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The fine-tuned universe and the existence of God

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The Fine-tuned Universe and the Existence of God

CHAN Man Ho

A thesis submitted in partial fulfilment of the requirements

for the degree of

Doctor of Philosophy

Principal Supervisor: Prof. KWAN Kai Man

Hong Kong Baptist University

May 2017

DECLARATION

I hereby declare that this thesis represents my own work which has been done after registration for the degree of PhD at Hong Kong Baptist University, and has not been previously included in a thesis, dissertation submitted to this or any other institution for a degree, diploma or other qualifications.

I have read the University's current research ethics guidelines, and accept responsibility for the conduct of the procedures in accordance with the University's Committee on the Use of Human & Animal Subjects in Teaching and Research (HASC). I have attempted to identify all the risks related to this research that may arise in conducting this research, and acknowledged my obligations and the rights of the participants.

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Abstract

Recent research in science indicates that we are living in a fine-tuned universe. Only a very small parameter space of universal fundamental constants in Physics is congenial for the existence of life. Moreover, recent studies in Biological evolution also reveal that fine-tuning did exist in the evolution. It seems that we are so lucky to exist as all universal fundamental constants and life-permitting factors really fall into such a very small life-allowing region. This problem is known as the fine-tuning problem. Does this phenomenon need an explanation? Can the fine-tuning problem point to the existence of God? Modern Science invokes the idea of multiverse to address the fine-tuning problem. Some scientists suggest that each universe in a set of infinitely many universes contains a typical set of fundamental constants. We should not be surprised why our universe is fine-tuned because we would not exist if the constants are not the life-allowed values. Some suggest that the existence of God can explain this fine-tuning problem. The naturalistic multiverse theory and the existence of God are the two most robust proposals to address the fine-tuning problem. Moreover, some argue that the fine-tuning problem is not real because we are just subject to observational selection effect. In this thesis, I will provide a comprehensive discussion on the fine-tuning phenomena in our universe. In particular, I will use the confirmation principle and the inference to the best explanation simultaneously to evaluate different hypotheses in a more systematic way and give some of the new and updated scientific and philosophical arguments to respond to the recent criticisms of the fine-tuning arguments. I conclude that the theistic hypothesis is the best among all to address the fine-tuning problem.

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Content

Chapter 1 Introduction

Many centuries ago, people believed that our natural world is designed by a designer. For example, the Stoic school founded by Zeno around 300 BCE suggested that the universe exhibits a great deal of order, which must be the result of intelligent agency.[1] This is one of the most primitive forms of the "Design Argument" or "Teleological Argument". Although there were some other contributions from Augustine and Boethius in a few centuries later, the Stoic school basically dominates the major idea of the Design Argument.[2]

Until the 13th century, Thomas Aquinas offered five arguments for the existence of God, which is known as the "Five Ways". The famous Fifth Way suggests that "*we see that things which lack knowledge, such as natural bodies, act for an end, and this is evident from their acting always, or nearly always, in the same way, so as to obtain the best result. Hence it is plain that they achieve their end not by chance, but by design*."[3] It is a posteriori in that it appeals to experience in order to establish that inanimate things act towards a goal.[4]

Later, in 1716, A Dutch mathematician called Bernard Nieuwentyt published a book on natural theology, which further improves the Design Argument.[5] Nieuwentyt suggests that only intelligent agency can produce systems of parts interacting strictly by mechanical means and having all of the following properties: 1. The interacting parts together accomplish a useful function; 2. The function is repeatedly or continuously produced by this arrangement of parts; 3. Altering any one part destroys the ability of the system to serve the useful function. Since the above properties can be found in many parts of our natural world, there exists a designer.[6] The argument from Nieuwentyt basically follows the major ideas from Stoic school. Nevertheless, Nieuwentyt identifies some similarity between the natural world and a watch, and he focuses more on the term "function".

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[1] Benjamin Jantzen, *An Introduction to Design Arguments* (Cambridge: Cambridge University Press, 2014), p.38.
[2] Ibid, p.51.
[3] Thomas Aquinas, "The Classical Cosmological Argument", *The Philosophy of Religion Reader*, ed. (New York: Routledge, 2008), p.195.
[4] Benjamin Jantzen, *An Introduction to Design Arguments* (Cambridge: Cambridge University Press, 2014), p.57.
[5] Bernard Nieuwentyt, *The Religious Philosopher; or, the Right Use of Contemplating the Works of the Creator*, trans. John Chamberlayne (London: J. Senex and W. Taylor, 1721).
[6] Benjamin Jantzen, *An Introduction to Design Arguments* (Cambridge: Cambridge University Press, 2014), pp.69-71.

In 1802, a theologian William Paley published his work on natural theology, which suggests that our complex natural world and life reveal a designer.[7] He thought that it is hard to think that there exists a complex watch without any watchmaker. By the same analogy, it is also hard to think that the complex features of our natural world and biological organisms are not designed by a designer.[8] His argument can be viewed as the argument from analogy:[9]

> Organisms are like watches with respect to properties P_1, P_2, P_3,…, P_n.
>
> Watches have designers.
>
> _____
>
> Organisms have designers.

On the other hand, Paley's argument can also be viewed as follow: The surprising properties found in a living thing can be explained by design and chance. Under the hypothesis of design, the properties of the living thing are much more probable than under the hypothesis of chance.[10]

Generally speaking, from Stoic school to Paley's argument, the major idea of the Design Argument is based on the existence of natural order and certain complex mechanisms in living things. I regard all the above mentioned design arguments versions of the "Classical Design Argument". However, the Classical Design Argument was strongly criticized by many philosophers and scientists such as Hume and Darwin in the 18th and 19th centuries. For examples, Hume denies that the existence of a designer could be derived from the existence of natural order. He says "*that order, arrangement, or the adjustment of final causes is not, of itself, any proof of design, but only so far as it has been experienced to proceed from that principle. For aught we can know a priori, matter may contain the source or spring of order originally, within itself, as well as mind does; and there is no more difficulty in conceiving, that the several elements, from an internal unknown cause, may fall into the most exquisite arrangement, than to conceive that their ideas, in the great, universal mind, from a like internal, unknown cause, fall into that arrangement.*" [11] This counterargument is further supported by the discovery of biological evolution. Charles Darwin proposes an alternative mechanism for generating the "natural order" that appears in organisms. Through

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[7] William Paley, "The Classical Design Argument", *The Philosophy of Religion Reader*, ed. (New York: Routledge, 2008), pp.251-255.

[8] William Paley, "The Classical Design Argument", *The Philosophy of Religion Reader*, ed. (New York: Routledge, 2008), pp.251-252.

[9] Benjamin Jantzen, *An Introduction to Design Arguments* (Cambridge: Cambridge University Press, 2014), p.125.

[10] Ibid, p.129.

[11] David Hume, *Dialogues Concerning Natural Religion and Other Writings*, ed. Dorothy Coleman (Cambridge: Cambridge University Press, 2007), pp.22-23

competitions among organisms and natural selection, some complex adaptations and behavior could be generated. After a long period of time, a certain complex properties in organisms would be formed. In other words, complex feature does not entail the requirement of design.

As a result, many modern philosophers and scientists deny this Classical Design Argument based on the counterarguments from Hume and Darwin. Nevertheless, some interesting discoveries in modern science give rise to a modern form of design argument. For example, recent research in science indicates that we are living in a fine-tuned universe. Only a very small parameter space of universal fundamental constants in physics is congenial for the existence of life.[12] Moreover, recent studies in biological evolution also reveal that fine-tuning did exist in the evolution.[13] It seems that we are so lucky to exist as all universal fundamental constants and life-permitting factors really fall into such a very small life-allowing region. These phenomena are known as the fine-tuning phenomena. Basically, the definition of fine-tuning can be formulated as follow (by Saward).[14]

Definition of fine-tuning: A universe Φ is fine-tuned for life if there is some constant σ in a physical law of Φ, such that

1. The range of values of σ compatible with the existence of life (life-permitting range) is much smaller than the range of possible values of σ;
2. σ is within the life-permitting range;
3. Φ is life-permitting.

Traditionally, the fine-tuning phenomena mainly focus on the fundamental constants and life-permitting range. However, the effects of the fundamental constants also depend on the initial conditions (see chapter 4). Therefore it is also very important to consider the fine-tuned conditions for life. Besides, if we further focus on the "intelligence-permitting range", some more fine-tuned parameters and conditions have to be considered. Therefore, we can enlarge the fine-tuning phenomena by including the evolution of intelligence, especially the evolution of human beings. Based on the above reasons, the new definition of fine-tuning can be stated as follow.

