophical analysis as a device for unlocking the riddles of their field."⁸⁰ But instead of taking the narrow definition of 'crisis' as proposed by Kuhn, I would suggest the broader concept of a scientific

⁸⁰ Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962), 88.

‘dispute.’ The Steady-State scientists found expanding relativistic cosmologies, such as the Big Bang, repugnant because, among other reasons, its fundamental precepts did not guarantee the repeatability of experiments over space and time. Steady-State scientists addressed this dispute with both experimental evidence and regular use of metascientific principles such as Mach’s principle. Reciprocally, the Big Bang cosmologists found implications of the Steady-State theory, primarily matter creation, to be scientific anathema. Traditionally bound to empirical explanations, some Big Bang cosmologists infused these same philosophical constructs into their arguments.

As another historical matter, “fine-tuned” laws of physics are commonly associated with the anthropic principle. This relationship is predominantly a modern phenomenon.⁸¹ A fine-tuned law is an ordinary fundamental law of physics, such as gravity, which if changed in the slightest would result in a drastically different (and often uninhabitable) universe. Until the late 1970s, cosmologists rarely emphasized fine-tuned evidence. The attribution of fine-tuning into the anthropic principle actually came after the fact from Barrow and Tipler. In their discussion of Carter’s 1973 presentation, they proclaim,

It is inevitable that some would look at the existence of these features from another angle, one reminiscent of the traditional ‘Design arguments’ that the Universe either must give rise to life or that it is specially engineered to support it. Carter gave the name ‘strong’ Anthropic Principle to the idea that the Universe must be ‘cognizable’ and ‘admit the creation of observers within it at some stage.’ This approach can be employed to ‘retrodict’ certain features of any cognizable universe.⁸²

⁸¹ For more on fine-tuning, I would suggest Barrow and Tipler, *The Anthropic Cosmological Principle*; Leslie, *Universes*; Martin Rees, *Before the Beginning: Our Universe and Others* (Reading, Mass.:Addison Wesley, 1997); and Paul Davies, *The Accidental Universe*, (Cambridge, UK: Cambridge University Press, 1982).

⁸² Barrow and Tipler, 248.

And ‘retrodict’ they did, declaring dozens of historical experiments to have given rise to the anthropic principle. But few if any of the scientists themselves believed their work evinced the privileged place of man in the universe. Even in 1973, Carter did not advocate a ‘strong’ position on the anthropic principle; rather, he approached it in a way similar to Dicke—that the existence of humans could reveal limits on the laws of physics.⁸³ As this chapter will show, fine-tuning just was not a major factor in the development of the anthropic principle, despite its modern importance. For this reason I will present ideas leading to Brandon Carter as they were understood in their own context. From 1950-1973, the ‘anthropic coincidences’ were generally considered to be the large number coincidences.

In summary, this chapter will illustrate the development of the anthropic principle as a pragmatic explanation resulting from the ongoing dispute between Steady-State scientists and Big Bang scientists. This debate often lacked observational evidence, so a historical account must reach beyond such matters. When viewed this way, the anthropic principle becomes part of the larger community of metascientific principles.

My approach to this chapter is innovative to the study of the anthropic principle. As noted, historians and philosophers have generally produced very narrow histories of the anthropic principle. Perhaps this is again due to the authoritative stance taken by Barrow and Tipler when they asserted that Eddington and Dirac’s work with large numbers presented “a new point of view that was to lead

⁸³ Carter, “Large Number Coincidences,” 298.

cosmologists *directly* to a modern form of the Anthropic Principle.”⁸⁴ My argument is that the large numbers did not lead directly to the anthropic principle. Instead, the anthropic principle was a result of a complex web of interrelations, namely the ‘scientific’ introduction of philosophy to cosmology, displayed by the Steady-State theorists and Robert Dicke. By addressing the mentioned issues, I hope to illuminate a tantalizing topic in the history of ideas and persuade historians to treat the anthropic principle as epiphenomenal to the growth of cosmology.

The Steady State Theory and Its Implications for the Anthropic Principle

Cosmology is the study of the general structure and characteristics of the universe. It includes a fundamental tenet: that the laws of physics are “isotropic,” or that they hold true across space and time. The same cannot be said for history and society, though, as more often than not events seem rather unbalanced. This was the case following World War II in Europe from the late 1940s until the mid-1960s. As nations rebuilt, the question of man’s place in the world coupled with competition among cosmologists as had never been seen before. As recalled by Hermann Bondi, the time “led to a considerable number of model universes, each of them interesting and remarkable in its own right, and the question which of them was the right ‘actual’ universe became of lesser interest.”⁸⁵ Relativistic cosmologies, such as the Big Bang, varied in their interpretations on the size, shape, and general structure of the universe. And the one characteristic they all had in common—a bang—nobody really understood. Because many cosmologies worked mathematically on paper but lacked

⁸⁴ Barrow and Tipler, 244. Emphasis mine.

⁸⁵ Bondi, *Cosmology*, 4.

necessary observational evidence, cosmology could rightly be called the most speculative of the sciences.

Into this environment arrived the Steady-State theory, proposed by Cambridge acquaintances in two separate papers in the October 1948 issue of the *Monthly Notices of the Royal Astronomical Society*—one by Hermann Bondi and Thomas Gold, and the other by Fred Hoyle. Despite their acquaintanceship, the two papers were very different in their approach. Bondi and Gold presented their argument by use of three philosophical maxims; Hoyle, uninterested in these arguments at the time, went about creating a mathematical model for his paper. By his international fame, Hoyle's paper was generally more well-known, but the Bondi-Gold paper was generally more debated. Hoyle thought this was due to the difficulty cosmologists had in refuting it.⁸⁶

As far as the account of the Steady-State goes, this paper will show a superficial bias toward the efforts of Hermann Bondi. While also involved in the defense of the Steady-State theory, Hoyle was not the primary target of attacks. Furthermore, in 1959, Gold left for Cornell, and Steady-State was largely a non-issue in America at the time. Manifold reasons exist for the development and defense of the Steady-State system, of which I will focus on the relations between the scientist and the universe at large.⁸⁷

⁸⁶ Fred Hoyle, "Steady State Cosmology Revisited" *Cosmology and Astrophysics: Essays in Honor of Thomas Gold*, eds., Yervant Terzian and Elizabeth Bilson (Ithaca, New York: Cornell University Press, 1982), 20.

⁸⁷ Often too much credit is given to Fred Hoyle's atheism in being the fundamental motivation behind the creationless Steady-State universe. We must remember that 'steady-state' theories had been popular explanations in geology since the eighteenth century. Other conditions playing foundational roles in the modern Steady-State theory range from dissatisfaction with the 1948 evidence that the

At the core of their cosmological system, Bondi and Gold propose the “perfect cosmological principle,” a philosophical argument that proclaims the large-scale universe remains homogeneous and unchanging over all time and space. Every place is equal in this cosmos and man can have no privileged place. Often, this primary argument is overlooked in favor of its implication for the Steady-State theory, namely the continuous creation of matter. Bondi, Gold, and Hoyle explain this in a manner reminiscent of Dirac: a small bit of matter is created over time, about one proton per cubic liter every billion years or so.⁸⁸ This preserves the integrity of the Steady-State model given the observed expansion of the universe—as galaxies move apart, the created matter forms new galaxies and maintains the large-scale homogeneity of the universe. The mechanics of matter creation is superfluous to the history of the anthropic principle. The point here is that the perfect cosmological principle connects one of Dirac’s lines of thought—matter creation—along with the argument that man had no special place in the universe. Being so disadvantaged, mankind could never place its home on a map. Dennis Sciama noted the plight of a poor traveler trapped in a Steady-State universe: “Our unfortunate presbyope in addition to being completely lost, would not know the time.”⁸⁹

earth was older than the known universe, Hoyle’s ‘radical’ attitude, and a horror movie. For more on this, see relevant chapters in Kragh, *Cosmology and Controversy*; Neil A. Porter, *Physicists in Conflict* (Bristol: Institute of Physics Publishing, 1998); and the commentaries by Hoyle, Bondi, and Gold in Yervant Terzian and Elizabeth Bilson, eds., *Cosmology and Astrophysics: Essays in Honor of Thomas Gold* (Ithaca, New York: Cornell University Press, 1982)

⁸⁸ Hermann Bondi and Thomas Gold, “The Steady-State Theory of the Expanding Universe,” *Monthly Notices of the Royal Astronomical Society* 8, no. 5 (Oct. 8, 1948): 256.

⁸⁹ Dennis Sciama, *The Unity of the Universe* (Garden City, New York: Doubleday and Co., 1959), 169.

The links between the Steady-State theory and the anthropic principle develop as a result of the interaction of Robert Dicke and Brandon Carter to matter creation and the Copernican principle, respectfully. Before continuing with this history, it would do well to define the metascientific principles important to this discourse. The perfect cosmological principle has already been defined, and the following briefly describes the characteristics and importance of Mach's principle, the cosmological principle, and the Copernican principle.

Steady-State scientists commonly used Mach's principle as a trope for explaining gravity. Einstein originally introduced it into his theory of relativity as a way of viewing inertial motion; or, inertia was the result of the attractive force of *every* object in the universe. After Einstein, cosmologists generally viewed Mach's principle as interesting but controversial. As Bondi noted, "A number of objections have been raised against [Mach's principle] by various authors. It is widely believed that Mach's principle is of philosophical rather than physical content, and that hence it can be of no physical relevance even if it were logically and philosophically tenable."⁹⁰ But Bondi and Gold believed it said something very important about the everyday scientific laboratory—objects near in an earthly lab were necessarily affected by the interaction with far away masses like stars and galaxies. If valid, Mach's principle then implied that,

The nature of any local dynamical experiment is fundamentally affected by distant matter. We can hence not contemplate a laboratory which is shielded so as to exclude all influence from outside; and for the same reason we cannot

⁹⁰ Bondi, *Cosmology*, 30.

have any logical basis for choosing physical laws and constants and assigning to them an existence independent of the structure of the universe.⁹¹

Which, put simply, meant that everything in the universe—man, rocks, gas, whatever—was affected by everything else in the universe. But if true, then, the Steady-State theorists demanded an answer to an even more fundamental question: what guaranteed these interloping forces to be constant over vast distances? Or put another way, what if capricious forces from the other side of the galaxy were interfering with laboratory experiments here on earth?

That guarantee had been taken for granted by most cosmologists: the universe was “isotropic,” or that physical laws acted uniformly in all directions. But as the Steady-State scientists pointed out, an expanding cosmology could not guarantee isotropy with a universe of varying density; rather, it needed to assume it. The Steady-State theory touted that Mach’s principle in a universe abiding by the perfect cosmological principle would promise uniform repeatability for experience. As Bondi said, “A displacement of the observer in space or time resulting in a substantial change in the picture presented to him by the universe would lead to great changes in his local system of dynamics such as (at least) a change of the constant of gravitation.”⁹² Therefore, in Bondi’s view, an isotropy could only be guaranteed in a universe that abided by the perfect cosmological principle and Mach’s principle. It will be seen later how Stephen Hawking and C.B. Collins took this sentiment of

⁹¹ Bondi and Gold, 253.

⁹² Bondi, *Cosmology*, 33.

Mach's principle and, in a much more contentious approach, argued that the universe is isotropic "because we are here."⁹³

For purposes of clarification, two more commonly used principles should be defined. Preceding the perfect cosmological principle was the more basic "cosmological principle." The cosmological principle argued the large-scale universe was homogeneous, but time went forward in the usual sense.⁹⁴ Bondi and Gold then expanded this into the perfect cosmological principle, which included time, so that the universe was eternally uniform. There was also the Copernican principle, which asserted, along the lines of Nicolaus Copernicus, that humans did not inhabit a preferred location in the universe. While not used in 1948 Steady-State article, Bondi would make significant use of the Copernican principle in his 1961 textbook *Cosmology*. Brandon Carter would later react against this usage in 1973.⁹⁵

In summary, the Steady-State theory combined the Copernican principle with the perfect cosmological principle and did so with appeal to isotropy and Mach's principle—or in more simple terms: mankind had no privileged place in the eternally uniform universe, and this was evinced by the fact that physical laws are repeatable. If *any* of this changed, there would be no guarantee that the laws applicable to mankind's area of the cosmos applied anywhere else in the universe, which would be contrary to observation and common sense.

⁹³ Collins and Hawking, 334.

⁹⁴ *Ibid.*, 254.

⁹⁵ The later chapter will address this. For more on this topic, see Hermann Bondi, *Cosmology* (Cambridge, UK: Cambridge University Press, 1961) and Carter, "Large Number Coincidences and The Anthropic Principle in Cosmology."

Hopefully, it should be clear after this review just how fertile the realm of Steady-State cosmology would be for growing ideas like the anthropic principle. It spoke of man's place in the universe. It spoke of a necessary guarantee that the universe should be a certain way or else everything would be drastically different. And, maybe most significantly, a profusion of principles made serious scientific claims. The Steady-State would become a target for Brandon Carter in 1973, but in the meantime, another scientist began presenting some unconventional arguments to counter Dirac's time-dependent gravity.

Robert Dicke and Mach's Principle—The Enigma of Gravity

Of all the scientists to be declared the 'first' to use the anthropic principle, Robert Dicke would seem an unlikely candidate. He was American, saw himself largely as a physicist, and thought the whole scene around large number coincidences interesting but ultimately misleading.⁹⁶ In the 1940s he developed an interest in astronomy and in the 1950s began formulating a new theory of gravity that he presented with his student Carl Brans in 1961. Among scientists he was probably most well-known for predicting the Cosmic Microwave Background Radiation. But to the supporters of the anthropic principle he was a different brand of hero—he reminded physicists that the plurality of physical models could be narrowed by simple consideration to their real consequences on the universe. In the case of his dispute

⁹⁶ Bruce Partridge, "Obituary: Robert Henry Dicke, 1916-1997," *Bulletin of the American Astronomical Society* 29, no. 4 (1997): 1469-1470

with Dirac, Dicke pointed out that if gravity was mutable, then it had serious repercussions for life on earth.

With Dicke, I do not speak of an ‘explanatory’ anthropic principle, because Dicke never intended to explain the relationship between man and the cosmos. Instead, he pointed out certain boundaries that human existence could place on a scientific claim. I will show here the extents to which Robert Dicke’s gravitational theory delivered attention to Mach’s principle, Dirac’s large number hypothesis, and the first recognized use of an anthropic observation to refute a scientific claim.