New definition of fine-tuning: A universe Φ is fine-tuned for intelligent life if there is some constant σ or condition η in a physical law of Φ, such that

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[12] See Alister McGrath, *A Fine-Tuned Universe* (Kentucky: Westminster John Knox Press, 2009).

[13] See Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998).

[14] Mark Saward, "Fine-tuning as Evidence for a Multiverse: Why White is Wrong," *International Journal for Philosophy of Religion* 73 (2013):243-253.

1'. The range of values of σ or the condition η compatible with the existence of intelligent life (intelligent-life-permitting range) is much smaller than the range of possible values of σ or η;

2'. σ or η is within the intelligent-life-permitting range;

3'. Φ is intelligent-life-permitting.

For the statement 1', the range of σ or the condition η for intelligent life being smaller than the possible values of σ or η means that the probability of getting the intelligent-life permitting σ or η is very small. Therefore, the statement 1' can be re-stated as "the probability of getting the intelligent-life permitting range σ or η is very low". If a certain condition is highly specific (i.e. many strict and specific requirements are needed), the probability of getting this condition by chance would be very low, and I regard this condition as a fine-tuned condition.

The fine-tuning phenomena can be addressed by two worldviews: theistic worldview and naturalistic worldview. In the theistic worldview, God designs and creates the universe in order to allow life to be evolved on Earth. Therefore, the existence of God explains why our universe is fine-tuned. This modern form of design argument does not build on analogy, but on certain analytical and philosophical arguments. For example, Richard Swinburne uses confirmation principle (see chapter 2) to show that the fine-tuning phenomena can be best explained by a theistic worldview (see chapter 6).[15] In the naturalistic worldview, all the evolving processes are natural and governed by natural laws. In particular, all the fine-tuned values in our universe can be generated through natural mechanisms. For example, Stephen Hawking suggests that the fine-tuning phenomena can be explained by the multiverse theory.[16]

In fact, most scientists believe that all physical events can be explained solely, and exclusively, in terms of other physical events. This way of thinking is usually known as "Scientific Naturalism".[17] Nevertheless, this Scientific Naturalism is just methodological naturalism. Since it is logically possible that God can create and intervene our universe through physical events, a scientist can also be a theist. In other words, Scientific Naturalism is not necessarily atheistic. The meaning of naturalism is usually founded on a commitment, voiced initially by W. V. O. Quine, to let the sciences be our guide in epistemology and metaphysics.[18] A more precise definition of naturalism can be stated as follow: "a

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[15] See Richard Swinburne, "Argument from the Fine-Tuning of the Universe," *Modern Cosmology and Philosophy*, ed. John Leslie (NY: Prometheus Books, 1998)

[16] Stephen Hawking and Leonard Mlodinow, *The Grand Design* (NY: Bantam Books, 2010), p.118.

[17] Rodney Holder, *God, the Multiverse, and Everything: Modern Cosmology and the Argument from Design* (VT: Ashgate, 2004), p.2.

[18] Alexander Rosenberg, *Darwinism in Philosophy, Social Science and Policy* (Cambridge: Cambridge University Press, 2000), p.1.

metaphysics that holds that whatever exists in any sense, is susceptible, both in fact and in right, to forms of inquiry oriented toward prediction and control."[19] Therefore, a metaphysical naturalism has to be considered as atheistic. Therefore, in a naturalistic worldview, no supernatural beings should be postulated.

Many religious beliefs have the concept of God or gods. God can be regarded as a supernatural being who can intervene in the nature. The discussion in this thesis does not point to any specific God. We will just discuss the probability of God's existence but not discuss which religious beliefs are better than the others. The existence of God is a controversial issue in religion, philosophy and science. Nevertheless, it is commonly believed that God is omnipotent, omniscience and perfectly good. These three properties are the simplest and most basic for God. According to the definition from Swinburne, the meaning of omnipotence is that God can do anything that is logically possible.[20] The meaning of omniscience is that God knows at any time all that is logically possible to know at that time.[21] God is perfectly good means that He will always do what is overall the best, and never do what is overall bad.[22] We will discuss the existence of God based on these properties in the following chapters.

In this thesis, I will give a comprehensive study on the arguments of fine-tuning and the modern form of design argument. I call this modern form argument the "anthropic design argument". We will first review all the scientific findings about the fine-tuning phenomena. Then we will examine both the theistic and naturalistic worldviews by considering the fine-tuning evidence and ascertain a best explanation of the fine-tuning phenomena. Many new arguments and findings will be described and discussed throughout the thesis. The thesis is divided into several parts. First, in chapter 2, I will describe and review the methodology used in this thesis. Then in chapters 3 and 4, I will discuss and review the fine-tuning phenomena in the nature, including the fine-tuning of fundamental constants and conditions. In these chapters, I will provide some new arguments to defend the existence of fine-tuning. In chapter 5, I will review some specific fine-tuned conditions in the evolution of intelligent human beings. In particular, I will provide some new evidence of fine-tuning based on latest discoveries. In chapter 6, I will discuss and evaluate some major hypotheses that are able to solve the fine-tuning problem. In fact, most of the discussion in the recent literatures concerning about different hypotheses are fragmented and simplified. Here, I will formulate a comprehensive analysis on the most popular hypotheses and give new arguments to assess the best explanation of the fine-tuning phenomena among the hypotheses. In fact, many previous

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[19] Philip Devine, "What is Naturalism", *Philosophia Christi* 8 (2006):125-139.
[20] Richard Swinburne, *Is There a God* (Oxford: Oxford University Press, 1996), pp.8-9.
[21] Ibid, p.9.
[22] Ibid, pp.13-14.

discussions mainly use the confirmation principle to evaluate the available hypotheses. For example, Swinburne uses the confirmation principle to show that the fine-tuning phenomena support the existence of God more than the multiverse hypothesis.[23] Besides, Robin Collins uses a similar method – "the likelihood principle" – to reach the same conclusion.[24] In this thesis, in addition to the confirmation principle, I will try another approach – the inference to the best explanation – to evaluate different hypotheses. In chapter 7, I will discuss the compatibility of the major hypotheses and reply to some major criticisms about the modern form of design argument. Here, I will give some new discussions on the relation between the existence of God and the multiverse hypothesis. Also, I will show that the disconfirmation of multiverse hypothesis can indirectly support the God hypothesis.

Generally speaking, the old discussions of the fine-tuning argument are fragmented. Most of the articles mainly focus on the comparison between the multiverse and the God hypotheses or the criticisms of different hypotheses. Furthermore, most of the discussions are narrow in perspective. The arguments are either based on science or philosophy. In this thesis, I try to give a comprehensive and thorough discussion on this topic. The anthropic design argument will be evaluated from both scientific and philosophical perspectives integrated in a single theoretical framework. My unique contributions for this topic are as follow:

1. I will use the confirmation principle and the inference to the best explanation simultaneously to evaluate different hypotheses in a more systematic way (in Chapter 6).
2. I will discuss the compatibility of the God hypothesis and the multiverse hypothesis and show that the incompatibility of the two hypotheses can give an indirect support of the anthropic design argument (in Chapter 7).
3. I will discuss some of the new and updated scientific and philosophical arguments (Chapter 3-5) and respond to recent criticisms of the fine-tuning arguments (Chapter 7).

Therefore, in this thesis, we can have a broader view and a more complete understanding of this interdisciplinary topic.

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[23] See Richard Swinburne, "Argument from the Fine-Tuning of the Universe," *Modern Cosmology and Philosophy*, ed. J. Leslie (New York: Prometheus Books, 1998).
[24] See Robin Collins, "The Teleological Argument." In *The Routledge Companion to Philosophy of Religion*, eds. C. Meister and P. Copan (New York: Routledge, 2007).

Chapter 2 The confirmation theory and the inference to the best explanation

When a hypothesis is going to explain the fine-tuning phenomena, how can we assess that hypothesis? In this thesis, I will use the confirmation theory developed by Swinburne and the inference to the best explanation to evaluate all the hypotheses.

2.1 Confirmation theory

2.1.1 Formalism

Confirmation theory seeks to state the rules for assessing how different evidence conferring probability on different hypotheses.[25] It is based on a theorem called Bayes theorem in the theory of probability, which is given by

$$P(A|B)P(B) = P(B|A)P(A), \tag{2.1}$$

where A and B are two independent events. Therefore, if we substitute A and B by theory T and evidence E respectively, we get

$$P(T|E) = \frac{P(E|T)P(T)}{P(E)}, \tag{2.2}$$

Here, P(T|E) means the probability of the theory being true given that the evidence E exists, P(E|T) means the probability of the evidence given that the theory is true, P(T) is the prior probability of the theory and P(E) is the prior probability of the evidence. In this context, confirmation theory states that the evidence E confirms theory T if and only if P(T|E) > P(T). This confirmation theory is a key philosophical foundation in determining whether a theory should be accepted in science. For example, the discovery of light bending in the 20th century during the solar eclipse matches the prediction made by General Relativity. Therefore, this is an evidence that support or confirm General Relativity.