Although Dicke did not support the Steady-State theory, he also utilized Mach’s principle to explain gravitational interactions.⁹⁷ In Einsteinian relativity, mass curved space and an object’s frame of reference determined the rate of acceleration compared to other objects. This could also hold true if an object was stationary and the surrounding objects were moving. Dicke said this view was not quite right, for it failed to adequately explain inertia. In Einsteinian relativity, the “inertial mass is purely a local property of the particle.”⁹⁸ As with Bondi, Dicke believed there was a more appealing way to describe Mach’s principle: “the inertial mass of a particle is determined by distant matter.”⁹⁹ In his work, Dicke enlarged the explanatory power of Mach’s principle: first, it eliminated locality of inertia; and second, which was probably most crucial to his theory, Mach’s principle established bounds that

⁹⁷ Robert H. Dicke, “Gravitation—An Enigma?” *American Scientist* 47, No. 1, (March 1959), 35-36. This is the most accessible description of Dicke’s gravitational theory. While other explanations are more technical in nature, they continue to adhere to the centrality of Mach’s principle.

⁹⁸ *Ibid.*, 35.

⁹⁹ *Ibid.*

relativity needed to work within.¹⁰⁰ In other words, any interpretation of relativity needed to apply to the real world.

Robert Dicke targeted Dirac's time-dependent gravity as the foil for his new theory of gravity. This work was commonly cited to be the first instance of an anthropic argument in science. However, Dicke's work should also be seen as a quiet refutation of Steady-State cosmology, which was not how cosmologists saw it at the time, but how Brandon Carter would see it in 1973. For this reason, I will show how Dicke's work did double-duty. His efforts would span from 1957 to 1961, embodied mostly in five articles. Two of them he published in the July 1957 *Physical Review* journal. It should be noted how Dicke was not instantly possessed by the anthropic principle as seen by Carter, but rather, over time he believed that the existence of mankind acted as a powerful litmus test for the plurality of scientific models.

Of his two articles that appeared in the same issue of the *Physical Review*, the first was the "Principle of Equivalence and Weak Interactions." Here, Dicke introduced his argument that treating gravity like the other nuclear forces was incorrect. To do this, he needed to add two concepts to the discussion: the "weak" and "strong" equivalence principles. In terminology, these would be important to Brandon Carter, and as metascientific principles they could guarantee the repeatability of experiments without appealing to the Steady-State cosmology. Generally speaking, these equivalence principles described the relation between an experiment and different frames of inertial reference—the weak applying to objects within the same gravitational field and the strong applying more or less universally.

¹⁰⁰ Ibid., 38.

Citing the work of the Hungarian physicist Loránd Eötvös, Dicke pointed out that an object had the same mass regardless of whether it was in an inertial or gravitational frame of reference. Or to put it another way, the kind of motion acting on an object had no effect on its mass, which gave credence to the belief that gravity and inertia were the same effect. Dicke then drew a line associating this with the ‘strong’ nuclear forces (strong, weak, and electromagnetic) to say that a corresponding increase or decrease in energy had a corresponding change of mass. Therefore, he said,

From these facts we conclude that the strong interaction constants are at least approximately *position independent*. If the strong interactions were to vary with position, the ratio of binding energy to particle rest energy would depend upon position and there would be an anomalous contribution to the weight associated with this variation.¹⁰¹

So, connecting the weak equivalence principle with the strong interaction principles, Dicke asserted that the basic properties of particles would remain uniform regardless of their location. In respect to the Steady-State, this provided an explanation for how physics could occur in a relativistic expanding universe—motion had no discernable effect on at least three of the fundamental forces.

But what about gravity? Dicke admitted gravity had little effect on the scale of particles, so the constancy of the strong interactions could not be immediately applied to the weak interaction. A general trend among Dicke’s work was his displeasure that once Einstein announced relativity, scientists blindly took it to be universally true. Much of his displeasure was aimed at, as noted with Bondi, the many different

¹⁰¹ Robert H. Dicke, “Principle of Equivalence and the Weak Interactions,” *Reviews of Modern Physics* 29, no. 3 (July 1957), 355. Emphasis mine.

cosmological models floating around. Of these, Dirac's happened to be ripe for Dicke to comment on the plurality of models and the constancy of gravity in one attack. Dirac's conjecture linked the constancy of the strong interactions with a variable gravity, the very problem Dicke needed to solve. Furthermore, the way Dicke approached this discussion was telling—the final blows would be delivered not with pages and pages of equations, but with a one page discussion of Mach's principle. While the historian cannot force a connection between the argumentation styles of conflicting cosmologists, it is revealing to know that Dicke's first article cites the first edition of Bondi's textbook *Cosmology* and their argumentation styles should be considered more philosophical than quantitative.

Dicke began addressing Dirac's hypothesis summarizing the different approaches to view the large number coincidence. Listing all of Eddington's large numbers, he explained them in three ways: 1) the universe was random, and "the weak interaction is weak, and that is all there is to it," 2) Eddington's explanation, to find the numbers as "solutions to very involved equations whose origin is not always crystal clear," and 3) Dirac's explanation, that there were unseen connections between the numbers and that since the age of the universe varied, the other relationships could vary.¹⁰² Focusing on Dirac, Dicke remarked that it was only applicable to a non-capricious universe.

Dicke, however, did not possess the normal means to approach the debate. There was no direct observational evidence contrary to Dirac's time-dependent gravity. The only way to go about addressing Dirac's system was to approach it in

¹⁰² Ibid. Dicke also adds Pascual Jordan to Dirac's style of explanation.

respects to the weak and strong equivalence principles. In respect to the strong equivalence principle, Dicke explained that if gravity weakens over time, then the corollary is that it also weakens over space. Acceleration would be dominated by the local strong interactions instead of massive bodies, and no bodies would fall with uniform motion. This obviously was not the case, so the strong equivalence principle ruled out Dirac's hypothesis.¹⁰³ Addressing Dirac's hypothesis in a local framework, or the weak equivalence principle, was a much more difficult approach.

Dicke utilized geology and astronomy to approach this aspect of Dirac's cosmology. In Dicke's mind, Edward Teller's analysis of surface temperature could no longer stand—in the ten years since its publication, the observed age of the universe had been tripled and the understanding of the atmosphere of the young earth had been completely overhauled.¹⁰⁴ Dicke narrowed Teller's argument and tried to convey that if gravity had been stronger in the past and the sun very much hotter, then the earth would be uninhabitable. But now biologists knew algae could survive in hot springs or otherwise human-unfriendly territory, and Dicke admitted it might be feasible that the "spontaneous origin of life in a condensed organic goo would be improved at a somewhat elevated temperature of about 100° C."¹⁰⁵ This caveat, that algae could survive where humans flounder, should demonstrate that at this time Dicke was not yet concrete in his belief of an 'anthropic' explanation. Ultimately, he was unsatisfied with his geological evidence, concluding that, "To summarize, none of the evidence reviewed here can be used to give strong support to Dirac's

¹⁰³ Ibid., 356-357.

¹⁰⁴ Ibid., 357.

¹⁰⁵ Ibid., 358.

hypothesis. On the other hand, it would appear that a variable gravitational interaction cannot easily be excluded by evidence reviewed here.”¹⁰⁶ Dirac’s hypothesis had not yet been completely refuted, prompting Dicke to pursue these arguments for the next few years.

Dicke’s following article, “Gravitation without a Principle of Equivalence,” tried to envision exactly what its title proposed. Moreover, it began with a brief commentary on the criterion for judging theories given the lack of observational evidence. “With so few experimental facts to guide one,” he said, “any number of *ad hoc* theories can be constructed. To choose between them, standards going beyond the observational evidence must be introduced. The danger of judging a theory on the basis of elegance, simplicity, or perfection is obvious.”¹⁰⁷ Clearly, this could be seen as a quiet referral to the perfect cosmological principle of the Steady-State theory. Undermining Steady-State, however, was not the point of this paper. It was to discuss a universe that lacked a universal constant of gravity at any given point in space. He briefly worked out the mathematics of this space, repeatedly adhering to the cosmological principle and Mach’s principle.

Toward the end of this paper, Dicke briefly addressed Dirac’s hypothesis again. Dicke had consciously worked out gravity without a principle of equivalence with a mind to keep everything time-independent so he could compare it to Dirac’s time-dependent conjecture. Dicke admitted his own proposal had a time-dependent dimensionless number (the dielectric constant), but that any relation between it and a

¹⁰⁶ Ibid., 362.

¹⁰⁷ Robert H. Dicke, “Gravitation without a Principle of Equivalence,” *Reviews of Modern Physics* 29, no. 3 (July 1957): 363.

larger number was largely illusory. “In the absence of a theory,” he said, “any of the large dimensionless numbers could contain a factor in the form of a power of this number without changing its order of magnitude. Consequently, the time dependence of a number cannot be inferred from its magnitude alone.”¹⁰⁸

So instead of just saying his time dependent number had significance by its numerological relationship to other numbers, Dicke worked out the implications of his theory. Eliminating most of Dirac’s numbers, he proposed the only “capricious” number was the number of atoms in the universe. Then, he applied the dielectric constant to the radiation rate of a star, realizing that if the time factor had been greater or lesser, it would “preclude the existence of man to consider this answer.”¹⁰⁹ Since man existed, the number must be within a certain range such that stars were neither too hot nor too cold. “The age of the universe, ‘now,’” he said, “is not random but conditioned by biological factors.”¹¹⁰ This argument, however, was very short—hardly more than a paragraph at the end of a fourteen page paper. Seen alongside his other paper, Dicke seemed reticent to rely on this logic to refute Dirac. It was, as Dicke feared, the very sort of *ad hoc* explanation he rued. Clearly, in 1957 Dicke was thinking on ways that human existence could restrict the many cosmologies in existence, but he was far from explaining the universe with this knowledge.

Now for an historical aside to illustrate the similarities and differences between my account and that of Barrow and Tipler. We agree that Dicke had unwittingly provided evidence against the Steady-State theory. That is about all we

¹⁰⁸ Ibid., 375.

¹⁰⁹ Ibid., 376

¹¹⁰ Ibid. 375.

agree on. Barrow and Tipler hail Dicke as the ‘inventor’ of the weak anthropic principle.¹¹¹ Even the thesis statement of their chapter, “The Rediscovery of the Anthropic Principle,” hails Dicke as the founder: “In this chapter we shall describe some of the background to these and other cosmological ‘coincidence’ and show how, in the period 1957-1961, they led to Dicke’s proposal of an anthropomorphic mode of explanation.”¹¹² Perhaps this disagreement stems from their assertion that Dicke’s contribution “provide[s] the first modern examples of a ‘weak’ anthropic principle; that the observation of certain, *a priori*, remarkable features of the Universe’s structure are necessary for our existence.”¹¹³ In my account, I endeavor to show Dicke’s initial reticence to use these arguments, and actually that his overall goal was not to point out the privileged position of man but to call for restraint among the various cosmologies.

In these respects, Barrow and Tipler’s account is a bit ahistorical. Instead of viewing Dicke as struggling to comprehend Dirac’s equations, they see him as having a single-minded goal: developing anthropic arguments. To me, it seems that in 1957, Dicke’s gravitational theory was still evolving, as was his opinion of using anthropic explanations. I am not arguing with the mathematical models of the Barrow and Tipler account, but rather portraying a new interpretation of the development of the road to the anthropic principle. I am, however, going to propose that Dicke came to

¹¹¹ Barrow and Tipler, 125.

¹¹² *Ibid.*, 219.

¹¹³ *Ibid.*, 248. It should also be noted that they give some credit to Gerald James Whitrow, a British cosmologist, for formulating an anthropomorphic explanation of the dimensionality of the universe in 1955. After examining this document, Whitrow is thinking along those lines, but I have decided not to include him because 1) he was not in communication with Dicke, and 2) no scientist at the time cites him as an influence. For more on this, please consult Gerald J. Whitrow, “Why Physical Space Has Three Dimensions,” *The British Journal for the Philosophy of Science* 6, no. 21, (May, 1955), 13-31.

terms with anthropic explanations in 1958, a position that neither Barrow and Tipler nor Brandon Carter have yet taken.¹¹⁴

In April 1958, Robert Dicke spoke before the Philosophical Society of Washington, giving the 27th annual Joseph Henry lecture on “Gravitation—An Enigma.”¹¹⁵ He began his presentation very much like his other papers: the uncharacteristic immediate acceptance of Einsteinian relativity, its weakness in defining inertia, the peculiarity of gravity as a weak force, and then the cases of Dirac’s cosmology. To consolidate his message, he presented only the numbers around 10^{40} : the ratio of the electrical to gravitational forces between an electron and a proton, the age of the universe in atomic units, and the square root of the number of atoms in the universe. Then he stopped to explain the implications: “Dirac’s hypothesis is very interesting as it suggests that the gravitational interaction between two particles is not purely a local phenomenon but depends upon distant matter. As the amount of matter in the visible universe becomes greater, the gravitational interaction becomes weaker.”¹¹⁶ Essentially, if one were to follow the entirety of Dirac’s hypothesis—that matter was continuously created *and* gravity weakened with time—then eventually there would be a time when gravity would be so weak that it could do nothing to affect the absolute bounty of matter in the universe. Dicke briefly listed seven arguments against Dirac’s cosmology, before summarizing a new argument.

¹¹⁴ Most likely, this is because Dicke did not publish a scientific article on it. It was a presentation to a philosophical panel.

¹¹⁵ Dicke, “Gravitation—An Enigma,” *American Scientist* 25-40.

¹¹⁶ *Ibid.*, 31.

The assault began with what Dicke called the “logical loophole” in Dirac’s cosmology.¹¹⁷ According to Dirac, because the age of the universe changed, only for a ‘short’ time would humans view the numbers around 10^{40} to be near the same value. But the problem was that this correlation could really happen at any time in history—although gravity was weakening, Dirac’s hypothesis had no way of telling how long it had been weakening or how long it would continue doing so. Dicke had already proposed some answers to this in his 1957 papers with the argument that a variable gravity would make the earth be habitable for a very specific time period.

At this 1958 conference he introduced another explanation with a very different implication: since humans were made of carbon and, in turn, carbon was made in stars, then stars needed to exist for at least a billion years to produce that carbon. Also, since stars eventually burned out and killed all known life on planets after about 10^{14} years, humans could not be living past this time. Therefore, humankind must inhabit a very specific point in cosmic time.¹¹⁸ His immediate conclusion was to proclaim the ratio of electrical and gravitational forces between the proton and electron to be fundamental, the age of the universe to be bounded by biological considerations, and the number of atoms in the universe unexplainable due to the inability to understand matter creation.¹¹⁹ This was just a more refined version of his 1957 argument.

So far in his speech, Dicke had set up and knocked down Dirac’s cosmology. For the first time, he refuted Dirac entirely by reference to anthropic observations.

¹¹⁷ Ibid., 33.

¹¹⁸ Ibid.

¹¹⁹ Ibid.

Dicke's anthropic system, however, was still incomplete. He had one more argument up his sleeve that he briefly elucidated on that day in April: the role of Mach's principle in constraining Einsteinian relativity. Two years later, this would become Dicke's favored tool in dismissing Dirac for once and for all.