Besides, the confirmation theory also enables us to evaluate which theory is the better theory. Suppose there are two competing theories, T_1 and T_2. Given that all other things being equal, we should choose T_1 rather than T_2 if the evidence E supports T_1 more than T_2, which means P(T_1|E) > P(T_2|E). This is a very important criterion in evaluating different theories. I will use this criterion to compare different hypotheses in explaining the fine-tuning phenomena.

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[25] Richard Swinburne, *An Introduction to Confirmation Theory* (London: Methuen, 1973), p.1.

According to the Bayes' theorem, $P(T_1|E) > P(T_2|E)$ if and only if

$$P(E|T_1)P(T_1) > P(E|T_2)P(T_2). \qquad (2.3)$$

The above inequality would be satisfied if we have both $P(E|T_1) > P(E|T_2)$ and $P(T_1) > P(T_2)$. If a theory T_1 renders E more probable than T_2 does, then we have $P(E|T_1) > P(E|T_2)$. Generally speaking, a good explanation of evidence E by theory T should satisfy the following three conditions:[26]

1. Causation condition: T can cause E.
2. Inference condition: E can be inferred from T, to a high degree.
3. Plausibility condition: T is relatively likely to be true, compared to competing theories, given our background knowledge.

Since the best theory should have the largest value of $P(E|T)P(T)$, we define the strength of a theory T by:

$$S(T,E) = P(E|T)P(T). \qquad (2.4)$$

In other words, the greatest strength of a theory is the best theory. Suppose there are N theories $(T_1, T_2, ..., T_N)$ that can explain an evidence E. We can write

$$P(T_1|E) = \frac{P(E|T_1)P(T_1)}{P(E|T_1)P(T_1)+P(E|T_2)P(T_2)+\cdots+P(E|T_N)P(T_N)} = \frac{S(T_1,E)}{\sum_{i=1}^{N} S(T_i|E)} \qquad (2.5)$$

If the value of $S(T_1, E)$ is much greater than $\sum_{i=2}^{N} S(T_i|E)$, $P(T_1|E)$ would be very large even though the actual value of $S(T_1, E)$ is small. Therefore, to show a theory T_1 is the best theory, we just need to show $S(T_1, E) > \sum_{i=2}^{N} S(T_i, E)$.

2.1.2 Simplicity of a theory

Given that the prior probabilities of theories T_1 and T_2 are equal and both theories can cause E, then we may just compare $P(E|T_1)$ and $P(E|T_2)$, which is known as the likelihood argument. This can be easily done by deductive arguments. What if $P(E|T_1)$ is comparable to $P(E|T_2)$? In general, we can easily design two theories such that they have nearly the same explanatory powers ($P(E|T_1) = P(E|T_2)$). If this happens, we have to compare the prior probabilities of theories T_1 and T_2. However, what criteria determine the prior probability of a theory? Swinburne suggests that the simplicity of a theory can determine the prior

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[26] Richard Johns, "Inference to the Best Explanation", http://faculty.arts.ubc.ca/rjohns/ibe.pdf.

probability.[27] Historically, there are many different proposals to define the meaning of a simple theory. For example, Popper suggests that the epistemological questions which arise in connection with the concept of simplicity can all be answered if we equate this concept with degree of falsifiability. In general, a simpler theory should be more falsifiable.[28] Later, Sober suggests that the simplest theory is the most informative theory in the sense of the one with respect to which you need to obtain less additional information in order to be able to answer the questions.[29] Based on the previous works from Popper and Sober, Swinburne further elaborates that the simplest theory should have the simplest formulation. He thinks that there are six criteria to assess what is the simplest theory:[30]

1. A simpler theory should have a fewer number of things postulated (Ockham's razor).
2. A simpler theory should have a fewer number of kinds of things (number of kinds of entities or properties of entities).
3. A formulation of a theory which contains a term referring to an entity or descriptive of a property which can only be grasped by someone who grasps some other term will be less simple than an otherwise equally simple formulation of a theory which contains the latter term instead.
4. A formulation of theory consisting of a few separate laws is simpler than the one consisting of many laws.
5. A formulation of a theory is simpler in which individual laws relate few variables rather than many.
6. A mathematically simpler formulation is simpler.

How do we know that we should choose a simple theory rather than a complicated theory? In view of the criteria above, a theory is simple if it is based on a few assumptions, a few kinds of entities and a few properties of entities. Therefore, theory T_1 is simpler than T_2 if the assumptions needed in T_2 is more than that in T_1 or the theory T_1 involves less entities or properties of entities than that of T_2. Keeping other factors constant, a simpler theory means a higher prior probability of the theory because each assumption in the theory would reduce the probability. For example, a theory T has N independent assumptions A_1, A_2, …, A_N. Then prior probability that the theory T is true is $P(T|A_1, A_2, … , A_N)$, which is

$$P(T|A_1, A_2, …, A_N) = P(T) \times \prod_i P(A_i) \qquad (2.6)$$

[27] Richard Swinburne, *Is there a God* (Oxford: Oxford University Press, 1996), p.24.
[28] Karl Popper, *The Logic of Scientific Discovery* (London: Hutchinson, 1959), p.140.
[29] Elliot Sober, *Simplicity* (Oxford: Clarendon Press, 1975).
[30] Richard Swinburne, *Simplicity as Evidence of Truth* (Milwaukee: Marquette University Press, 1997), pp.24-26.

where P(A_i) is the probability that the ith assumption is true. A multiplication of these probabilities further decreases the prior probability P(T). Therefore, fewer assumptions make a theory more probable.[31]

Besides, Bentham states that "*that which is used to prove everything else… cannot itself be proved.*"[32] This means that there must be a fundamental principle which cannot be proved. It cannot be justified or proven by mathematics or logic. For example, the axioms in Euclidean geometry are the fundamental principles. These principles can generate many different theorems by deduction. Here, we may regard the "principle of simplicity" to be the fundamental principle for our assessment. Although this principle cannot be proved to be true, it is widely-held by scientists, and science history tells us that a simpler theory usually gives a better prediction. In view of this, Swinburne says "the fact that in general simpler theories have worked well in the past which justifies us in assuming that they will work well in the future."[33] In fact, if we do not assume this principle of simplicity, scientists might encounter many problems in scientific investigation. For example, scientists usually use a straight line to represent the relation between the elastic force of a spring F and the length of compression e. This is known as the Hooke's law ($F = ke$). However, there are infinitely many ways to link up the data points about the elastic force and the length of compression (such as a higher order polynomial function) because the actual number of data points in an experiment must be finite. There must be some space between the data points and we can always choose another curve other than straight line to fit the data points. Therefore, based on the principle of simplicity, we choose the simplest way, a straight line (the fewest degrees of freedom and the simplest formulation), to fit the data points. If we do not use this principle, the justification of most of the scientific laws would break down.

2.1.3 Other knowledge

Besides considering the simplicity of a theory, the prior probability can also be assessed by our background knowledge about the theory. If we have other data or evidence (e.g. E_1, E_2, …) besides the evidence E, we can assess the value of P(T) by these other data or evidence (i.e. P(T|E_1,E_2,…)). For example, the theory of General Relativity (theory T) can explain the precession of the perihelion of Mercury (evidence E). In other words, the value of P(E|T) is high. Moreover, some other experiments

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[31] Richard Swinburne, "Argument from the Fine-Tuning of the Universe," *Modern Cosmology and Philosophy*, ed. J. Leslie (NY: Prometheus Books, 1998), p.177.

[32] Jeremy Bentham, *An Introduction to the Principles of Morals and Legislation* (NY: Doubleday, 1961), p.19.

[33] Richard Swinburne, *Simplicity as Evidence of Truth* (Milwaukee: Marquette University Press, 1997), p.45.

such as data from Gravitational Redshift support General Relativity. This increases the value of P(T) and gives a high value of P(T|E).

2.1.4 Objection to the confirmation theory

However, although the confirmation theory is based on some solid mathematical theorems, there are some objections to this theory. One of the most important criticisms is called the "old evidence problem".