In 1961, Dicke wrote a short letter to the editor in *Nature* which crammed the majority of his arguments into one page. In his conclusion, Dicke solved the connection between the number of atoms in the universe and the gravitational relationship between particles: it was explainable by Mach's principle. Given the definitions of Mach's principle developed separately by Dennis Sciama¹²⁰ and himself, the large number called the gravitational coupling constant was no longer a constant but a function of the mass distribution of the universe. Dicke then proclaimed, "The reason for the smallness of the gravitational coupling constant is the enormous amount of matter in the universe."¹²¹ Concluding, he announced:

The statistical support for Dirac's cosmology is found to be missing. However, the existence of physicists now and the assumption of the validity of Mach's principle are sufficient to demand that the order of magnitude relations between the three [dimensionless numbers]...be satisfied.¹²²

Dicke had completed his refutation of Dirac. Dicke had provided three different examples of anthropic observations in his work—intolerable solar temperatures made by time-dependent gravity, the finite life-span of stars, and the distribution of mass in the galaxy. The same issue of *Nature* included Dirac's

¹²⁰ Dennis W. Sciama, "On the Origin of Inertia," *Monthly Notices of the Royal Astronomical Society* 113, no. 1 (1953): 34-42. This will be discussed in chapter three.

¹²¹ Robert H. Dicke, "Dirac's Cosmology and Mach's Principle," *Nature* 192, (Nov. 1961), 440-441.

¹²² *Ibid.*, 441.

response. He flipped Dicke's assertion around and took a pessimistic interpretation: if humankind needed live at a time when the solar system had habitable properties, then it followed there would be a time when planets would be inhospitable to life. Dirac found this repugnant at the time, instead proclaiming, "With my assumption they could exist indefinitely in the future and life need never end."¹²³

My account portrays this critical developmental time of the anthropic principle as being a struggle of Robert Dicke to come up with an alternate method of critiquing scientific claims and appealing to his own scientific principles and also Mach's principle. Barrow and Tipler and Carter generally assume Dicke had always possessed his anthropic explanations. My account stems from extensive analysis of Dicke's work and analyzing its development. Perhaps most telling is an interview he gave in 1988. Here, Dicke explains his 'anthropic principle' was completely non-controversial; it just took some observations and used them to refute another argument. Carter's "exciting" version, however, "would require quite a revolution in the way of doing physics."¹²⁴ In the end, Dicke did use anthropic observations in a scientific way, but the sentiments required a few more players, discussed in chapter 3, before Carter's 1973 paper could be proposed.

Fertile Ideas: The Introduction of the Anthropic Principle

By now, the reader should be acquainted with the general scene of theoretical astronomy going into the 1960s. The debate among the Steady-State and Big Bang

¹²³ Paul Dirac, "Dirac's Cosmology and Mach's Principle," *Nature* 192, (Nov. 1961), 441.

¹²⁴ Alan Lightman and Roberta Brawer, *Origins: The Lives and Worlds of Modern Cosmologists* (Cambridge, Mass: Harvard University Press, 1990), 211.

theories pushed philosophical principles into the everyday world of cosmologists. Of particular importance at the time, cosmologists wanted to understand the relationship between man and the cosmos—from Eddington’s *Fundamental Theory*, to Dirac’s relationship between the microscopic and the macroscopic, to the increasing usage of Mach’s principle in scientific literature. Dicke became the first physicist to cogently argue human existence could rule out arbitrary scientific theories, but these limits were just observations. If a scientist were to take this mid-twentieth century fascination with the relationship between man and the cosmos to an explanatory level, he would be arguing the first true instance of the anthropic principle. This man would be Brandon Carter in 1973.

In contrast to Robert Dicke, Carter would probably be a very likely character to engage in anthropic explanations. His fruitful relationship with Cambridge and his colleagues—Dennis Sciama, Stephen Hawking, George Ellis, and Martin Rees—will be discussed in chapter three. At Cambridge, Carter attended lectures by Paul Dirac and Fred Hoyle. During post-doctoral work in America, he met John Wheeler and Robert Dicke. Perhaps most revelatory, Carter had his own leanings toward an explanation of man and the cosmos before he met Dicke. Carter admits that at the time, Dicke did not directly influence his ideas, but that he received encouragement to pursue his goals from this like-minded scientist.¹²⁵

Pushed by John Wheeler, Brandon Carter showed up to the Copernicus Symposium in Krakow, Poland in mid-September 1973. Carter had been circulating a paper among his Cambridge friends, discussing the relationship between man and the

¹²⁵ Brandon Carter, personal communication, January 9, 2007.

cosmos.¹²⁶ It had taken quite well with his colleagues—by now, Stephen Hawking had already published two papers using its logic. Even now in Krakow, Hawking had just announced that “Since we could not observe the universe to be different if we were not here, one can say, in a sense, that the isotropy of the universe is a consequence of our very existence.”¹²⁷ Shortly after Hawking’s presentation, Carter would propose that mankind’s existence may have something very special to say about the universe.

It was clear that at the time that Carter was a bit unsure whether he should be presenting. He began by saying, “This concerns a line of thought which I believe to be potentially fertile, but which I did not write up at the time because I felt (as I still feel) that it needs further development.”¹²⁸ Wheeler had convinced him, however, that this conference, in recognition of Copernicus’ five-hundredth birthday, would be the right time and place. Carter finished his introduction by saying his speech “consists basically of a reaction against exaggerated subservience to the ‘Copernican principle.’”¹²⁹

Now here is the historical moment that most accounts ignore in favor of the more tantalizing predictions brought up later in the paper. Carter describes how he had read Bondi’s textbook *Cosmology* and been taken with the discussion of large

¹²⁶ This preprint, “Large Numbers in Astrophysics and Cosmology,” is thought to be housed somewhere in Cambridge. Mark Hurn, the librarian of the Institute of Astronomy, could not find the paper anywhere. The Department of Applied Mathematics and Theoretical Physics did not respond to any communication. Carter himself pointed to two articles that contained the bulk of his argument.

¹²⁷ Stephen Hawking, “The Anisotropy of the Universe at Large Times,” *Confrontation of Cosmological Theories With Observational Data*, ed. M.S. Longair (Dordrecht, Holland: D. Reidel Publishing Co., 1974) [Symposium No. 63 (Copernicus Symposium II) Held in Cracow, Poland, 10-12 September 1973], 286.

¹²⁸ Carter, “Large Number Coincidences,” 291.

¹²⁹ *Ibid.*, 291.

number coincidences. He did not agree with the “dogma” of the perfect cosmological principle, though, and in refutation of it he cites, of all people, Dicke’s 1961 letter to the editor.¹³⁰ As demonstrated, Dicke’s paper actually had no overt interest in Steady-State; its purpose was to show that Dirac’s hypothesis was untenable by appeal to Mach’s principle. However, Carter took Dicke’s evidence that man must live in a defined time of the universe and extended it to demonstrate that the eternally uniform Steady-State theory was wrong. Continuing this logic, Carter argued that the Copernican principle was also incorrect—along with a very specific time, man must live in a very specific place in the universe. Hopefully now the connection between Steady-State, Dicke, and Carter is crystal clear.

Continuing his argument, Carter proposed a new interpretation of the large number coincidences, which deserves to be quoted at length:

I am now convinced of the opposite thesis: i.e. that far from being evidence in favor of exotic theories these coincidences should rather be considered as confirming ‘conventional’ (General Relativistic Big Bang) physics and cosmology which could in principle have been used to predict them all in advance of their observation. However these predictions do require the use of what may be termed the *anthropic principle* to the effect that what we can expect to observe must be restricted by the conditions necessary for our presence as observers. (Although our situation is not necessarily *central*, it is inevitably privileged to some extent)¹³¹

From this, Carter would present his arguments for two different forms of the anthropic principle in ways reminiscent of Robert Dicke: the “weak” and the “strong” anthropic principles.

¹³⁰ Ibid.

¹³¹ Ibid.

Carter knew this claim treaded on shaky ground, and made sure to emphasize that these “predictions” would be within the realm of what an observer would expect to find in a universe compatible with life. It was an issue of semantics—Carter proposed that just from a proper understanding general relativity and the existence of life, all of these numbers could have been predicted to be within a certain range. To illustrate this possibility, he chose two large numbers presented by Bondi, the first being a relationship between the expansion of the universe and the gravitational coupling constant. Essentially, he argued the same way as Dicke—humans could not exist when stars were too cold or too hot. This number could be predicted by the *weak anthropic principle*, “To the effect that we must be prepared to take account of the fact that our location in the universe is *necessarily* privileged to the extent of being compatible with our existence as observers.”¹³² It should be clarified that when he said ‘location,’ he meant space and time.

Carter then postulated that taking this number and putting it into a closed universe would have drastic implications for fundamental parameters. Given the way the equation developed, it could go one of two ways—either the universe was infinitely full of radiation or it was not. Humans (or any known life form) could not exist in a universe made of pure energy. He then realized this assumption made a different claim than the weak principle: “It implies a fairly severe restriction not merely on *our location* within the universe but on one of the fundamental parameters of the *universe itself*.”¹³³ A scientist could then predict the outcome of the

¹³² Ibid., 293.

¹³³ Ibid. Emphasis Carter.

fundamental parameter using the *strong anthropic principle*, “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.”¹³⁴ In other words, because life developed, the fundamental parameters must have been conducive to its development, and by his or her existence a scientist could disregard incongruent possibilities.¹³⁵

Carter then clarified:

It remains true however that whereas a prediction based only on the *weak* anthropic principle (as used by Dicke) can amount to a complete physical explanation, on the other hand even an entirely rigorous prediction based on the *strong* principle will not be completely satisfying from a physicist’s point of view since the possibility will remain of finding a deeper underlying theory explaining the relationships that have been predicted.¹³⁶

Here Carter favors the weak principle, which essentially meant that one would expect to find the universe compatible with existence and nothing more. Being the first to publicly speak of the general scientific utility of human existence, Carter continued to establish boundaries of where the anthropic principle could go. His last explanation would venture furthest from conventional science, and despite his initial reticence, would become a popular explanation among many supporters of the anthropic principle.

Carter’s introduced this last section by saying, “It is of course always philosophically possible—as a last resort, when no stronger physical argument is available—to promote a *prediction* based on the strong anthropic principle to the

¹³⁴ Ibid., 294.

¹³⁵ This should *not* be confused with Barrow and Tipler’s claim that the universe is organized for the sole purpose of developing life.

¹³⁶ Ibid., 295

status of an *explanation* by thinking in terms of a ‘world ensemble.’”¹³⁷ Here he meant an ensemble of universes, each characterized by a specific set of fundamental parameters. In this case, only some universes would produce observers, and these universes would necessarily possess certain qualities that might otherwise seem capricious. Carter’s target for this explanation: the gravitational coupling constant. Scientists from Eddington to Dicke had struggled to explain this weak constant. Carter could explain it, although not in a way he preferred, by pointing out that if the constant had been much different, then the universe would be filled with hot red stars or cold blue stars and nothing in-between. Carter concluded, “This suggests a conceivable world ensemble explanation of the weakness of the gravitational constant.”¹³⁸

It is conceivable Carter included this section as one possible way to investigate the fuzzy possibilities of the world ensemble. It is generally agreed among cosmologists that if there are multiple universes, there could be no way of jumping out of this universe to learn the finer points of another universe. This could be circumvented, however, if humans considered themselves to occupy one of the universes which possessed the right combinations of fundamental constants which produced life. By determining the likelihood of ‘fine-tuned’ properties (not Carter’s terminology) like the gravitational coupling constant, it is conceivable that the anthropic principle would give insight to the validity of what became known as the

¹³⁷ Ibid. Emphasis Carter.

¹³⁸ Ibid., 297.

Many Worlds Hypothesis. Carter wanted to qualify these intentions, concluding by saying:

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 able to be construed as evidence that the world ensemble philosophy should be taken seriously—even if one did not like it.¹³⁹

Essentially, Carter invited cosmologists to entertain his idea to see how effective it might be in producing useful information about the fundamental structure of the cosmos. *If* it worked often, then modern scientists may have found in their law-like patterns an underlying unity of the cosmos.

In summary, Carter's anthropic principle argued that the existence of life—of which he inadvertently picked the loaded word 'anthropic'—could be used to point out limitations of scientific theories and some restrictions on the fundamental parameters of the universe. His difference between the two principles was a matter of magnitude: from the weak principle's assertion that man lived in a necessarily privileged location, to the strong principle's assertion that because man existed the fundamental parameters of the universe must have been such to allow the observed development of life. This difference would then be interpreted in a different way by Barrow and Tipler, leading to the popular teleological anthropic principles.

¹³⁹ Ibid., 298.

Conclusion

As noted in the chapter introduction, Barrow and Tipler made one of the more contentious attributions to Carter's principle when they said, "It is inevitable that some would look at the existence of these features from another angle, one reminiscent of the traditional 'Design arguments' that the Universe..."¹⁴⁰ After examining Carter's principle, it should be fairly clear that he had no intention of design. In 2006 Carter remarked, "Indeed the term "anthropic principle" has become so popular that it has been borrowed to describe ideas (e.g. that the universe was teleologically designed for our kind of life, which is what I would call a "finality principle") that are quite different from, and even contradictory with, what I intended."¹⁴¹ Clearly, Carter is talking about the Barrow and Tipler models here.

The anthropic principle originally developed as a reaction to the Copernican principle and in response to the greater metascientific principles spoken of by Steady-State cosmologists. I would claim it is really just another form of a metascientific principle, like Mach's principle or the cosmological principle. As mentioned in the introduction, a simple change in the syntax of Mach's principle as described in Bondi and Gold's Steady-State paper, "Our observations of the universe depend on the interactions between the rest of the universe and ourselves," arrives at Carter's generalized anthropic principle: "What we can expect to observe must be restricted by the conditions necessary for our presence as observers." Looking at the history from

¹⁴⁰ Barrow and Tipler, 248.

¹⁴¹ Brandon Carter, "Anthropic Principle in Cosmology," [online] available: http://uk.arxiv.org/PS_cache/gr-qc/pdf/0606/0606117.pdf (preprint submitted 27 June 2006). Accessed 21 January 2007.

Bondi to Dicke to Carter, it should be clear how they could use these principles to make scientific claims where traditional methods failed. The next chapter presents an entirely different strategy toward the history of the anthropic principle based on Carter's collegiate community.

Chapter Three

A New Approach to the Development and Dissemination of the Anthropic Principle

The first two chapters demonstrated the development of the anthropic principle as being epiphenomenal to the rise of cosmology: its development drew upon existing discussions of observation selection effects, the increased use of particular metascientific principles, and their utility in analyzing the large number coincidences. As an analysis of the causal relations between scientific ideas over time, this approach would do justice to the anthropic principle's traditional placement within the realm of the history and philosophy of science. However, this methodology cannot explain a very fundamental question posed at the beginning of this thesis: how did the local scientific milieu affect the development of the anthropic principle? Or in other words, to what degree did environmental factors like social networks, such as friends and mentors, and institutional networks, such as Cambridge and the broader discipline of cosmology, influence Brandon Carter? And how did they continue to be influential after the introduction of the anthropic principle? This chapter will address these questions and propose that a complete history of the anthropic principle needs to consider these very interesting environmental factors.

This approach demands awareness that environmental factors are often considered 'subjective,' which can be confused with discussions of scientific validity. When speaking historically, this is an important distinction. Using the example of Eddington's selective subjectivism, he argued that the mind could only know what it

had experienced. This did not mean, however, that his corpus of knowledge was limited to chats with friends; it was also tempered by nights with telescopes and mathematical equations. I want to form an historical approach to the anthropic principle that includes these environmental and scientific considerations. In addition to discussions over the large number coincidences, it is important to consider Brandon Carter's circle of colleagues and the important roles they played in the formation and dissemination of the anthropic principle. This method naturally forms two distinct periods in the development of the anthropic principle: first into Carter's model, then into the Barrow and Tipler model.

Andrew Warwick's *Masters of Theory* best exemplifies this approach through his analysis of the rise of mathematical physics in nineteenth and early twentieth century Cambridge. Here he considers the development of knowledge through the eyes of a student struggling with an academic discipline, particularly how they approach difficult problems based on their educational background. Warwick's description of this methodology: "I also contend that *how* and *by whom* students were taught is as important as *what* they were taught."¹⁴² Extending this to the anthropic principle, I will cover the known connections between Brandon Carter and a cadre of prominent cosmologists who emerged from the tutorship of Dennis Sciama in the 1960s, and how they used a base of knowledge to formulate answers to very perplexing cosmological questions.

¹⁴² Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics* (Chicago: University of Chicago Press, 2003), x.

This approach then puts a focus on how and where a group can interact, in this case, the setting of Cambridge University in the 1960s. Some historical accounts would demand that a scientist interact with his peers in a laboratory setting, but this poses somewhat of a problem for cosmologists—their laboratory is the universe. Since an historical analysis of the interactions between all the inhabitants of the universe is a bit beyond the scope of this paper, it will suffice to replace the traditional laboratory setting with an investigation of the relations between colleagues in the proximity of Cambridge University. This approach combats the “everywhere is nowhere” account so familiar to the anthropic principle, in which an isolated Brandon Carter makes his announcement that then becomes omnipresent for the use of scientists.¹⁴³

This framework then places the anthropic principle alongside a framework utilized by Martin Rudwick. When he approached a debate between geologists over the role of certain rocks in the English countryside, he explained his methodology like this:

What [is] needed, for a fuller understanding of the processes by which scientific knowledge is shaped, are empirical studies of science in the making—whether in the past or the present is of lesser consequence—which focus not on one individual scientist but on a specific *problem* that brought together some *group* of individuals in an interacting network of exchange.¹⁴⁴

¹⁴³ Jan Golinski, *Making Natural Knowledge: Constructivism and the History of Science*, 2nd Ed. (Chicago: University of Chicago Press, 2005), 80. Here, Golinski battles the idea that once announced, an idea no longer has a home. The extension of this argument to the anthropic principle is my own doing.

¹⁴⁴ Martin J.S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985), 6.

This characterizes the anthropic principle quite well, actually. When removed from the narrow focus of the history of science and philosophy, the development of the anthropic principle takes a new life. The ‘problems’ to be explained are the large numbers, Dirac’s hypothesis of a time-dependent gravity, and Bondi and Gold’s perfect cosmological principle. The people are Dennis Sciama’s students. The network of exchange begins in Cambridge and continues through article publishing. After Carter’s presentation, this network of relations becomes the most important factor for the dissemination of the anthropic principle.

By placing importance on local influences, however, such an approach runs the risk of “institutional solipsism.”¹⁴⁵ In a history of Oxford physics, Robert Fox and Graeme Gooday warned: “Analysis that touches insufficiently on contextual elements on the national or international scale will necessarily be flawed, even with regard to a university as apparently autonomous as Oxford.”¹⁴⁶ This argument applies equally as well to Cambridge, and is an issue for this paper. Modern histories of Cambridge are scarce and rarely concerned with science. Perhaps more surprising is the paucity of modern cosmological histories—while Helge Kragh’s books are celebrated achievements, in many cases they are chronicles rather than analyses. The literature of the history of cosmology has determined the salient events and who opposed who, but historians have given little input to the interaction between cosmological ideas among scientists and their influence on the discipline and the public realm. I will try to counteract the dearth of secondary sources by utilizing the full spectrum of primary

¹⁴⁵ Robert Fox and Graeme Gooday, eds. *Physics in Oxford 1839-1939* (Oxford: Oxford University Press, 2005), 5.

¹⁴⁶ *Ibid.*

sources on contemporary cosmology—autobiographies, popular works, and scientific articles.

Putting it into perspective, then, this chapter proposes what no other history of the anthropic principle has yet tried: the elucidation of the social and cultural roles active in the development and dissemination of the anthropic principle. Chapters one and two argue that certain approaches to understanding the universe have a great impact on the scientific development of the anthropic principle, namely Eddington's Fundamental Theory, Dirac's large number hypothesis, and the work of Robert Dicke. This chapter then argues that the development of the anthropic principle owes, in part, its creation and dissemination to the existence of the Cambridge social network.

I will begin this chapter with a broader view of the utility of cosmology and its scientific explanations, which is a very influential environmental factor surrounding the development of the anthropic principle. Cosmologists, in general, have explanations geared toward a very different purpose than other scientists. The following brief analysis of the utility of cosmology will nicely frame the later discussion of Dennis Sciama and his students.

Cosmology and the Anthropic Principle: An Ordinary and Useful Relationship?

After World War II, aspiring scientists treaded through sweeping changes in Cambridge University. The booming numbers of undergrads brought vitality to scholastics and campus life, but also put a burden on educational finances. In one account of Cambridge, Christopher Brooke thought the students solved this dilemma

by virtue of their subculture, remarking that they “had long hair, ill-fitting, tattered clothes, sang hideous songs and rarely washed. The student uprising—whether one views it as a great surge of human idealism or a sordid outflow of human violence—was a godsend to those who handled the country’s finances.”¹⁴⁷ Regardless of whether the hippies really caused a clamp-down on university funding, it marked a time in the post-War period when pressure fell upon students to make their work ‘useful.’ This utility played an influential role in the idiosyncrasies common to cosmologists and cosmology that formed a community conducive to the anthropic principle.

Pressure to succeed forced many young scientists to view their profession as necessarily privileged: if they did well enough, they might become the next Fred Hoyle or Francis Crick. As summarized in an educational report:

Scientists, [students] believe, are educated in universities and go on, if they are lucky, to ‘do research’: research is glamorous, ‘interesting,’ leads to exciting new discoveries, is not really ‘work,’ and may well make one famous. Technologists, on the other hand, have low social prestige, are less intelligent and less well paid than scientists, and their work is often ‘boring.’¹⁴⁸

This sentiment went far beyond a simple delineation of science and technology, though.

In May 1959, Charles Pearce Snow, better known as C.P., spoke before the Senate House at Cambridge on the gap he perceived between scientists and the larger

¹⁴⁷ Christopher N.L. Brooke, *A History of the University of Cambridge*, vol. 4, (Cambridge, UK: Cambridge University Press, 1993), 512.

¹⁴⁸ Donald Hutchings, *The Science Undergraduate: A Study of Science Students at Five English Universities* (Oxford: Oxford University Department of Education, 1967), 9.

literary tradition of Britain. A trained physicist and well-published science fiction writer, he lamented the nation's educational policy perpetuated by the Cambridge and Oxford tradition:

Somehow we have set ourselves the task of producing a tiny *elite*—far smaller proportionately than in any comparable country—educated in one academic skill. For a hundred and fifty years in Cambridge it was mathematics: then it was mathematics or classics: then natural science was allowed in. But still the choice had to be a single one.¹⁴⁹

In the 1960s, Snow asserted, the stereotypical British scientist possessed great intelligence but was unaware of society at large—he could help the world with a head full of knowledge if he just left the lab once in a while. This led, according to Snow, to scientists reveling in their usefulness and quickly forgetting that literary intellectuals, who did the ‘boring’ work and earned half as much in wages, dominated the political sphere and controlled the scientists’ funding.¹⁵⁰ Snow named these estranged fields the “Two Cultures,” and called for renewed relations. I neither affirm nor deny Snow’s thesis or its political ramifications, but instead use it to point out a feature held in common with modern cosmology.

Modern cosmologists have been renowned for bridging the communicative gap, what Snow calls the ‘Third Culture.’ Many cosmologists believe their study of the grandeur of the cosmos translates to insight of the human condition. They slough through the cultural gap predicted by Snow—one of fawning interest by some readers and irreverence by others. For instance, Stephen Hawking’s *A Brief History of Time*, often derided by his colleagues for its presentation of simplistic physics and

¹⁴⁹ C.P. Snow, *The Two Cultures* (Cambridge, UK: Cambridge University Press, 2001) [First edition 1959, Second Edition 1964], 19.

¹⁵⁰ *Ibid.*, 18.

astronomical conjecture, has sold millions of copies in many languages and is considered a staple of popular physics.¹⁵¹ Its success rubbed off on Hawking's earlier technical work, *The Large Scale Structure of Spacetime*, which sold over 20,000 copies despite being "completely unreadable except by experts working in the field of cosmology."¹⁵² This is just one example of how cosmologists fashion lucid expositions of their esoteric work for popular consumption.

Despite success in the third culture, in many ways cosmologists remain distanced from the practical world. To make a comparison, Rachel Carson's *Silent Spring* helped ban DDT; to this date, however, there is no known movement to protect the earth from black holes. Many cosmologists believe, however, that their insight extends beyond cosmic dangers and into the very nature of existence.

Astrophysicist Paul Davies (a published supporter of the anthropic principle) deserves to be quoted on this at length:

It's difficult to disentangle the problem of the two cultures and the third culture from the class and regional prejudices that pervade British society. One of the distinctive features of British intellectual life is its dominance by just two universities: Oxford and Cambridge. Most of the politicians and members of the establishment—the civil service, the media, and the people who control the media—are Oxford arts graduates. As a result, the public's perception of an intellectual is a graying, bespectacled gentleman who studies Greek mythology, drinks sherry, and punts leisurely and contemplatively on the river through the grounds of an ancient college. And with this perception is accorded a status suggesting that it's the art and literary intellectuals who have a God-given monopoly on the great issues of existence.¹⁵³

¹⁵¹ Michael White and John Gribbin, *Stephen Hawking: A Life in Science*, 2nd Ed. (Washington, D.C.: Joseph Henry Press, 2002), 126-128 and 250.

¹⁵² *Ibid.*, 127.

¹⁵³ Quoted in John Brockman, *The Third Culture* (New York: Simon and Schuster, 1995), 24. It would be prudent to mention Paul Davies's works, such as *God and the New Physics*, often place him near the realm of pantheism, and this might explain why he felt cosmology provided insight to the 'great issues of existence.' For more on this, see Phil Dowe, *Galileo, Darwin, Hawking: The Interplay*

His words are sufficient to point out that cosmology also grants rights to discuss issues of existence. The work of cosmologists inspires curiosity by the sheer mystique of its subject matter: the cosmos. Martin Rees, the current Astronomer Royal and supporter of the anthropic principle, echoed this sentiment:

The public is always interested in fundamental questions of origins. Just as they like dinosaurs, they're interested in cosmology. It's rather remarkable that the subjects which interest the public most consistently are sometimes so remote from everyday concerns. People who say that we have to make our work 'relevant' to attract public interest are clearly on the wrong lines, because nothing could be less relevant than dinosaurs and cosmology.¹⁵⁴

Cosmology, then, resides in a peculiar niche of scientific professions: it is engrossing yet by its nature superfluous to worldly matters. It is widely read yet often misunderstood. And maybe most onerous, cosmologists become famous without doing the 'work' of the technologists. Cosmology, then, should be considered a useful science, albeit in a very different way than other sciences.

In 1965, philosopher John David North posed a question of great importance to the field: "Is cosmology an ordinary science?"¹⁵⁵ Perhaps this was inspired in part by Dennis Sciama's 1959 assertion, "Cosmology is a highly controversial subject which contains little or no agreed body of doctrine."¹⁵⁶ North, however, disagreed, and I will support his conclusion that cosmology is an 'ordinary' science, for it follows the rules of the "scientific game;" the difference, however are "the concepts

of Science, Reason, and Religion (Grand Rapids, MI: Williams B. Eerdmans Publishing Co, 2005), 157.

¹⁵⁴ Martin Rees, "An Ensemble of Universes," In Brockman, *The Third Culture*, 263.

¹⁵⁵ J.D. North, *The Measure of the Universe: A History of Modern Cosmology* (Oxford: Clarendon Press, 1965), xxvii.

¹⁵⁶ Dennis Sciama, *The Unity of the Universe* (Garden City, New York: Doubleday and Co., 1959), 7.

and the methods of handling [the rules] in some way mark out a subject which, at least for the time being, tends to be separated from the rest of physics.”¹⁵⁷ In other words, there may not be an agreed ‘doctrine,’ but in making explanations, cosmology follows a basic grammar and syntax common to scientists.

This begs another important question in regards to cosmology and explanations like the anthropic principle: how would a cosmologist (or any theoretical scientist for that matter) explain their ideas differently than other scientists? Firstly, there is the basic tenet of an inductive scientific theory, as explained by Ian Barbour: “The mere amassing of data or cataloging of facts does not produce a scientific theory. But new concepts and abstract interpretive constructions do enable us to see coherent patterns of relationship among the data.”¹⁵⁸ These patterns connect nicely to an explanation given by physicist Steven Weinberg (who has used the anthropic principle in at least one instance¹⁵⁹): “We explain a physical principle when we show that it can be deduced from a more fundamental physical principle.”¹⁶⁰ A scientific principle is then formed from observations and causal connections coupled with perceived relationships.

¹⁵⁷ Ibid., xxvii.

¹⁵⁸ Ian Barbour, *Issues in Science and Religion* (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1966), 142.

¹⁵⁹ See Lawrence M. Krauss, “A Just-So Story,” *Nature* 423, (May 2003), 230-231. Also of interest is Steven Weinberg, “A Designer Universe,” [online] Available: http://www.physlink.com/Education/essay_weinberg.cfm, accessed 6 October, 2006. Weinberg is not as committed to the validity of the anthropic principle as many of his colleagues, but he has used its logic as a way of explaining the cosmological constant. Weinberg is also the author of a best-selling book on the Big Bang, *The First Three Minutes: A Modern View of the Origin of the Universe* (New York: Basic Books, 1977).