The old evidence problem states that if an evidence is already known, the probability of getting the evidence P(E) should be 1. If P(E) = 1, according to the Bayes theorem, and since P(E|T) ≤ 1, we get P(T|E) ≤ P(T). That means for all theories that can account for or explain the old evidence would be disconfirmed. However, whether a theory is confirmed or not should not be based on whether the evidence is old or new. Therefore, the confirmation theory may have some intrinsic problem. One of the most famous examples to illustrate this problem is the precession of the perihelion of Mercury. Well before the publication of General Relativity, scientists had already known that the precession of the perihelion of Mercury cannot be fully addressed by Newton's laws. Nevertheless, after Einstein published his theory of General Relativity, the discrepancy between the theory and observation is reconciled. Although the precession problem of Mercury is old evidence at that time, most scientists regard that piece of evidence confirms the General Relativity.[34] How can we reconcile the problem of old evidence and the confirmation theory? The answer is that P(E) is not 1 in the old evidence's case. The evidence is old or new depends solely on the time of the discovery. One can treat all the old evidence as the predicted evidence. This means that P(E) is not 1, but may be a small value. This is valid because there is no logical difference between a theory T predicting an observation O or an observation O generating a theory T. The only difference is that T appears earlier than O in the former case while T appears later than O in the latter case. However, the logical connection between T and O should not be affected by the chronological order. Swinburne says that[35]

"I cannot see that it matters as regards the support given by observations to the theory whether, say, 100 observations are made first and the theory then constructed to explain them, or whether the theory is constructed on the basis of fifty observations and it successfully predicts another fifty. The support given

[34] Bradley Monton, "God, Fine-tuning, and the Problem of Old Evidence," *British Journal of Philosophy of Science* 57 (2006): 405-424.
[35] Richard Swinburne, *Is There a God* (Oxford: Oxford University Press, 1996), p.30.

by observations to a theory concerns a logical relation between observations and the theory, and is independent of when the observations are made."

In general, it is always possible for us to divide the evidence into two categories: new evidence e (not yet observed evidence) and background evidence k (already observed evidence). Swinburne suggests that they are the same thing. The division between e and k can be made where you like. As stated in the previous example, you can assume we don't know the precession of the perihelion of Mercury (assign k as e) and assess the General Relativity by using the confirmation principle. Similarly, Dawes suggests that a theory can be corroborated if it is able to predict some fact that cannot be explained by, or that apparently falsifies, its predecessor. Whether the fact is known or unknown is irrelevant.[36] From this point of view, we could always treat the known evidence as a "prediction" if that evidence cannot be explained by existing theories. This kind of understanding is following the so-called Hempel's covering-law models of scientific explanation (the deductive-nomological (DN) model and the inductive-statistical (IS) model).[37] These models suggest a symmetry exists between explanation and prediction (explanation-prediction symmetry) because they have the same logical structure (it conforms to the covering-law model).[38] However, Miller thinks that the above arguments "*suppose that the test of an explanatory hypothesis must have the form of a prediction deduced from general laws and independent statements of antecedents which are part of the hypothesis itself*".[39] In other words, he thinks that we can always tailor-make a theory to explain the data. Nevertheless, it is more difficult for us to formulate a theory such that the prediction matches the data in future observations. Therefore, there has been an interesting debate for the past few decades, on whether successful prediction provides more epistemic warrant to a theory than accommodation (explanation). For example, Scheffler critiques the idea of a strict logical parallel between the explanation and prediction. He says that explanations are required to be true if they were to be acceptable explanations. While for predictions, we could produce successful predictions without adequate explanations. [40] Although the nature of prediction and explanation might be a bit different, many philosophical studies inclined to support the explanation-prediction symmetry due to the logical

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[36] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.121.

[37] C. G. Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science* (New York: The Free Press, 1965), p.337.

[38] See C. G. Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science* (New York: The Free Press, 1965), p.368. In particular, the explanation-prediction symmetry thesis can be divided into two sub-theses, namely that "every adequate explanation is a potential prediction" and "every adequate prediction is a potential explanation".

[39] Richard Miller*, Fact and Method: Explanation, Confirmation and Reality in the Natural and the Social Sciences* (New Jersey: Princeton University Press, 1987), p.49.

[40] Israel Scheffler, "Explanation, Prediction, and Abstraction", *British Journal for the Philosophy of Science* 7(1957):293-309.

symmetry. [41] In the DN-model, predictions were just explanations given at a different epistemic-temporal location. In other words, explanations were merely late predictions (some call it retrodiction or postdiction).[42] Practically, the function and value of explanation and prediction are not totally independent. Douglas thinks that the relationship between explanation and prediction is a tight, functional one. Explanations provide the cognitive path to predictions, which then serve to test and refine the explanations.[43] As mentioned above, the precession problem of Mercury can be a piece of evidence to confirm General Relativity, though the discovery of the precession problem was many years earlier than the formulation of General Relativity. Here, the evidence is merely a late prediction (retrodiction).

Since the confirmation theory is related to the logical structure of an explanation (time independent), the symmetry of explanation and prediction still applies to a certain extent. However, as stated above, it seems that prediction is not totally the same as retrodiction.[44] My standpoint is that we need not completely resolve the issue here. The above debate does not affect my claim in this thesis. In applying the confirmation principle, we can simply assume that explanation share some similarity with "late prediction", but they are not identical. Therefore, we assume that we did not know the evidence E to be true so that P(E) is not 1, but a certain small value that is less than 1. Then, we can assess a theory whether it can be confirmed by the evidence by comparing P(T|E) and P(T).

2.2 Inference to the best explanation

Although the confirmation principle can help us to assess which theory is a better explanation, sometimes it is not easy for us to compare the values of $S(T, E)$. For example, if both the likelihoods and the prior probabilities of all available theories are small, the variation of $S(T, E)$ for different theories would be too small to compare. Therefore, we have to invoke another useful principle to judge the best theory.

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[41] See Paul Dietl, "Paresis and the Alleged Asymmetry between Explanation and Prediction", *The British Journal for the Philosophy of Science* 17 (1967):313-318; Robert Lee, "A Critical Analysis of the Thesis of the Symmetry between Explanation and Prediction: Including a Case Study of Evolutionary Theory", PhD thesis, The University of British Columbia, 1979.
[42] Heather Douglas, "Reintroducing Prediction to Explanation", *Philosophy of Science* 76(2009):444-463.
[43] Ibid.
[44] See the discussion about this "asymmetry problem" from Kent Staley, *An Introduction to the Philosophy of Science* (Cambridge: Cambridge University Press, 2014), pp.207-208.

2.2.1 Formalism

In science, we usually have several models or theories that can explain certain observational data. The meaning of explanation can be defined as follow:[45]

Definition: An explanation is a story about what caused an object to exist, or an event to occur.

If there are more than one theories that can provide explanation, what criteria should we use to determine which theory is the right one to explain those observations? Most scientists and philosophers invoke "inference to the best explanation" to choose the best theory. This principle states that we should choose a theory that displays, to a greater degree than any competitor, certain explanatory virtues.[46]

Definition: The method "inference to the best explanation" tells you which theory T to infer from the available evidence E. It says you should infer the theory T that best explains E.[47] The structure of the argument can be formulated as follow:[48]

P1: The surprising fact, E, is observed.

P2: A hypothesis H would be a satisfactory explanation of E.

P3: No available competing hypothesis would explain E as well as H does.

C: Therefore, H is true.

The above version is a strong version of the "inference to the best explanation". A weaker version can be obtained by replacing the conclusion by "Therefore it is reasonable to accept H". If a theory can display certain explanatory virtues, that theory could be regarded as a satisfactory explanation (i.e. satisfy P2). What are the explanatory virtues? Kuhn suggests that a good scientific theory should have five characteristics. They are accuracy, consistency, simplicity, fruitfulness, and broad scope.[49] Later, Dawes summarizes several explanatory virtues commonly used by scientists and philosophers. They are explanatory power, degree of testability, simplicity, consistency from background knowledge, informativeness, and fecundity.[50] The meanings of explanatory power and simplicity have been discussed

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[45] Richard Johns, "Inference to the Best Explanation", http://faculty.arts.ubc.ca/rjohns/ibe.pdf.
[46] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.112.
[47] Richard Johns, "Inference to the Best Explanation", http://faculty.arts.ubc.ca/rjohns/ibe.pdf.
[48] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.111.
[49] Thomas Kuhn, *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago: University of Chicago Press, 1977), pp.321-322.
[50] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.112.

in 2.1.1 and 2.1.2, respectively. In the following, we briefly discuss the importance of the remaining explanatory virtues suggested by Dawes.

2.2.2 Degree of testability

Testability is usually regarded as a necessary condition of at least a scientific explanation. A better theory should have a high degree of testability. In general, a hypothesis is independently testable if we can use it to make predictions (lead us to expect) about facts other than those it purports to explain.[51] Therefore, a testable hypothesis should have some chance that the prediction it makes will turn out to be false. This means that a hypothesis must contain some degree of empirical content. In other words, the greater the degree of empirical content, the higher the degree of testability. As mentioned above, predictions can also include retrodiction of the known evidence.