¹⁶⁰ Steven Weinberg, “Can Science Explain Everything? Can Science Explain Anything?” In *Explanations: Styles of Explanation in Science*, ed. John Cornwell (Oxford: Oxford University Press, 2004), 26.

Using this definition, cosmology then becomes an ideal field for the emergence of the anthropic principle. As Eddington noted, the individual particles that make up the universe are completely unobserved by the human mind, yet form everything that is observable and perceptible. Sometimes scientists have to develop theories that rely on undiscovered phenomena, like the Higgs boson and the graviton. When thinking cosmologically, however, the question “why?” these particles exist continuously appears. As Weinberg notes, “In some cases we can deduce something without explaining it.”¹⁶¹ As an example of this, Martin Rees points to eclipses: they could be predicted before they could be explained. Now they can be predicted far into the future, but whether the sky will be cloudy or sunny remains unpredictable until hours before the event.¹⁶² Combining it all, then, cosmologists believe that there are necessary laws of the universe, many of which cannot be explained. Then, as Rees points out, if some facet of the universe defies any explanation through current naturalistic understanding, such as Carter’s large numbers or Barrow’s fine-tuned properties, then “anthropic explanations will then be the best we can hope for, and cosmology will in some respects resemble the science of evolutionary biology.”¹⁶³

Cosmology, then, is an ordinary kind of science that uses extraordinary explanations, which gives it an important place among all sciences. Cosmological explanations are often scientifically useful, although rarely so in the utilitarian sense of other explanations such as radioactivity, which has manifold practical uses ranging from radioactive dating to treating cancer. This distinction between kinds of utility

¹⁶¹ Ibid., 31.

¹⁶² Martin Rees, “Explaining the Universe,” *Explanations*, 40.

¹⁶³ Ibid., 65.

among scientific fields is doubly important: 1) it illustrates why the anthropic principle is at home among cosmological explanations, and 2) it explains why the current form of the anthropic principle did not show up in other disciplines. As Alan Guth, founder of the inflationary model of the Big Bang, notes: “I’ve yet, for example, to hear an anthropic principle of world history. Historians don’t talk in those terms. They have more concrete things to say.”¹⁶⁴ Regardless of whether historians think the anthropic principle is concrete or not, they should acknowledge that many prominent cosmologists are willing to support such an idea in the public and professional realm.

To shift this distinction back to the 1960s and Dennis Sciama’s group, however, demands a certain qualification: cosmology then was not the same as cosmology now. It could be rightly said that Cambridge did not produce a true cosmologist until the 1970s, as the basic infrastructure to do so barely existed—the Department of Applied Mathematics and Theoretical Physics formed only in 1959, and the Institute of Theoretical Astronomy in 1968. While it might be unfeasible to say these men were *trained* cosmologists, the requirement to be classified as a cosmologist from 1920-1970 seemed to be the possession of a scientifically informed view of the cosmos. Martin Rees explained the distinction: “I would describe myself as an astrophysicist and cosmologist in that order. An astrophysicist tried to understand individual objects, like galaxies, quasars, stars, and their evolution, whereas a cosmologist is concerned with the entire universe, not the contents of it. I

¹⁶⁴ Alan Guth, In *Origins: The Lives and Worlds of Modern Cosmologists*, eds. Alan Lightman and Roberta Brawer (Cambridge, Mass: Harvard University Press, 1990), 479.

try to span those two disciplines, which after all are very closely linked.”¹⁶⁵ In some cases the title of cosmologist was thrust unwillingly upon the recipient, as in the case of mathematician Hermann Bondi: “I always detest being referred to as a cosmologist. Though I got fame from that subject it was far from being the only field in which I did research.”¹⁶⁶ Despite these feelings, many scientists showed no qualms about wearing any number of titles, as remembered by Jane Hawking, ex-wife of Stephen Hawking:

The distinction between these various terms was never quite clear to me, except that their identities seemed to change according to the titles of the conferences: they would all become astrophysicists if the next conference was a conference of the Astrophysical Union or relativist if it was a General Relativity conference and so on.¹⁶⁷

Among Sciama’s students, it could be said that the titles of astronomer, mathematician, physicist, and cosmologist are interchangeable. It is with no intention of malice or anachronism, then, that for simplicity this chapter uses the term ‘cosmologist,’ as I usually speak only of the scientist’s contributions to cosmology.

Cambridge Connections

Given this broad background, I will switch focus to very local setting of Cambridge and the group of students around Dennis Sciama.¹⁶⁸ Born on November 18, 1926, Sciama worked on solid state physics during the war. Afterwards, he obtained all of his degrees from Cambridge, receiving his doctorate in 1953 after

¹⁶⁵ Martin Rees, “An Ensemble of Universes,” John Brockman, *The Third Culture* (New York: Simon and Schuster, 1995), 263.

¹⁶⁶ Hermann Bondi, *Science, Churchill and Me: The Autobiography of Hermann Bondi, Master of Churchill College Cambridge* (Oxford: Pergamon Press, 1990), 63.

¹⁶⁷ Jane Hawking, 91.

¹⁶⁸ It is pronounced *Sharma*. Jane Hawking, 17.

working on Mach's principle and inertia under the supervision of Paul Dirac. Familiar with relativity and cosmology, he often shared ideas with the Steady-State scientists and supported their model throughout the 1950s. In the 1960s he did quite well for himself: in addition to being named Lecturer in Mathematics at Cambridge in 1961 and presenting foundational work in the study of quasars and dark matter, he mentored one of the most successful groups of cosmologists ever assembled: Martin Rees, Stephen Hawking, George Ellis, and Brandon Carter.¹⁶⁹

The success of this group is almost unparalleled in scientific history. It is regretful that no scholar has even put forth consideration as to their collegiate relationship, of which intricacies can be gleaned from their scientific and popular papers and the many biographies of Hawking. Each scientist deserves a brief introduction before continuing, and the specifics of their roles in disseminating the anthropic principle will be covered in a later section.

Stephen Hawking is probably the most famous of the group. Granted the Lucasian Professorship of Mathematics at Cambridge in 1980, he shares the honor with other notables such as Isaac Newton, Charles Babbage, and Paul Dirac. His affliction with amyotrophic lateral sclerosis has confined him to a wheelchair for the majority of his adult life, and he has spent much of the last two decades popularizing science. His early work, however, continues to influence modern cosmology. In the mid-1960s, Sciama took his group of students to watch Hermann Bondi's lectures in

¹⁶⁹ For more on Sciama, including an extensive 'family tree' of his students, please see the introduction of George Ellis, Antonio Lanza, and John Miller, eds., *The Renaissance of General Relativity and Cosmology: A Survey to Celebrate the 65th Birthday of Dennis Sciama* (Cambridge, UK: Cambridge University Press, 1993)

mathematics at University College, London, where Hawking met Roger Penrose, then a student in mathematics at Birkbeck College, London. At the time, Penrose had postulated that a very peculiar entity, a singularity, resided at the center of a black hole. Hawking, struggling for Ph.D. topic at the time, had realized after one of these meetings that Penrose's singularity might apply to the beginning of the universe. Much of his adult life has been spent advocating this solution, along with other particulars about black holes.¹⁷⁰ In respect to the anthropic principle, he had published research using its logic twice before Carter even announced the principle, and his major books *A Brief History of Time* and *The Universe in a Nutshell* both contain repeated references.¹⁷¹

Martin Rees, the current Astronomer Royal and President of the Royal Society, is arguably the most accomplished of the group. His early interest in relativity put him alongside Sciama for influential papers on quasars and the cosmic background radiation; in fact, of his first twenty published papers between 1966 and 1968, eleven are co-published with Sciama.¹⁷² He has long been associated with the anthropic principle, and many (incorrectly) see him as its originator due to his popular

¹⁷⁰ For more on Hawking, please consult the very excellent Jane Hawking, *Music to Move the Stars: A Life With Stephen* (London: Macmillan, 1999), and the more concise Michael White and John Gribbin, *Stephen Hawking: A Life in Science*, 2nd Ed. (Washington, D.C.: Joseph Henry Press, 2002).

¹⁷¹ His first two documents have been talked about in chapter 2, but for ease here are the references again: C.B Collins and Stephen W. Hawking, "Why Is the Universe Isotropic?" *The Astrophysical Journal* 180, No. 2, Part 1, (1973), 317-334; Stephen W. Hawking, "The Anisotropy of the Universe at Large Times," *Confrontation of Cosmological Theories With Observational Data*, ed. M.S. Longair, (Dordrecht, Holland: D. Reidel Publishing Co., 1974) [Symposium No. 63 (Copernicus Symposium II) Held in Cracow, Poland, 10-12 September 1973]: 283-286. His popular works are *A Brief History of Time: From the Big Bang to Black Holes* (New York: Bantam Books, 1988) and *The Universe in a Nutshell* (New York: Bantam Books, 2001).

¹⁷² A complete list of Rees' publications can be found on his webpage: <http://www.ast.cam.ac.uk/IOA/staff/mjr/publications/>. Comparatively, Hawking and Ellis each co-published one paper with Sciama, and Carter had none. Of Sciama's other students in the same time period, only four received co-publishing credit.

1979 *Nature* article with Bernard Carr, “The Anthropic Principle and the Structure of the Physical World.”¹⁷³ Here, Rees and Carr point out many of the large number coincidences and modes of explaining them. In some cases, they said, “The anthropic explanation is the only candidate and the discovery of every extra anthropic coincidence increases the *post hoc* evidence for it.”¹⁷⁴ While this article will be discussed later, it is worth pointing out now that Carr was Hawking’s student during the very fertile period from 1972-1975 and that Sciama acted as his doctoral examiner.¹⁷⁵

George Ellis, a South African, has split his life between research and political action against apartheid in his home country. His career began by looking at the same singularities as Hawking. With him, Ellis co-authored *The Large Scale Structure of Spacetime* in 1973, the obtusely difficult book that managed to sell over 20,000 copies in the wake of Hawking’s fame. In 2004, he received the Templeton Award for his life work promoting the understanding of science and religion, a distinction he shares with other scientists who have published in varying degrees on the anthropic principle: John Barrow, Rev. John Polkinghorne, Freeman Dyson, and Paul Davies.¹⁷⁶

¹⁷³ Bernard Carr and Martin Rees, “The Anthropic Principle and the Structure of the Physical World,” *Nature* 278 (April 12, 1979): 605- 612.

¹⁷⁴ *Ibid.*, 612.

¹⁷⁵ Bernard Carr, “The Formation of Primordial Black Holes,” In *The Renaissance of General Relativity and Cosmology: A Survey to Celebrate the 65th Birthday of Dennis Sciama*, eds. George Ellis, Antonio Lanza, and John Miller (Cambridge, UK: Cambridge University Press, 1993), 254.

¹⁷⁶ For more on this, see the Templeton Award website:
http://www.templetonprize.org/bios_recent.html

Ellis may be the member of the group least affiliated with the anthropic principle, as his only known contribution is a presentation during a 1993 conference.¹⁷⁷

Brandon Carter completed the Cambridge group. He spent his early career working on stellar phenomena and black holes, which gave him a significant familiarity with Dicke's assertion that the hotness and coldness of stars had an impact on the sustainability of life. His 1971 article, "Axisymmetric Black Hole Has Only Two Degrees of Freedom," worked with Hawking to prove the 'no-hair' theorem of black holes: that when an object passes the event horizon, all information of its structure is lost except for its mass, angular momentum, and electric charge.¹⁷⁸ Currently working in France, Carter has distanced himself from the modern discussion of the anthropic principle, noting the current definition has nothing to do with his original definition. His version of the anthropic principle is involved in the Doomsday argument, a philosophical matter that tries to predict human sustainability in the face of natural and manmade disasters.¹⁷⁹

The relevance of the Cambridge group to the discipline of cosmology and the anthropic principle should be clear now, but one remaining student of Sciama's played the biggest role in the dissemination of the anthropic principle: John Barrow. In 1970, Sciama moved to Oxford, taking the position of Senior Research Fellow. Four years later, the undergraduate Barrow walked into his office and first learned

¹⁷⁷ George F.R. Ellis, "The Anthropic Principle: Laws and Environments," In *The Anthropic Principle: Proceedings of the Second Venice Conference on Cosmology and Philosophy*. eds. F. Bertola and U. Curi. (Cambridge: Cambridge University Press, 1993)

¹⁷⁸ For Carter, see "Axisymmetric Black Hole Has Only Two Degrees of Freedom," *Physical Review Letters*, 26 (1971): 331-333. For Hawking's no-hair theorem, see his preprint, "Information Loss in Black Holes," available: <http://arxiv.org/abs/hep-th/0507171>

¹⁷⁹ John Leslie, ed., *Modern Cosmology and Philosophy* (Amherst, NY: Prometheus Books, 1998), 305.

about “the large scale regularity of the universe” and other factors “without making special assumptions about initial conditions.”¹⁸⁰ This started his career-long study of the early universe, with over 400 articles published and almost 20 books to his name. While he played no role in Carter’s formation of the principle, it is impossible to ignore that the two most important figures affiliated with the anthropic principle had the same mentor.

Now, without introducing a single bit of science, the historian can illustrate this family tree: Arthur Eddington taught Paul Dirac who mentored Dennis Sciama. While in school, Sciama met Bondi, Gold, and Hoyle and supported their ideas. Sciama then mentored his famous group and took them to attend Bondi’s lectures. Carter disliked portions of Bondi’s book, and argued against them by using the anthropic principle. The next year Sciama began his relationship with John Barrow, who then expanded upon the anthropic principle and essentially became its spokesman. Viewing it this way, Warwick’s argument that the teacher matters more than the subject sounds very compelling.

Sciama’s dedication to teaching amplified his significance among the group considering the alternate mentoring candidates. In the Department of Applied Mathematics and Theoretical Physics, students had the possibility of working with some of the most renowned scientists in the world. Paul Dirac held the Lucasian Chair at the time, but he was renowned for his taciturn demeanor. He referred to his

¹⁸⁰ John Barrow, “Cosmological Principles,” In *The Renaissance of General Relativity and Cosmology: A Survey to Celebrate the 65th Birthday of Dennis Sciama*, eds. George Ellis, Antonio Lanza, and John Miller (Cambridge, UK: Cambridge University Press, 1993), 201.

wife Margit, the sister of Hungarian physicist Eugene Wigner, as “Wigner’s sister.”¹⁸¹ Or there was Fred Hoyle, the famed Steady-State theorist who could be heard on the BBC ridiculing what he coined the “Big Bang” theory. When Hawking came to Cambridge he wanted to study with Hoyle, and initially took it as great blow to learn he was assigned to Sciama. Gradually it dawned on Hawking that Hoyle’s fame and plane-hopping made him a poor mentor.¹⁸² While Sciama lacked the prestige of Dirac or the glamour of Hoyle, he remained on the cutting edge of science and brought his students along. His office, next-door to Hoyle’s, covered the walls with modern art and scientific journals.¹⁸³ When once approached by a desperate Douglas Gough, a researcher for another professor involved in a major disagreement, Sciama remarked, “I don’t know what the issues are, but if you feel sure of your case, stick to your guns; and if you need support, I’ll give it to you.”¹⁸⁴ Unlike his associates, Sciama garnered a reputation as a good mentor both through his work and his demeanor.