2.2.3 Consistency with background knowledge

Background knowledge includes known successful theories and our basic experience and knowledge. The proposed theory should be consistent with our best existing theories.[52] Furthermore, the suggested theory should be comprehensible by our background knowledge. Dawes suggests that "*for other things being equal, the explanations afforded by a theory are better explanations if the theory is familiar, that is, introduces mechanisms, entities, or concepts that are used in established explanations. The use of familiar models is not essential to explanation, but it helps*".[53] Therefore, a theory which is more consistent with our best existing theories and comprehensible by our background knowledge would be a better theory.

How about the past explanatory success? From a Bayesian point of view, the past explanatory success of a theory might increase its prior probability. However, strictly speaking, it does not apply to the assessment of worldviews. It is because we do not have the track records of the theistic worldview and naturalistic worldview. In particular, the past failure of explanation from a theistic worldview does not preclude future success. Therefore, the past failure of explanation from a certain worldview would not be assessed in the following discussion.

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[51] Ibid, p.117.
[52] Ibid, p.126.
[53] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.127.

2.2.4 Informativeness

An informative theory is close to what Peter Lipton describes as the loveliness of a proposed explanation.[54] A lovely explanation is one that specifies some articulated casual mechanism whose description allows us to deduce the precise details of the effect.[55] Lipton argues that we should prefer the loveliest explanation to the likeliest explanation. It is because while "likeliness speaks the truth", "loveliness speaks of potential understanding".[56] Therefore, an informative theory should intrinsically possess some detailed mechanisms, and we should have ability to deduce the subsequent effect of that theory.

2.2.5 Fecundity

Dawes suggests that a good theory should possess fecundity – able to suggest new lines of research.[57] In general, a true theory would show its effects in many aspects. For example, the theory of General Relativity does not only explain the motion of Mercury, but also the light path. Therefore, General Relativity suggests a new line of research on Gravitational redshift and Gravitational lensing effect. In other words, a large fecundity of a theory would raise its prior probability.

2.3 Criticisms of the inference to the best explanation

The major criticism of the inference to the best explanation is its alleged subjectivity. In particular, we may have biases and prejudices in assessing the prior probability of a theory. Choosing the simplest theory according to the above criteria might be objective. However, the assessment of a theory based on the explanatory virtues may be affected by our prior knowledge or subjective experience. For example, a God-believer may believe that the existence of God is consistent with our background knowledge while an atheist might disagree with that. This is because the subjective experience of a God-believer would contribute to the assessment.

Although it is widely accepted that the inference to the best explanation involves a certain degree of subjectivity, it does not mean that this principle should be denied in assessing different theories. In

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[54] Ibid, p.138.
[55] Peter Lipton, *Inference to the Best Explanation* (London: Routledge, 1991), p.118.
[56] Ibid, p.59.
[57] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.116.

science, scientists still use this principle to determine the best theory to explain observations. There may be some different subjective assessments of the prior probability of a theory at the very beginning. Nevertheless, when the observational data become plentiful and accurate, the initial biases would eventually converge on the same opinion. Those prejudices can be overwhelmed by the empirical evidence. This defense of scientific rationality is often called "the washing out of the priors".[58]

Besides the problem of subjectivity, some criticisms suggest that it is possible to have a theory which is the best theory among all the competitors but a very bad theory (P(T|E) is very low, but it is the largest value among all available theories). In general, a theory would be justified if P(T|E) > 0.5 and there exists no competing hypothesis whose probability is higher. However, in many cases, it is difficult for us to get such a high posterior probability. In fact, there are many instances of people accepting scientific theories even though their posterior probability has not yet been shown to be greater than 0.5.[59] Therefore, it is still reasonable for us to choose the best theory if it displays an overall greater degree of explanatory virtues than any competitor, though the value of P(T|E) might not be greater than 0.5.

What if there is only one possible explanation for a certain evidence? Would the theory win by default based on the inference to the best explanation? Sober thinks that no conclusion can be drawn if there is no comparison, even P(T|E) is high.[60] However, Musgrave suggests that we can always think of a theory as being tested against a competitor, even if that theory is empty or tautologous.[61] This is similar to the usage of "null hypothesis" in statistics. In statistics, we usually compare a statistical result with a result from "null hypothesis" – a hypothesis that assumes all results are randomly generated. Therefore, we can always compare a theory with a "null theory", which suggests every phenomenon is due to random events. Based on the above discussions, most of the suggested conceptual problem for the inference to the best explanation can be solved.

2.4 Residual confirmation

Consider some hypotheses that can explain an observation. In general, some of the hypotheses are not mutually exclusive. Therefore, some hypotheses can co-exist together and contribute to an explanation of the observation. For example, the origin of life can be explained by God's creation or theory of chemical

[58] Richard Johns, "Inference to the Best Explanation", http://faculty.arts.ubc.ca/rjohns/ibe.pdf.
[59] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.111.
[60] Elliot Sober, "Testability", *Proceedings and Addresses of the American Philosophical Association* 73 (1999):47-76.
[61] Alan Musgrave, *Essays on Realism and Rationality*, Studies in the Philosophy of Karl R. Popper and Critical Rationalism 12 (Amsterdam: Editions Rodopi, 1999), p.246.

evolution. In general, both theories are not mutually exclusive. If this happens, it can be shown that the degree of confirmation would be affected if both theories can co-exist. This effect can be measured by "Residual confirmation (RC)".

Before defining RC, let's define a concept called "marginally independent". A and B are said to be marginally independent if P(A|B) = P(A).[62] That means the existence of B would not affect the probability of A. Otherwise, A and B are not independent.

Suppose there are two theories T_1 and T_2 which can explain an evidence E. If we now confirm T_2 is true, the confirmation of T_2 would probably explain away the evidence for T_1 by a certain extent. In other words, the degree of confirmation of T_1 would be very small if T_2 can almost explain away the evidence E for T_1. This effect can be measured by the degree of residual confirmation, which is defined by[63]

$$RC = \log\left[\frac{P(T_1|E,T_2)}{P(T_1)}\right]. \tag{2.7}$$

According to the confirmation principle, the theory T_1 can still be confirmed if RC is positive. If T_1 and T_2 are marginally independent, it can be shown that

$$RC = \log\left[P(T_1) + \frac{P(E|\sim T_1,T_2)}{P(E|T_1,T_2)}P(\sim T_1)\right]^{-1}. \tag{2.8}$$

In this case, RC would be positive if $P(E|T_1,T_2) > P(E|\sim T_1,T_2)$. If we have $P(E|T_1,T_2) \leq P(E|\sim T_1,T_2)$, T_1 can be regarded as completely explained away by T_2. If T_1 and T_2 are not independent, we have

$$RC = \log\left[P(T_1) + \frac{P(E|\sim T_1,T_2)}{P(E|T_1,T_2)}\frac{P(T_2|\sim T_1)}{P(T_2|T_1)}P(\sim T_1)\right]^{-1}. \tag{2.9}$$

In this case, RC would be positive if $P(E|T_1,T_2) > P(E|\sim T_1,T_2)$ and $P(T_2|T_1) > P(T_2|\sim T_1)$.

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[62] David Glass, "Can Evidence for Design be Explained Away?" *Probability in the Philosophy of Religion*, eds. Jake Chandler and Victoria Harrison (Oxford: Oxford University Press, 2012), pp.79-102.
[63] Ibid.

2.5 The effect of other negative evidence

Suppose there is an evidence E_1 that confirms a theory T while there is another evidence E_2 which disconfirms T. How would the degree of confirmation be affected? The posterior probability of T given that E_1 and E_2 are true is given by[64]

$$P(T|E_1, E_2) = \frac{P(E_1, E_2|T)P(T)}{P(E_1, E_2|T)P(T) + P(E_1, E_2|\sim T)P(\sim T)}.$$ (2.10)

The RC can be written as

$$RC = \log\left[\frac{P(T|E_1, E_2)}{P(T)}\right] = \log\left[P(T) + \frac{P(E_1, E_2|\sim T)}{P(E_1, E_2|T)}P(\sim T)\right]^{-1}.$$ (2.11)

Therefore, RC would be positive if $P(E_1, E_2|\sim T) < P(E_1, E_2|T)$.

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[64] Richard Swinburne, "Bayes, God, and the Multiverse", *Probability in the Philosophy of Religion*, eds. Jake Chandler and Victoria Harrison (Oxford: Oxford University Press, 2012), pp.102-123.