This respect rings clearly among his students. Jane Hawking remembers:

For all his ebullience, Dennis Sciama selflessly promoted his students’ careers rather than his own. His desire to understand the working of the universe was more passionate than any personal ambition. By sending his students off to conferences and meetings, whether in London or abroad, and by making them scrutinize and report back on every relevant publication, he dramatically increased his own fund of knowledge as well as theirs, and succeeded in nurturing a generation of exceptional cosmologists, relativists, astrophysicists, applied mathematicians and theoretical physicists.¹⁸⁵

¹⁸¹ Jane Hawking, 296.

¹⁸² White and Gribbon, 58.

¹⁸³ *Ibid.*, 65.

¹⁸⁴ Ellis, In *The Renaissance of General Relativity and Cosmology: A Survey to Celebrate the 65th Birthday of Dennis Sciama*, eds. George Ellis, Antonio Lanza, and John Miller (Cambridge, UK: Cambridge University Press, 1993), 4. This is the same Douglas Gough listed in the bibliography for his edited work of Fred Hoyle.

¹⁸⁵ Jane Hawking, 91.

It is with good reason the Hawkings remember Sciama so well, for he influenced every aspect of Stephen's career throughout the 1960s. Sciama introduced Hawking to Penrose, a meeting which birthed a new age of cosmology. After Hawking's diagnosis of ALS in 1963, Sciama refused to let him slide through the Ph.D., instead coaxing the Institute of Physics to pay for twice-weekly visits by a private physiotherapist.¹⁸⁶ When the new Institute of Astronomy opened in 1968, Sciama teamed up with Bondi to get the young Hawking the necessary recommendations for a position that paid enough to cover medical costs.¹⁸⁷

It is needless to add more praise to Sciama—he cultivated students as well as he cultivated knowledge. The question now remaining is how this group would be conducive to the development of the anthropic principle. This explanation is sort of roundabout, because the environmental factors influencing the Carter anthropic principle are both scientific and social. Specifically, Sciama and his students were involved in just about every major issue in cosmology throughout the 1960s—the Steady-State theory, quasars, black holes, the Big Bang, et cetera. The influence of this environment on Carter can be recreated through analyzing the group's interaction among the larger scientific community, so what follows is an account of how they participated and reacted amongst themselves and the cosmological community throughout the 1960s.

¹⁸⁶ Ibid., 114.

¹⁸⁷ Ibid., 190-191.

Sciama's first paper, "On the Origin of Inertia," appeared in *Monthly Notices of the Royal Astronomical Society* in 1953.¹⁸⁸ Influenced by talks with Bondi and Gold, it showed a middle-ground between their work and that of Hoyle. Mentioned briefly during Robert Dicke's section, and I will now discuss this document's importance.

Sciama argued that Mach's principle was the only way to understand gravity in a relativistic universe. As noted, Mach's principle countered the Newtonian absolute space by explaining inertia as an object's motion influenced by all matter in the universe. The problem, then, was explaining why Newton's laws worked so well. Sciama presented no clear solution, but instead separated the paper down into six sections, each of them crafted to oppose various cosmological models. The importance of this was two-fold: 1) Sciama purposefully ignored speaking of gravity as an electromagnetic force or a scalar field (of which Dicke made these features the backbone of his argument), and 2) Sciama limited cosmological models, which Dicke and Carter would also do. This document, then, had no *direct* influence on the development of the anthropic principle, but given the importance it played in Dicke's model and the style of explanation that would be mimicked in Carter's model, it stood as a foundational article in the scientific environment surrounding the anthropic principle.

Sciama's first popular book, *The Unity of the Universe*, appeared in 1959. Its dedication thanked Bondi, Gold, and Hoyle. Juxtaposing the Big Bang and the Steady

¹⁸⁸ Dennis W. Sciama, "On the Origin of Inertia," *Monthly Notices of the Royal Astronomical Society* 113, no. 1 (1953): 34-42.

State theories, Sciama clearly favored the Steady State model. When considering the origin of the universe, one glaring problem arose in the expanding models: the laws of nature were a consequence of ‘accidental’ initial parameters.¹⁸⁹ Steady-State theory eliminated this problem because there was no beginning in which the universe somehow figured out its own parameters. Furthermore, Steady-State agreed with the definition of Mach’s principle that had already been discussed by Bondi, Gold, and Sciama. For now the reader should note his reluctance of ‘accidental’ parameters, as I must turn to a significant debate fueled by the potential realization of these ‘accidents’ and their relation on the development of the anthropic principle within Sciama’s group.

Anthropic Explanations? Hoyle’s Triple Alpha Process and Sciama’s

Interpretation

Fred Hoyle was a scientific polyglot—he contributed influential work not only to cosmology but also to exobiology and nuclear physics. In regards to this latter category, he was most well-known for his work on nuclear synthesis with Geoffrey and Margaret Burbidge and Willy Fowler in 1957 (famously called the B²FH paper). This article outlined how elements were forged in stars and remains to this day one of the most significant scientific publications in the twentieth century. It is with no malice that I intend to avoid this famous paper in favor of Hoyle’s preceding work with carbon-12, in which Hoyle demonstrated the narrowly constrained parameters

¹⁸⁹ Sciama, *The Unity of the Universe*, 181.

required to make carbon in stars, and is often cited as influential in the development of the anthropic principle.

In the early 1950s, Hoyle's work showed that a very specific energy level, or 'resonance,' was required for the creation of carbon. Hoyle had predicted that carbon must possess an energy level of 7.65 MeV (mega-electronvolts), but at the time no known state of carbon had been recorded at that level. Following the Pauli Exclusion Principle, nuclei only exist at specific energy levels and nowhere in-between. It has been claimed that Hoyle, realizing the plentitude of carbon and its role as a building block for the human body, argued there must be a resonance level of carbon at exactly 7.65 MeV. The resonance level of oxygen was only slightly higher, so if conditions were not ideal, oxygen would trump carbon, and no life forms would exist. To jump to the conclusion, it was discovered that in a collapsing star three helium nuclei—or alpha particles—needed to crash into each other on an incredibly short timescale to produce carbon. Some authors cite the discovery of the 'triple-alpha' process as a result of the anthropic principle.

The authenticity of this statement is mired in the historiography, because nowhere in the popular or technical literature does Hoyle make this claim; rather, it seems to be in his personal notes. What makes this a particularly specious connection is that he is inconsistently cited in the literature. Of two recent biographies written by people familiar with Hoyle, Simon Mitton mentions nothing of this logic¹⁹⁰, while Jane Gregory asserts it without citation and later makes the anthropic principle

¹⁹⁰ Simon Mitton, *Conflict in the Cosmos: Fred Hoyle's Life in Science* (Washington, D.C.: Joseph Henry Press, 2005), 211-223.

reference.¹⁹¹ Hopefully the earlier chapters of this thesis made it clear that even if Hoyle did use anthropic explanations, he did not use the ‘anthropic principle’ as it is currently understood.

Perhaps most intriguingly, Barrow and Tipler litter the triple-alpha story with words like “anthropic prediction” and “fine-tuning.” A sample of their exact words:

Hoyle realized that this remarkable chain of coincidences—the unusual longevity of beryllium, the existence of an advantageous resonance level in C^{12} and the non-existence of a disadvantageous level in O^{16} —were necessary, and remarkably fine-tuned, conditions for our own existences and indeed the existence of any carbon based life in the universe.¹⁹²

It is interesting, however, that although their book contains over a thousand footnotes, they do not cite Hoyle as specifically saying these words. Instead, they make use of some significant editing in citing another of Hoyle’s works published fifteen years later as justification of his ‘fine-tuning’ with this example:

...we can exist only in the portions of the universe where these levels happen to be correctly placed. In other places the level in O^{16} might be a little higher, so that the addition of alpha-particles to C^{12} was highly-resonant. In such a place...creatures like ourselves could not exist.¹⁹³

Hoyle’s real words deserve to be quoted at length, because they show a slant toward a form of the weak anthropic principle and do raise the question of fine-tuning:

I would like to refer back to my whimsical fantasies concerning the binding of Be^8 , and the curious levels in the nuclei of C^{12} and O^{16} . I began what I regard as a fascinating topic of speculation, and then edged away from it. Obviously, at the present time we have more than enough to do in order to understand how the world works the way we find it. But I think one must have at least a modicum of curiosity about the strange dimensionless numbers that appear in physics, and on which, in the last analysis, the precise positioning of the levels in a nucleus such as C^{12} or O^{16} must depend. Are these numbers

¹⁹¹ Jane Gregory, *Fred Hoyle’s Universe* (Oxford: Oxford University Press, 2005), 63.

¹⁹² Barrow and Tipler, 253.

¹⁹³ *Ibid.*, 254.

immutable, like the atoms of the nineteenth century physicist? Could there be a consistent physics with different values for the numbers?

There seem to be two lines of attack on questions such as these, the first to demonstrate that the precise numerical values of the dimensionless numbers are all entirely necessary to the logical consistency of physics. The second point of view is that some, if not all, of the numbers in question are fluctuations; that in other places of the universe their values would be different. My inclination is to favor this second point of view, because certain numerical coincidences have the aspect of fluctuations (e.g. the ratio of electrical to gravitational forces is of the order of the square root of the number of particles contained within a cube of side c/H . H , the Hubble constant). On this second basis the curious placing of the levels in C^{12} and O^{16} need no longer have the appearance of astonishing accidents. It could simply be that since creatures like ourselves depend on a balance between carbon and oxygen, we can exist only in the portions of the universe where these levels happen to be correctly placed. In other places the level in O^{16} might be a little higher, so that the addition of alpha-particles to C^{12} was highly resonant. In such a place oxygen would be overwhelmingly more abundant than carbon, and creatures like ourselves could not exist.¹⁹⁴

The question then becomes what Fred Hoyle meant when he said ‘astonishing accident.’ Recall that in 1959, Sciama supported the Steady-State because it eliminated the ‘accidental’ parameters of the Big Bang, which would probably be better described in modern terminology as ‘arbitrary’ parameters. Steady-State scientists believed that no current law of physics could remain stable when pushed into the density of the big bang. Their repugnance with an ‘accidental’ law, then, would be that in the big bang universe, the laws of physics somehow transcended the different epochs of universe expansion. When Hoyle made his above statement in 1965, he still adhered to a form of Steady-State cosmology (the same book contained two chapters on it). If, then, he is using ‘no longer an astonishing accident’ in Sciama’s sense of the word, then he would be saying that the resonance parameters

¹⁹⁴ Fred Hoyle, *Galaxies, Nuclei, and Quasars* (New York: Harper and Row Publishers, 1965), 159-160.

are just a given, like all other Steady-State parameters. If he is using ‘accident’ in the sense of a Big Bang cosmology, then he would be implying ‘fine-tuning’ as asserted by Barrow and Tipler.

While it may seem a matter of semantics, this issue over Hoyle’s fine-tuning is, in my opinion, very important to the scientific environment surrounding the anthropic principle. Given the importance of Hoyle’s work and the ‘retrodition’ of Barrow and Tipler, this issue has proven thorny for many histories. Hoyle is obviously using an anthropic explanation, although due to his adherence to the Steady-State cosmology (which includes the Copernican principle), it is naturally contrary to Carter’s anthropic principle. The way to analyze Hoyle’s influence on Sciama’s group, then, is to make a quick analysis of how the literature reacted to Hoyle’s triple-alpha process.

The simplest answer on the outset is that Sciama and Bondi talk around the fine-tuning issues, and Carter just has no interest. In Carter’s paper, the three most influential citations he makes are to Bondi’s *Cosmology* book, to Dicke’s 1961 letter against Dirac, and to Sciama’s 1953 *On the Origin of Inertia*. There is no discussion of Hoyle. Most likely, a hypothetical 1973 Carter would explain any apparent ‘fine-tuning’ through a familiar passage in his presentation: “That far from being evidence in favor of the exotic theories these coincidences should rather be considered as confirming ‘conventional’ (General Relativistic Big Bang) physics and cosmology which could in principle have been used to predict them all in advance of their

observation.”¹⁹⁵ By his work, Carter seems to be unimpressed with any argument of fine-tuning.

Bondi brushes off Hoyle in his book *Cosmology*. His words exactly:

In the course of constructing his theory, Hoyle was forced to postulate the exact value of a previously ill-determined nuclear energy level in C^{12} which has since been verified experimentally.

Since it has also been shown that any hot dense early stage of the universe could not have left us any nuclei heavier than helium, the origin of such nuclei is no longer a question of cosmology.¹⁹⁶

Not much can be determined from Bondi’s words, but it seems unlikely he would support ‘fine-tuned’ evidence.

Sciama’s response, however, is very significant. No historian has pointed out how Sciama writes on “The Formation of the Elements” in *The Unity of the Universe*, where he says this:

We have still to see whether more detailed properties of the universe—such as the existence of planets or of life—are also inevitable consequences of the laws of nature. And if they *are* inevitable we must then accept the ultimate challenge: to show that we ourselves are not some haphazard outcome of the by-play of cosmic forces. For surely we are no more accidental than the matter we are made of.¹⁹⁷

This can be rephrased like this: *if* the laws of nature, which are not accidental, inevitably lead to the development of life, then the development of life is not accidental. This certainly sounds like an anthropic explanation, but again, Sciama says nothing of ‘fine-tuned’ results.

As warned, this discussion has been roundabout, but here is the point: Carter’s own mentor and colleagues had been entertaining their own anthropic explanations in

¹⁹⁵ Carter, “Large Number Coincidences,” 291.

¹⁹⁶ Bondi, *Cosmology*, 58.

¹⁹⁷ Sciama, *The Unity of the Universe*, 215.

the 1950s. Unlike the Dicke and Dirac scene, there is no overt critique between Sciama, Bondi, or Hoyle, but there is manifest musing over the utility of such explanations. Clearly, they are not using these arguments in the same way Carter or Barrow and Tipler would, but it is important to note the presence of the idea among Sciama's group.