Chapter 3   Fine-tuning of the Physical constants

Life is composed by many different kinds of elements. For example, the fundamental biological system - cell - contains many elements such as carbon, hydrogen, oxygen, nitrogen, sulfur and phosphorous. In some essential metabolic mechanisms for life, we also need some metal elements such as sodium, magnesium, potassium, calcium, manganese, iron, nickel, copper and zinc. Most of these metals contribute to the reduction and oxidation transformations that are critical to all life.[65] Basically, out of 92 naturally occurring elements, 25 are presently considered essential for life.[66] In the following, I call all these crucial elements for life "the anthropic elements". In fact, these elements form various compounds and serve for different functions in life. I call these crucial molecules for life "the anthropic molecules".

Among all the above mentioned elements, carbon is the most important for life evolution. Therefore, life is "carbon-based". In general, it is possible to have non-carbon-based life, for example, silicon-based life, which is suspected to be an alternative possible form. It is because silicon shares similar chemical properties with carbon. However, some studies indicate that silicon-silicon bond is weaker than carbon-carbon bond so that their biotic potential in oxygen-rich environments is severely reduced. Also, silicon cannot form double or triple bonds, or any biologically significant form of delocalized bond that are found in carbon compounds. Furthermore, silicon dioxide is insoluble solid which is difficult to generate silicon cycle in the environment.[67] Even if it is possible for silicon to form some basic building blocks, there is no evidence for the higher organization of the hypothetical silicon life forms, including possible analogs cell membranes, enzymes, coding systems, etc.[68] Based on the above arguments, though we cannot hundred percent rule out the possibility, silicon-based life is not likely to exist. The reason why we focus on carbon is that in the mid-twentieth century, scientists discovered that the production of carbon in the nature looks like a fine-tuned process. Later on, various studies indicate that the production of many anthropic elements and molecules are dependent on the values of some fundamental constants in physics. In order to make life possible, many values have to be fine-tuned – only a very narrow range of the value is friendly for life. Our nature seems to be biocentric.

In this chapter, I will discuss the production of the anthropic elements and how these anthropic elements depend on the fundamental constants. I call this the primary fine-tuning. In addition, many physical and chemical properties of the anthropic molecules are very crucial to life. I will also discuss how these

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[65] Alister McGrath, *A Fine-Tuned Universe* (Kentucky: Westminster John Knox Press, 2009), p.156.
[66] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.74.
[67] Alister McGrath, *A Fine-Tuned Universe* (Kentucky: Westminster John Knox Press, 2009), p.139.
[68] Michael Denton, "The Place of Life and Man in Nature: Defending the Anthropocentric Thesis," *Bio-complexity* 2013 (2013): pp.1-15.

properties are fine-tuned in nature. I call this the secondary fine-tuning. Lastly, I will review some arguments against the idea of fine-tuning.

3.1 How elements were produced?

It is commonly believed that our present universe originated from the Big Bang. The temperature of the universe is decreasing when the universe is expanding. In the period called Big Bang Nucleosynthesis, hydrogen, helium and a tiny amount of lithium were formed in the first three minutes since Big Bang. [69] All elements heavier than lithium (atomic number larger than 3) would not be formed because beryllium (atomic number = 4) is highly unstable. All beryllium formed will decay into lithium quickly. But why do we have carbon, oxygen, etc. in the universe now? The answer is that all heavier elements were produced by nuclear fusion in stars and a nucleosynthetic process in supernovae.

Stars generate energy by nuclear fusion. A large amount of hydrogen and helium formed during Big Bang Nucleosynthesis would form stars. When the density and central temperature is high enough, 4 hydrogen atoms would form 1 helium atom by some physical processes and a large amount of energy is released. When most of the hydrogen is consumed, the core of the star starts to contract, and the temperature would be increased. When the temperature reaches 120 million Kelvin, helium starts to form carbon and oxygen through some physical processes called triple alpha process.[70] For some heavier stars (mass greater than 4 solar mass), carbon will be ignited to form neon, magnesium and sodium. For a star which has mass greater than 20 solar mass, nuclear fusion can generate iron as product. As far as we know, iron is the most stable element (largest binding energy per nucleon). No heavier elements will be generated through nuclear fusion in stars. When the nuclear fusion ends, the core of the star will contract and generate a severe explosion called supernova. Due to the high energy release, all elements heavier than iron could be generated. During supernova, most of the materials in the star, including hydrogen, helium, and products of nuclear fusion will be ejected to other regions. These ejected materials can later form another star or planets. Generally speaking, all the elements found in Earth were produced by stars from the previous generations. In other words, we are made from stars!

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[69] Bradley Carroll and Dale Ostlie, *An Introduction to Modern Astrophysics* (San Francisco: Pearson, 2007), pp.1177-1179.
[70] Ibid, p.312.

3.2 Fine-tuning of the fundamental constants

All these element-generating processes have been known for several decades. However, astrophysicists Fred Hoyle and William Fowler discovered in 1957 that the synthesis of carbon in stars is a fine-tuned process.[71] In the triple alpha process mentioned above, the production of oxygen and carbon requires three important processes:[72]

$$He + He \rightarrow Be \qquad (3.1)$$

$$Be + He \rightarrow C \qquad (3.2)$$

$$C + He \rightarrow O \qquad (3.3)$$

It is not quite probable for 3 helium nuclei (He) to form a carbon atom (C) by collisions. It would be possible only if an energy level 7.65 MeV exists in carbon so that beryllium (Be) can be formed to react with one more helium (the second process). Later, Hoyle found that there really exists an energy level 7.65 MeV in carbon. This excited energy level (resonant level) has to be fine-tuned to exactly this value in order for carbon-based life to exist. On the other hand, since the carbon produced in the second process will probably be consumed to form oxygen in the third process (2.3), carbon may be just an intermediate product but not the final product. If so, no carbon will be produced in star and no carbon-based life is allowed. Fortunately, a significant amount of carbon is retained because oxygen has an energy level at 7.12 MeV, which is just below the combined energies of carbon and helium at 7.19 MeV. As a result, the existence of these two energy levels (7.65 MeV in carbon and 7.12 MeV in oxygen) produces a significant amount of both carbon and oxygen. Later, Hoyle gave a remarkable reflection on this result: [73]

"From 1953 onward, Willy Fowler and I have always been intrigued by the remarkable relation of the 7.65 MeV energy level in the nucleus of carbon to the 7.12 MeV level in oxygen. If you wanted to produce carbon and oxygen in roughly equal quantities by stellar nucleosynthesis, there are two levels you would have to fix, and your fixing would have to be just where these levels are actually found to be."

Therefore, the energy levels in carbon and oxygen seem to be fine-tuned so that carbon can be produced and life can exist. These values are mainly controlled by the electromagnetic force and quite sensitive to the strong force in nature. This means that the fundamental constants for electromagnetic force and strong

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[71] Margaret Burbidge et al., "Synthesis of the Elements in Stars," *Review of Modern Physics* 29 (1957): pp.547-650.
[72] Bradley Carroll and Dale Ostlie, *An Introduction to Modern Astrophysics* (San Francisco: Pearson, 2007), pp.312-313.
[73] Fred Hoyle, "The Universe: Past and Present Reflections," *Annual Review of Astronomy and Astrophysics* 20 (1982): pp.1-35 (at p.16).

force are needed to be fine-tuned. Calculations show that even a four percent shift of strong force would severely deplete the amount of carbon made.[74]

In fact, the fine-tuning phenomenon does not only occur in triple-alpha process. Scientists discover that our universe is fine-tuned in many ways for life. As mentioned above, the formation of stars is crucial for life (no stars, no life). Recent studies reveal that the gravitational constant needs to be fine-tuned in order to form stars. Calculations by Brandon Carter show that if gravity had been stronger or weaker by one part in 10^{40}, then life-sustaining stars like the sun could not exist.[75] On the other hand, the fundamental constant for weak force is also fine-tuned. If this number is somewhat greater, some heavier elements that are crucial for life would not be produced by supernovae. No hydrogen would be formed if this number is somewhat smaller than the actual values.[76] Moreover, if the strong force were to have been as little as 2 percent stronger relative to the other forces, all hydrogen would have been converted into helium. If it were 5 percent weaker, no helium at all would have formed and there would be nothing but hydrogen.[77] Therefore, all forces in the nature – electromagnetic force, gravitational force, strong force and weak force – and the corresponding fundamental constants are fine-tuned for life. The relative strengths for gravitational force, nuclear strong force, electromagnetic force and weak force are 5.9×10^{-39}, 15, 3.05×10^{-12} and 7.03×10^{-3} respectively.[78] In addition to the forces in nature, the formation of stars also depends on the matter content and the initial state of the universe. These properties can be characterized by some other physical constants.