Expanding beyond this discussion of interpretation, Hoyle left a tantalizing explanation as to the appeal of anthropic explanations. Regardless of whether Hoyle's colleagues entertained fine-tuning in the 1950s, Hoyle might have supported a form of fine-tuning. Going beyond the scientific literature, in 1965, Hoyle contributed a book to the Credo series on his personal beliefs. Tucked away on the last page, Hoyle wrote this passage:

Suppose we conceive that such dimensionless quantities as the fine-structure constant—which governs the emission and absorption of electromagnetic radiation by matter, and which controls all chemical properties—could be changed either in different parts of the Universe or at different times. Then the microscopic behavior of matter could be widely different. Living creatures, for example, obeying quite different systems of chemistry would now become a possibility.¹⁹⁸

This very revealing passage showed Hoyle's ponderings on a universe with different physical properties—slight changes would result in different life forms, but he had no intimation of design. On this last page, Hoyle admitted he had been losing interest in the Steady-State theory but continued to support it because of its guarantee of the isotropy of the laws of physics. If these number coincidences were true, however, then they uprooted the Steady-State theory and gave credence to a Big Bang universe. He closed the book with these prescient words:

¹⁹⁸ Fred Hoyle, *Encounter with the Future* (New York: Trident Press, 1965), 108.

As I have already hinted, today I am more hopeful and feel that in the next ten years we may witness a real breakthrough in the relation between cosmology and physics. After spending so much time and effort on the Steady-State theory I am naturally reluctant to let it go; but the wider possibilities presented by these new ideas [dimensionless numbers] may ultimately prove much more rewarding.¹⁹⁹

Is it a coincidence, then, that Sciama and his students pursued so fervently the relativistic Big Bang model and anthropic coincidences concomitantly? This is the question I will approach in the next section.

So now, without introducing Dicke, the historian can see these anthropic explanations circulating among Sciama and his colleagues. Of course, being affiliated with Dirac, they would have been familiar with Dicke's work. There is no smoking gun as to where Carter got the idea (just like none of the Steady-State theorists agreed how they got their idea), but now there are two potential avenues: Dicke and Hoyle. Referring back to chapter two, Carter mentioned he had been thinking along anthropic lines before meeting Dicke in the late-1960s. The historian cannot ignore, then, that Carter's mentor had also been thinking about this topic along with Hoyle. For now, the most concrete evidence the historian can make is that the social network surrounding the scientific environment first transported these ideas to Carter.

The Overhaul of the Universe: The Anthropic Principle and the New Cosmology

Roughly speaking, the period from the early 1960s until the mid-1970s has been called the "Renaissance" or "Golden Age" of cosmology, particularly when Sciama's students speak of it. Sciama involved his students in every cutting-edge

¹⁹⁹ Ibid.

field, from quasars to the singularity at the beginning of time. During this period, the literature reveals that Carter had been talking about the anthropic principle as early as 1968 and that it fascinated his friends. What follows is a short discussion of Sciama's students and their contributions to research over the 1960s, and how Carter found an outlet for his ideas in Stephen Hawking.

This 'renaissance' in cosmology began, at least in respect to Sciama's group, in 1961 when he began research that unintentionally undermined the Steady-State system he had supported so thoroughly in the 1950s. With the development of more advanced radio telescopes, astronomers discovered very loud radio emissions coming from the heavens. Some of these "radio sources" were discovered to be stars, but many of the more powerful sources could not be visually identified by telescopes—they could only be 'heard' by radio telescopes. The sources then became "quasi-stellar radio sources," known better now as its abbreviation "quasar." When Sciama acquired Rees as his student in 1966, they published at least four articles on quasars together among many more on inhomogeneities in the universe. By the end of the 1960s, it had been determined that quasars exist only at distances of billions of light years, meaning that they only existed at the beginning of time. For the Steady-State to be true, quasars would need to be evenly distributed among the cosmos. Not being the case, Sciama switched teams and adopted the Big Bang model of the universe.

Bernard Carr remembered his first meeting of Sciama in 1968: "I well recall that he was 'wearing sackcloth and ashes' as a result of his previous endorsement of Steady-State theory. This made a great impression on me and was an important factor in my

later choosing to do research in Big Bang cosmology.”²⁰⁰ Sciama received much respect for acknowledging the evidence, particularly compared to Hoyle, who changed the Steady-State around for it to work with observations. After this switch, Sciama encouraged his students to work with the Big Bang model.

This decision was influential on Hawking, Ellis, and Carter. There were many other fields the students in which the students contributed, but their work on black holes, singularities, and isotropy influenced the anthropic principle the most. This was also the time when Hawking’s body slowly weakened. He needed more and more help, but refused to be considered a victim of his disease. He developed a very close relationship to Carter at this time, and it is to this connection that I now turn.

Between Hawking and Carter, research was more than locking themselves into an office (although that did happen a lot)—their families knew each other quite well. With their husbands busy (and talking scientific jargon), Lucette Carter and Jane Hawking found a kinship in Proust and taking the kids for walks. The males attended mathematical lectures together and worked on the no-hair theorem together. At the opening of the Institute of Astronomy in 1968, they shared the same desk. Within their years of collegiality, one day in particular is most interesting.

Sometime in late 1967 or early 1968, Stephen Hawking attended a graduate lecture with his wife. Jane was very slowly attaining her Ph.D. in medieval literature while caring for Stephen and their young child. One night, the topic of medieval

²⁰⁰ Bernard Carr, “The Formation and Evaporation of Primordial Black Holes,” In *The Renaissance of General Relativity and Cosmology: A Survey to Celebrate the 65th Birthday of Dennis Sciama*, eds. George Ellis, Antonio Lanza, and John Miller (Cambridge, UK: Cambridge University Press, 1993), 258.

cosmology arose in her seminar and she invited Stephen and his colleague Nigel Weiss along. After discussion, “The two scientists were forced to concede that the thinking of the twelfth-century philosophers, Thierry of Chartres, Alan of Lille and, in the thirteenth century Robert Grosseteste and Roger Bacon among many others, was extraordinarily far-sighted, accurate and perceptive.”²⁰¹ It is true that the anthropic principle resonates like a medieval cosmology, and perhaps this is why it is important to draw a connection between Stephen’s seminar attendance and Brandon Carter’s 1968 manuscript, “Large Numbers in Astrophysics and Cosmology.”²⁰²

Jane Hawking recalls of their connection on the anthropic principle:

This was one of those subjects on which, during that period at the end of the 1960s and the early 1970s, Stephen spent long hours of concentrated argument with Brandon Cater, usually on Saturday afternoons when we drove out of Cambridge to the pastoral bliss of the country cottage which Brandon and his Belgian wife, Lucette, had been renovating since their recent marriage. Lucette and I would take [the Hawking’s son] for long walks across the fields, converse in French about our favorite authors, painters, and composers, prepare tea and supper, and still Brandon and Stephen would be engaged in an intellectual contest over the fine detail of the principle which neither was prepared to concede.²⁰³

Jane thought the anthropic principle sounded a lot like the Ptolemaic system, and while it is unknown whether Stephen would find a similar connection, she saw that her husband and Brandon were speaking of the medieval concepts of binding the existence of God to the persistence of the universe. However, and this is a key point in downplaying design arguments among Hawking and Carter, Jane described that these “intellectual heirs” of the medieval cosmologists “seemed intent on distancing

²⁰¹ Jane Hawking, 152.

²⁰² As mentioned in chapter 2, this oft-referenced manuscript cannot be found in Cambridge as of this time.

²⁰³ Jane Hawking, 153.

science as far as possible from religion and on excluding God from any role in Creation.”²⁰⁴ She then noted on their reductionism of cosmological questions to simple equations:

In the face of such dogmatically rational arguments, there was no point in raising questions of spirituality and religious faith, of the soul and of a God who was prepared to suffer for the sake of humanity—questions which ran completely counter to the selfish reality of genetic theory. Questions of morality, conscience, appreciation of the arts, were best kept out of the arena lest they too were to become victims of the positivist approach. Since I did not have the mathematical language at my disposal, I was powerless to defend such concepts in the only terms that were acceptable to my debating adversaries and was therefore obliged to keep my own counsel, seeking to satisfy my own spiritual needs as best I could.²⁰⁵

This is a telling passage: on the surface it shows Jane’s extreme frustration in her husband’s denial of her medieval expertise. While Jane was not a devout Christian at the time, she felt that her own husband would listen to these remarkably similar *design* arguments possessed by medieval theologians. In denying Jane this basic entrance to the discourse, it shows how at least Hawking (and probably, by implication, Carter) cared nothing at the time for design arguments.

The connection between Hawking and Carter and the anthropic principle should be getting clearer. Carter’s manuscript was very influential among his colleagues, being oft-cited by Rees and Hawking. As pointed out in chapter two and this chapter, Hawking made use of the anthropic principle twice before Carter had even introduced it. The last remaining step between the 1968 and 1973 requires a step outside of the Sciamia group, back to Robert Dicke.

²⁰⁴ Ibid., 155.

²⁰⁵ Ibid., 156.

In February 1969, Robert Dicke presented at the Jayne lectures over the three day meeting of the American Philosophical Society. Since his refutation of Dirac almost a decade ago, he had been involved in studying the cosmic microwave background radiation, and had been asked to present his ideas on relativity before the collected audience. His presentation was probably overly technical, given his audience of philosophers instead of physicists, but nonetheless he was delighted to be invited. A tantalizing little problem lodged within his third day's discussion forecasted an important cosmological problem. Speaking of the Big Bang, he asked: "How did the initial explosion become started with such precision, the outward radial motion became so finely adjusted as to enable the various parts of the universe to fly apart while continuously slowing in the rate of expansion?"²⁰⁶ This is now known as the 'flatness problem' in the Big Bang model.

At the time, Dicke presented the problem like this: "There seems to be no fundamental theoretical reason for such a fine balance. If the fireball had expanded only .1 per cent faster, the present rate of expansion would have been 3×10^3 times as great. Had the initial expansion rate been .1 per cent less and the Universe would have expanded to only 3×10^{-6} of its present radius before collapsing."²⁰⁷ The result if the explosion had been slightly different: "No stars could have formed in such a universe, for it would not have existed long enough to form stars."²⁰⁸ By 1979, Dicke

²⁰⁶ Robert H. Dicke, *Gravitation and the Universe* [Jayne Lectures for 1969] (Philadelphia: American Philosophical Society, 1970), 62.

²⁰⁷ Ibid.

²⁰⁸ Ibid.

had constrained this Ω down to 1 part in 10^{14} .²⁰⁹ Currently, it is believed the universe had to expand at a certain rate with the precision of 1 part in 10^{60} for stars and galaxies to form.²¹⁰ I should make two points now: 1) as the determined precision of the universe's expansion is much narrower now than thirty years ago, the flatness problem stands out much more now than it did in 1969, and 2) most scientists were not aware of the flatness problem until Dicke's 1979 paper.²¹¹

Stephen Hawking, however, was aware of the flatness problem back in 1967, and it became very influential in the development of the anthropic principle.²¹² When Dicke had been asked if the anthropic principle played a role in his realization of the flatness problem, he said:

No. At the time I wrote these notes [the Jayne Lectures of 1969], I doubt it. The anthropic explanation had been used earlier, in connection with the Dirac argument about the gravitational constant. But I don't think I was thinking of it in this relation. I had the feeling that this [the close balance of gravitational and kinetic energy] implied the universe was very nearly flat for a good physical reason.²¹³

Hawking remembers, however, that Carter saw this problem in a different light in the manuscript he circulated among friends: "At that time, the only explanation seemed

²⁰⁹ Robert Dicke and P.J.E. Peebles, "The Big Bang Cosmology—Enigmas and Nostrums," In *General Relativity: An Einstein Centenary Survey*, eds. Stephen Hawking and Werner Israel (Cambridge, UK: Cambridge University Press, 1979), 507.

²¹⁰ John Leslie, *Universes* (London: Routledge, 1989), 3.

²¹¹ See Alan Lightman and Roberta Brawer, *Origins: The Lives and Worlds of Modern Cosmologists* (Cambridge, Mass: Harvard University Press, 1990), particularly the interviews with Dicke and Peebles.

²¹² Stephen Hawking, In *Origins: The Lives and Worlds of Modern Cosmologists*, eds. Alan Lightman and Roberta Brawer, (Cambridge, Mass: Harvard University Press, 1990), 397.

²¹³ Robert Dicke, in *Origins: The Lives and Worlds of Modern Cosmologists*, eds. Alan Lightman and Roberta Brawer, (Cambridge, Mass: Harvard University Press, 1990), 208.

to be the anthropic principle. Brandon Carter discussed it in an unpublished paper in about 1970.”²¹⁴ The flatness problem, then, gave birth to the anthropic principle.

Hawking’s paper, “Why is the Universe Isotropic,” has been mentioned before, but given the background of cosmology in the 1960s and the relationship between Carter and Hawking and the rest of Sciama’s group, it is much clearer why Hawking pursued such an explanation. After introducing the precision of isotropy present in the universe (the term ‘flatness problem’ did not come around until 1981), Hawking says this:

We shall now put forward an idea which offers a possible way out of this difficulty. This idea is based on the discovery that homogeneous cosmological models *do* in general tend toward isotropy if they have exactly the escape velocity. Of course, such ‘parabolic’ homogeneous models form a set of measure zero among all homogeneous models. However, we can justify their consideration by adopting a philosophy which has been suggested by Dicke (1961) and Carter (1968). In this approach one postulated that there is not one universe but a whole infinite ensemble of universes with all possible initial conditions....The existence of galaxies would seem to be a necessary precondition for the development of any form of intelligent life. Thus there will be life only in those universes which tend toward isotropy at large times. The fact that we have observed the universe to be isotropic is therefore only a consequence of our own existence.²¹⁵

Several months later, Carter proposed the anthropic principle. The idea, so to say, was out there for scientific consumption. The task now is to see how the idea left its local Cambridge group to meet a wider audience.

²¹⁴ Stephen Hawking, In *Origins: The Lives and Worlds of Modern Cosmologists*, 397.

²¹⁵ C.B Collins and Stephen W. Hawking, “Why Is the Universe Isotropic?” *The Astrophysical Journal* 180, No. 2, Part 1, (1973), 319. It should be noted that Collins, Hawking’s student, probably just wrote the article, as by now Stephen needed help in doing such tasks.

The Dissemination of the Anthropic Principle

The anthropic principle was not an immediate success. Actually, hardly anybody noticed at first. Immediately following his presentation at the Copernicus symposium, Carter fielded only one question—an attendee wondering why he thought anything in the universe need be constant.²¹⁶ Carter would say nothing more until a meeting on the Constants of Physics in 1983. There can be no more telling fact that the anthropic principle changed dramatically over the decade than Carter's own words at the meeting: "If I had guessed the term 'anthropic principle' would come to be so widely adopted I would have been more careful in my original choice of words. The imperfection of this now standard terminology is that it conveys the suggestion that the principle applies only to mankind."²¹⁷ This section briefly discusses the major works that propagated and altered the anthropic principle throughout the 1970s and 1980s.

Because Carter did not act on the anthropic principle in the 1970s, the Sciama connections became manifestly important to the survival of the principle, seen most explicitly in the work of the Martin Rees. His career had been going quite well since the quasar work with Sciama, having been named the Plumian Professor in 1973. Rees, too, had been privy to the discussions surrounding the anthropic principle in its early years. He recalls the subject came up in a mathematics lecture he attended with

²¹⁶ Carter, "Large Number Coincidence and the Anthropic Principle in Cosmology," 298.

²¹⁷ Brandon Carter and W.H. McCrea, "The Anthropic Principle and its Implications for Biological Evolution," *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences* 310, No. 1512, The Constants of Physics, (Dec 20, 1983), 348.

Carter in 1965.²¹⁸ In 1972, Rees submitted some comments on the large number coincidences using a preprint of Hawking's isotropy article and Carter's unpublished manuscript. At the conclusion he remarked, "To ascribe fundamental significance to these crude coincidences is probably pushing numerology too far!....They merely indicate that the fact that various 'coincidences' and inequalities are fulfilled need occasion no surprise in a 'cognizable' universe."²¹⁹ He then echoed this sentiment in a 1975 textbook, *Black Holes, Gravitational Waves, and Cosmology: An Introduction to Current Research*.²²⁰ 1979 brought his most well-known contribution to the anthropic principle, "The Anthropic Principle and the Structure of the Physical World," co-published with Bernard Carr.

If any document can be considered the 'transition' phase from Carter's principle to Barrow and Tipler's principle, it would be Rees and Carr's document. While the authors do put an emphasis on fine-tuning, it is in a limited sense and most definitely *not* teleological. Rees and Carr's document can be a bit misleading because it is organized to see whether the anthropic principle can solve some of the large number coincidences, but in presenting so many 'fine-tuned' equations the authors convey a different message. In big letters on the first page, their abstract concludes like this: "But several aspects of our universe—some of which seem to be prerequisites for the evolution of any form of life—depend rather delicately on

²¹⁸ Martin Rees, *Before the Beginning: Our Universe and Others* (Reading, Mass.:Addison Wesley, 1997), 247.

²¹⁹ Martin Rees, "Cosmological Significance of the e^2/Gm^2 and Related 'Large Numbers,'" *Comments on Astrophysics and Space Physics* 6, no. 6 (Nov.-Dec. 1972): 185.

²²⁰ Martin Rees, Remo Ruffini, and John Archibald Wheeler, *Black Holes, Gravitational Waves and Cosmology: An Introduction to Current Research* (New York: Gordon and Breach Science Publishers, 1975), 283-285.

apparent ‘coincidences’ among physical constants.”²²¹ They then list all the heretofore discussed large number coincidences, from Dirac to Dicke to Hoyle’s triple-alpha resonance. Their point, however, is hidden in the conclusion.

Rees and Carr point out the anthropic principle is “unsatisfactory” in three respects: 1) it does not predict any feature of the universe; 2) it is “unduly” anthropocentric, or that another form of life might live in a different universe; 3) it does not explain the exact values of the large numbers, only their magnitude.²²² However, the anthropic principle did go so far as to merit some degree of explanatory power for the large numbers, particularly in the case of a universe ensemble. But, they say, “These arguments go a little way towards giving the anthropic principle the status of a physical theory but only a little: it may never aspire to being much more than a philosophical curiosity.”²²³ Essentially, Rees and Carr find the anthropic principle an intriguing way to frame some of the large number coincidences, but an idea that would probably be overturned with the development of more advanced theories.

An interesting exception to the Sciama group in the propagation of the anthropic principle came in 1982-1983, with Paul Davies’ *The Accidental Universe* and *God and the New Physics*. A student at University College, London working on black holes at the same time as Hawking and Penrose, Davies would probably have been familiar with the anthropic principle as it came into being. His first articles on

²²¹ B.J. Carr and Martin Rees, “The Anthropic Principle and the Structure of the Physical World,” *Nature* 278, (April 1979): 605.

²²² *Ibid.*, 612.

²²³ *Ibid.*

the subject, however, did not appear until 1981, while working in the School of Physics at the University of Newcastle upon Tyne.²²⁴

The Accidental Universe is an interesting case, as Davies's work focuses very much on fine-tuning and the anthropic principle. He states in his preface: "I am especially indebted to Dr. Bernard Carr and Professor Martin Rees, on whose review article much of this book is based. I have received many helpful comments and suggestions from these authors, as well as from Dr. John Barrow, Dr. Frank Tipler, and Dr. John Leslie."²²⁵ Having established that Rees and Carr do not speak of teleology while Barrow and Tipler do (at this time they were still in the preprint process of their book), Paul Davies acts as an interesting transition in this integration of teleology, fine-tuning, and the anthropic principle. In *The Accidental Universe*, he writes:

Normally 'the observer' is discounted in consideration of physical science. We are here, it is usually assumed, just 'for the ride.' Some scientists have challenged this traditional assumption, declaring that the structure of the physical world is inseparable from the inhabitants that observe it, in a very fundamental sense. They argue that there does indeed exist a guiding principle which works to fine-tune the cosmos to incredible accuracy. It is not a physical principle, however, but an *anthropic principle*.²²⁶

Davies is then the figure—whether he intended to or not—that introduced teleology into the anthropic principle. The last step in the process of disseminating the anthropic principle has been mentioned at length already: *The Anthropic Cosmological Principle*.

²²⁴ Paul Davies and S.D. Unwin, "Why is the Cosmological Constant So Small?" *Proceedings of the Royal Society of London, Series A* 377, no. 1769, (Jun 25, 1981): 147-149.

²²⁵ Paul Davies, *The Accidental Universe*, (Cambridge, UK: Cambridge University Press, 1982), ix.

²²⁶ *Ibid.*, 110-111.

As stated, John Barrow met Dennis Sciama in 1974 and immediately took up an interest in the narrowly constrained parameters that interested Sciama's Cambridge students. At this first meeting, Barrow learned of the flatness problem (well ahead of many other cosmologists).²²⁷ Barrow's first two articles would be on the synthesis of light elements, which although they lacked any references to fine-tuning, are located in a field well-known for its relationship to the anthropic principle.²²⁸ His contribution to *The Anthropic Cosmological Principle* was a long way in coming: he published its fourth chapter under the title "The Lore of Large Numbers: Some Historical Background to the Anthropic Principle" in 1981²²⁹, and marked his territory in 1983 with his article "Anthropic Definitions."²³⁰ Given the definitions he used with Tipler in 1986, it seemed that his 1983 definitions needed a lot of clearing up. This was his early version of the weak anthropic principle:

The observed values of physical variables are not arbitrary but take on values $V(x,t)$ restricted by the spatial requirement that $x \in L$, where L is the set of sites able to sustain life; and by the temporal constraint that t is bounded by the time scales for biological and cosmological evolution of living organisms and life-supporting environment.²³¹

Obviously he did not like this definition, as changed dramatically in its final publication. Similarly, the strong anthropic principle was in a very nascent form:

²²⁷ John Barrow, "Cosmological Principles," 201.

²²⁸ The better example is John Barrow, "Light Elements and the Isotropy of the Universe," *Monthly Notice of the Royal Astronomical Society* 175 (1976): 359-370.

²²⁹ John Barrow, "The Lore of Large Numbers: Some Historical Background to the Anthropic Principle," *The Quarterly Journal of the Royal Astronomical Society* 22, no. 4, (Dec 1981): 388-420. This is an abridged version of what appears in *The Anthropic Cosmological Principle*.

²³⁰ John Barrow, "Anthropic Definitions," *Quarterly Journal of the Royal Astronomical Society* 24, (1983), 146-153.

²³¹ *Ibid.*, 147.

The Universe must contain life. An equivalent statement would be that the constants and laws of Nature must be such that life can exist.²³²

As noted, the more finalized forms appeared in *The Anthropic Cosmological Principle*. Their appearance, however, was accompanied by a brand new history—one that included design arguments and portrayed science as teleological. The anthropic principle was no longer supposed to point out flawed cosmological models, but to point out the ‘just-right’ universe that humans inhabited.

From Carter to Barrow, the anthropic principle ran through a social network and came out an entirely different principle. As early as 1983, Carter lamented his choice of words, and this echoed more strongly by 1993. In the first ever official conference held on the anthropic principle (which included presentations by Barrow, Carter, Ellis, Sciama, and Hoyle among others), Carter quietly added this comment to the published text:

Other writers referred to in the comprehensive treatise of Barrow and Tipler, have in recent years made further clarification necessary by extending the ‘anthropic’ nomenclature to concepts such as ‘anthropic finality’ whose teleological nature is, as John Leslie has emphasized, quite contrary to the conventionally ‘scientific,’ spirit of the anthropic (*ex post facto* selection) principle as I intended it to be understood.²³³

The anthropic principle had been reborn in a new teleological fashion, thanks to the same social network surrounding Dennis Sciama that helped bring the initial idea to light.

²³² Ibid., 149.

²³³ Brandon Carter, “The Anthropic Selection Principle and the Ultra-Darwinian Synthesis,” In *The Anthropic Principle: Proceedings of the Second Venice Conference on Cosmology and Philosophy*. eds. F. Bertola and U. Curi. (Cambridge: Cambridge University Press, 1993), 36.

Conclusion

It would be helpful to summarize the differences between Carter and Barrow and Tipler with a table:

Anthropic Issues	Carter	Barrow and Tipler
Date Introduced:	Private-1968 Public-1973	Definitions: 1983 <i>TACP</i> : 1986
WAP Definition:	“We must be prepared to take account of the fact that our location in the universe is <i>necessarily</i> privileged to the extent of being compatible with our existence as observers.”	“The observed values of all physical and cosmological quantities are not equally probable but they take on values restricted by the requirement that there exist sites where carbon based life can evolve and by the requirement that the universe be old enough for it to have already done so.”
SAP Definition:	“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.”	“The Universe must have those properties which allow life to develop within it at some stage in its history.”
Support Fine-Tuning?	Probably not: “That far from being evidence in favor of the exotic theories these coincidences should rather be considered as confirming ‘conventional’ (General Relativistic Big Bang) physics and cosmology which could in principle have been used to predict them all in advance of their observation.”	Yes: “...arbitrarily chosen initial conditions at the Big Bang do not necessarily evolve to produce a universe looking like the one we observe... We would like to know if the subset of initial conditions that does produce universes like our own has a significant intersection with the subset that allows the eventual evolution of life.
Support Design/Teleology?	Nothing said.	Yes. “...it is important to present it in its true historical perspective in relation to the plethora of Design Arguments beloved of philosophers, scientists and theologians in past centuries and which still permeate the popular mind...”

When juxtaposed, the principles are clearly worlds apart. This chapter has tried to recreate the environmental factors, namely the relations of scientists to Dennis

Sciama, that played a role in the development of the anthropic principle. By this approach, it can be pinpointed how Sciama interacted in the general scene of cosmology and picked up anthropic arguments from Hoyle. By social interaction, this method of explanation seeped into Sciama's students, who were doing research on ideal fields to help them make anthropic arguments. Carter had a group of friends to which he could communicate his ideas, and this group continued the anthropic principle throughout the 1970s. As it passed through their hands, the anthropic principle changed bit by bit, and in 1986, it had become an entirely new idea in the hands of John Barrow and Frank Tipler.

Conclusion

For whatever reason, the anthropic principle has been left largely abandoned by historians. As noted earlier, the anthropic principle has propelled the careers of many modern cosmologists, and of particular interest are the many adherents of the teleological anthropic principle that have won the Templeton Prize, most notably John Barrow and Paul Davies. A quick search of the preprint archive at Cornell (arXiv.org) reveals a flourishing discussion on the subject, with over thirty papers discussing the anthropic principle and its variants since 2005. Yet despite this discourse, the literature remains confused on just what an anthropic principle is or who came up with it. As to what it is, I leave that to the philosophers. As to who came up with it, I have clearly sided with Brandon Carter as the first instance, with Barrow and Tipler responsible for a second creation.

This paper ends with Barrow and Tipler because a similar analysis of their anthropic principle would require another thesis. If anything, I have tried to remain neutral on the utility of all principles, saying at most that scientists find them useful. However, much of my historical approach has been purposely contrary to that of Barrow and Tipler. Whiggish approaches can be helpful in comprehending historical accounts, but as I have shown in many places, Barrow and Tipler take this beyond description to the blatant rewriting of history. This only hurts the current discussion of the anthropic principle, and such confusion may damage scientific understanding.

Historians need to approach modern science much more confidently. In the introduction to *Modern Cosmology in Retrospect*—an historical account of cosmology as remembered at a meeting by the scientists involved—the editors call

out historians. In their opinion, historians distrust the accounts of scientists, are too slow and rigid in their approach, and fear the technicality of modern science.²³⁴

Scientists, they feel, can also do the categorizing and organizing that historians find themselves so specially enabled to handle. Some of the scientists at the meeting who tried their hand at history failed miserably. Following Hermann Bondi's presentation on cosmology from 1945-1952, historian J.D. North raised his hand and reminded those in attendance,

I feel rather ashamed to make such a trivial observation after such a splendid lecture, but my point is simply that cosmology is not only created by the interaction between the cosmologist and the universe, but by the interaction between cosmologists and other cosmologists. This is really a warning to historians who might consider that because an idea was published, therefore it was somehow public domain, and so must have influenced people. I was reminded of this during the morning session, for many of the wonderful ideas then brought to light had not, in their day, been particularly influential.²³⁵

Immediately following Bondi, Fred Hoyle took the stage and gave an entirely different account of the origins of the Steady-State theory. It is the job of the historian to step-in and mediate these disagreements. If we are to believe Bondi, the inspiration underlying the Steady-State was the disagreement among an expanding universe and the isotropy of the laws of physics; if we are to believe Hoyle, the Steady-State was inspired by the horror film *Dead of Night*. If Hoyle is correct, then historians of science should really start looking more into film history.

Given that the anthropic principle continues to thrive in modern cosmological explanations, it is imperative that historians, philosophers, and scientists alike

²³⁴ B. Bertotti, R. Balbinot, S. Bergia, A. Messina, *Modern Cosmology in Retrospect* (Cambridge, UK: Cambridge University Press, 1990), xiv-xv.

²³⁵ *Ibid.*, 195.

recognize the many forms floating around. An historical approach helps achieve this goal. Historians, and scholars in general, need to recognize that different minds understand ideas in different ways. Perhaps the best way to end this thesis is to cite one who has been so influential in its making, Martin Rees:

And when ruminating on the anthropic principle, the universe, and the place of planet earth in it, one's attitude depends very much on whether one thinks that there is something unique in the laws of nature, whether there is going to be a unified theory, which is going to tell us that the constants could not be otherwise. Or, alternatively, could there have been a universe or different parts of our universe beyond our present horizon where things were different? That question, whose answer will have to await further developments in physics, is going to make a difference in one's attitude to the anthropic principle.²³⁶

²³⁶ Martin Rees, In *Origins: The Lives and Worlds of Modern Cosmologists*, eds. Alan Lightman and Roberta Brawer, (Cambridge, Mass: Harvard University Press, 1990), 167.

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