Martin Rees summarized all the fine-tuning phenomena and suggested that six important numbers are fine-tuned for life. They are the strength of the electric forces that hold atoms together divided by the force of gravity between them ($N = 10^{36}$), a number which defines how firmly atomic nuclei bind together and how all the atoms were made ($\varepsilon = 0.007$), the number which defines how much material in our universe (Ω), the cosmological constant (λ), the primordial or initial quantum fluctuation ($Q = 10^{-5}$) and number of the spatial dimension ($D = 3$).[79] The numbers N and ε represent the fundamental forces in nature. The numbers Ω and λ represent the amount of matter and energy that exist in our universe. The number Q represents the initial condition of our universe. The number D represents the actual dimensions which have not been contracted. A slight change in any of these numbers would make the necessary

[74] Martin Rees, *Just Six Numbers* (New York: Basic Book), p.50.
[75] Robin Collins, "God, Design, and Fine-Tuning," in Raymond Martin and Christopher Bernard (ed), *God Matters: Readings in the Philosophy of Religion*, (New York: Longman Press, 2002).
[76] Alister McGrath, *Science and Religion: An Introduction* (Oxford: Blackwell Publishers Ltd., 1999).
[77] Ernan McMulin, "Indifference Principle and Anthropic Principle in Cosmology," *Studies in the History and Philosophy of Science* 24 (1993): pp.359-389.
[78] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.12.
[79] Martin Rees, *Just Six Numbers* (New York: Basic Books), pp.2-3.

anthropic elements disappear (primary fine-tuning). We have already discussed the fine-tuning of N and ε. Moreover, some express another fine-tuning evidence by stating that the masses of proton and neutron are fine-tuned for life (or the ratio of proton mass to neutron mass).[80] Actually, this is just another expression by combining N and ε.

In the following sections, we will have a brief discussion on the fine-tuning of energy and matter content and the initial conditions of our universe. Since the contraction of dimensions requires some uncertainties and technical details in string theory, we will not discuss the fine-tuning of D in this thesis.

3.3 Fine-tuning of the state of the Universe

Cosmological studies reveal that the formation of galaxies and stars depends sensitively on the matter content of the universe. The constant Ω that characterizes the matter content needs to have the right value in order to permit life. The required precision is astonishing: at one second after the Big Bang, Ω cannot have differed from unity by more than 0.000000000000001.[81] That means one second after the Big Bang, $0.999999999999999 \leq \Omega \leq 1.000000000000001$, where this number in general can be any values. This fine-tuning problem is previously known as the "flatness problem". It is commonly believed that this problem can be solved by the existence of an inflation field at the very beginning of the Big Bang. This is known as the inflation theory. This theory suggests that an unknown scalar field (energy) exists at the very beginning of our universe. This field makes our universe expand suddenly by a huge amount so that the matter density becomes much smaller due to a huge increase in volume. As a result, the matter content Ω becomes very small and equal to the value that we measured. However, the inflation should start and end at a right time and the amount of inflation field should be greater than some value.[82] Therefore, the flatness problem is just displaced by another problem with some other fine-tuned values. A famous scientist Steinhardt says that "*In a typical inflationary model, the value must be near 10^{-15}—that is, zero to 15 decimal places. A less fine-tuned choice, such as zero to only 12 or 10 or eight decimal places, would produce bad inflation: the same degree of accelerated expansion (or more) but with a large temperature*

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[80] Robin Collins, "God, Design, and Fine-Tuning," in Raymond Martin and Christopher Bernard (ed), *God Matters: Readings in the Philosophy of Religion*, (New York: Longman Press, 2002).

[81] Martin Rees, *Just Six Numbers* (New York: Basic Book), p.88.

[82] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.

variation that is inconsistent with observations".[83] In other words, the fine-tuning problem of matter content still exists and cannot be addressed by the inflation model alone.

Another intriguing parameter called the cosmological constant λ, re-entered the cosmological model in 1998 because of the observation of acceleration in universe expansion. It measures the content of dark energy that exists in the universe. Although we do not know what it is and why it exists, we can measure its value by observing the cosmic microwave background radiation. If this number is too large, all matter in the universe will not form structures. If this number is too small, the gravity will be strong enough to pull everything together after a rather short time, which means that there is not enough time for life to evolve.[84]

Besides physical laws, all subsequent motion of particles also depends on initial conditions. For example, you need to tell me the position and the initial velocity of a particle in order to predict its position and velocity after some time interval. Same as the expansion of the universe, a constant called primordial or initial quantum fluctuation Q characterizes the amplitude of initial irregularities when the Big Bang starts. The current measured value is about $Q = 10^{-5}$.[85] Calculations show that the star formation would be slow and inefficient if Q is smaller than 10^{-5}. If it were smaller than 10^{-6}, gas would never condense into structures at all. If it were substantially larger than 10^{-5}, regions far bigger than galaxies would condense early in its history, and they wouldn't fragment into stars.[86]

To conclude, the existence of stars and anthropic elements are highly dependent on the 5 fine-tuned values N, ε, Ω, λ and Q (and also the dimension D). If one of the parameters change slightly, says, 10 times larger, no life would exist.

3.4 Secondary fine-tuning

The existence of some anthropic elements is very sensitive to the fundamental constants. In fact, many compounds formed from these elements are crucial to life. Recent studies reveal that the properties of these compounds are also fine-tuned for life (secondary fine-tuning). These properties depend on complex interactions among gravitational force, electromagnetic force and strong force. This suggests that the feasible parameter space for life would be further narrowed. In this section, I will outline several major

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[83] Paul Steinhardt, "The Inflation Debate," *Scientific American* 304 (April 2011): pp.38-43.
[84] Martin Rees, *Just Six Numbers* (New York: Basic Book), pp.96-97.
[85] Ibid, p.115.
[86] Ibid, p.115.

physical and chemical properties of some important compounds or structures such as water, carbon dioxide, oxygen, proteins and DNA.

3.4.1 Fine-tuning of water

The most important compound for life is water. Water molecules have several important fine-tuned properties that are crucial for life.

By vital coincidence, the temperature range in which water is a fluid (0-100℃) overlaps with the temperature range in which chemical bonds can be readily manipulated by biochemical system. [87] Moreover, because the properties of expansion and contraction of liquid water and ice are unique, water would not be frozen easily on Earth. The high latent heat of vapourization and specific heat capacity helps to stabilize our climate in order to make life possible.[88] Besides, its high dielectric constant is responsible for its ability to dissolve virtually all charged molecules so that the distribution of chemical species is possible.[89] Furthermore, the viscosity of water is nearly the minimum known for any fluid. This makes the movement of fish possible, and the development of higher organisms depends critically on the ability of cells to move and crawl around during embryogenesis.[90] The viscosity of ice also lies within an appropriate range for life. If the viscosity of ice is too large, water will be immobilized at the poles and high mountains which change our climate severely. If the viscosity of ice is too small, the glacial activity would be much less effective in grinding down the mountains and releasing vital minerals into the hydrosphere.[91]

The above properties are independent of each other and are adapted to serve cooperatively the same biological end. In summary, the unique properties of water serve to stabilize the weather, preserve the liquid water in Earth and help temperature regulation. Life would not be possible to evolve if any of these properties change significantly. For example, life is possible only in a very narrow temperature interval, just 1-2% between 0 K to surface temperature of Earth. Moreover, the most suitable temperature range for

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[87] Michael Denton, "The Place of Life and Man in Nature: Defending the Anthropocentric Thesis", *Bio-complexity* 2013 (2013): pp.1-15.
[88] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.28.
[89] Michael Denton, "The Place of Life and Man in Nature: Defending the Anthropocentric Thesis", *Bio-complexity* 2013 (2013): pp.1-15.
[90] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), pp.32-34.
[91] Ibid, p.38.

organic chemistry is about $-20°C - 120°C$.[92] Therefore, it is very important to stabilize the climate and regulate the temperature change in organisms.

3.4.2 Fine-tuning of carbon dioxide

Henderson points out that carbon dioxide is an innocuous gas soluble in water, and present therefore wherever there is water throughout the biosphere.[93] Carbon dioxide dissolves in water and will be converted to bicarbonate. This chemical has excellent buffering capacities to maintain the acid-base balance in the body and in the hydrosphere.[94] The acidity of blood is mainly controlled by the acid dissociation constant (pKa). The pKa of carbonic acid is close to 6.1 in blood. Surprisingly, the buffer function of bicarbonate is optimum at pKa = 6.1.[95] Also, this dissolving property makes the oxidative metabolism in organisms and carbon cycle in Earth possible, which are crucial mechanisms in generating energy and sustain life on Earth respectively.[96]

3.4.3 Fine-tuning of oxygen

Oxygen is essential for life to generate energy. Most oxygen must be first dissolved in water in order to undergo metabolisms. Therefore, the solubility of oxygen is an essential property for life. Scientific studies indicate that the solubility of oxygen is fine-tuned. Organisms would not be able to extract oxygen from an aqueous solution for metabolic needs and circulatory or respiratory system would be suppressed if the solubility of oxygen is too low. On the other hand, oxygen would interact with water to produce radicals which is harmful to life if the solubility of oxygen is too high.[97] Interestingly, the best solubility of oxygen should be at temperature range $0 - 50°C$, which coincides with many best working ranges of other essential chemicals for life.[98]

[92] Ibid, p.115.
[93] Lawrence Hendenson, *The Fitness of the Environment: An Enquiry into the Biological Significance of the Properties of Matter* (New York: Macmillan Co., 1913), pp.136-139.
[94] Michael Denton, "The Place of Life and Man in Nature: Defending the Anthropocentric Thesis", *Bio-complexity* 2013 (2013): pp.1-15.
[95] Michael Denton, "The Place of Life and Man in Nature: Defending the Anthropocentric Thesis", *Bio-complexity* 2013 (2013): pp.1-15.
[96] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.134.
[97] Ibid, pp.123-124.
[98] Ibid, p.124-125.

3.4.4 Fine-tuning of protein

Protein is one of the crucial building blocks of life. Its molecule is complex and formed from bonding different amino acid molecules together. To carry out biological functions, protein molecules must necessarily associate intimately with other molecules in cell, termed "ligands".[99] These associations are formed by the weak chemical bonds. Recent studies indicate that the strength of this weak bond is fine-tuned. If the bond is weaker, no protein would bind specifically to any molecule in cell. If the bond is stronger, protein and ligand would be bound so strong never be separated. This would decrease the mobility of protein. As a result, the proteins and all constituents of the cell would be frozen into rigid immobile structures and would be incompatible with cellular existence.[100] This weak bond strength is approximately 1/20 of the strong bond strength. It would be problematic if the strength is 1/2 or 1/200 of the strong bond strength.[101]

3.4.5 Fine-tuning of DNA

One of the most important discoveries in Life Science is the discovery of DNA. DNA has a double helical structure to store genetic information for life. It is a polymer made up of four subunits called nucleotides. Each nucleotide consists of a phosphate, a ribose sugar, and one of four bases: guanine (G), cytosine (C), thymine (T), or adenine (A). The DNA is composed of two strands, and the strands are twisted around one another to form the double helical structure.

There exist some fine-tuned properties of DNA that make life possible. First of all, it is relatively stable in a solution, even at room temperature for months. As a result, the DNA cannot be broken down easily by chemicals.[102] Although the two strands bind strongly, their affinity is not so great. This makes dissociation of the two strands possible during replication. The binding force strength between two strands is fine-tuned for biological function. Stronger or weaker of the force would make both strands immobile or fall apart respectively.[103] No biological functions would be effective if either case happened.

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[99] Ibid, p.182.
[100] Ibid, p.183.
[101] Ibid, p.183.
[102] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.153.
[103] Ibid, p.153.

3.5 Combination of primary and secondary fine-tuning

Generally speaking, all the above examples of secondary fine-tuning require fine-tuned fundamental constants of electromagnetic force and strong force. All these properties are totally independent of the requirement of the existence of elements. Therefore, the fine-tuned ranges of fundamental constants for existence of anthropic elements coincide with the fine-tuned ranges of fundamental constants for the essential properties for life of anthropic molecules. In fact, the values of the fundamental constants in the primary fine-tuning would probably restrict the scope of the secondary fine-tuning, which make the secondary fine-tuning less likely. If the probabilities of getting the primary and secondary fine-tuned values are $P(p)$ and $P(s)$ respectively, the conditional probability $P(s|p)$ would be less than $P(s)$. Therefore, the total probability of getting both primary and secondary fine-tuned values is

$$P(s \text{ and } p) = P(s|p) \times P(p) \leq P(s) \times P(p),\tag{3.4}$$

Since P(s) and P(p) are very small, P(s and p) is an extremely small value. As a result, the secondary fine-tuning further narrows down the life-allowing parameter space. It is highly improbable for life to exist if these values were chosen randomly. In other words, it seems that we are so lucky to be living in this universe.

3.6 Arguments against the existence of fine-tuning

All the above information indicates that fine-tuning of some physical constants is required for life. The life-allowing parameter space that includes N, ε, Ω, λ, Q and D is extremely small. In this section, I will briefly describe some arguments against the fine-tuning thesis.

3.6.1 Zooming argument

The parameter space is not absolute, but depends on the scales of the axes. For example, the life-allowing region shown in Figure 1 depends on the scale you choose. You can make it look big by deftly choosing the limits of the plot. You could also distort parameter space using logarithmic axes or any other arbitrary axes.[104] Therefore, argument becomes:

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[104] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.

P1: The parameter space depends on the scale of the axes.

P2: The probability of getting the life-allowing region depends on the area of the parameter space.

P3: The axes are arbitrary.

C1: The probability of getting the life-allowing region is indeterminate.

C2: Fine-tuning argument is a fallacy.

In other words, this argument indicates that you can always zoom-in to the figure and get a larger probability. The life-allowing region will be much larger if you zoom-in on its neighbourhood.
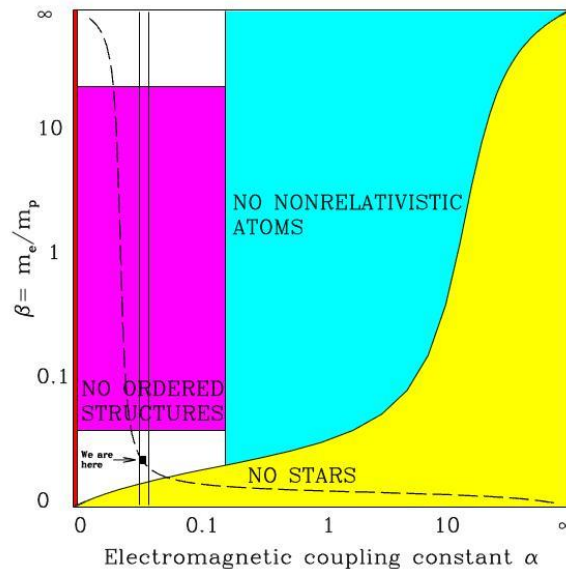
Figure 1. The parameter space for electron mass to proton mass ratio and electromagnetic coupling constant. The life-allowed region is the small black rectangle.[105]

In fact, the premises P1 and P3 are correct. However, the premise P2 is not correct. When you zoom into the parameter space, the life-allowing region will also be enlarged. The probability is area of the life-allowing region A divided by the whole possible parameter space A_w. Making A_w larger will simultaneously make A larger to the same extent. Therefore, the ratio A/A_w would not change if you choose any other arbitrary axes.

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[105] http://blog.focus.it/quantum-beat/2012/02/27/la-regolazione-fine-dell-universo/fine-tuning/

3.6.2 Coarse-tuning objection

Some may argue that the total parameter space A_w should be infinitely large as there is no limitation on the values of the physical constants. Therefore, no matter how large the A is, the probability of getting the life-allowing region must be close to 0. For example, we know that $0.006 \leq \varepsilon \leq 0.008$ for life-permitting universe. Since the total parameter space A_w is infinitely large, the probability of getting this range of ε is zero. Even if the life-permitting universe needs $0.006 \leq \varepsilon \leq 6000$, the probability of getting this range is also zero because the total parameter space A_w is infinitely large. Therefore, no matter it is fine-tuning or coarse-tuning, the probability is the same – zero. Should we still care about the fine-tuning problem?

The above argument is based on the logical interpretation of probability and the Principle of Indifference - treating all equal intervals for all parameters as equally probable. T. McGrew, L. McGrew and Vestrup state that since the possible sets of values for the fundamental constants are unbounded, it is non-normalizable. The probabilities make sense only if the sum of the logically possible disjoint alternatives adds up to one.[106] Therefore, either each possibility will be assigned probability zero, in which case the total will be zero, or each possibility will be assigned some fixed positive probability, in which case the total will be infinite.[107] Since the definition of the fine-tuning probability is not clear, the fine-tuning argument is not well-defined.

To address this problem, Koperski suggests that the probability of getting the fine-tuned values can still be defined by considering the ratio of life-permitting region A to the total parameter space A_w:

$$P = \frac{A}{A_w}, \tag{3.5}$$

if the numerator does not diverge.[108] However, it is possible that A_w is not an actual infinity. In the Hilbert's Hotel paradox, even though the hotel has no vacancies, a large number of guests can be accommodated by having everyone move up a fixed number of rooms. Any countable number of guests could just as easily be fit into this "full" hotel.[109] However, it is a contradiction that a "full hotel" can still be occupied by many more guests. Craig thinks that the Hilbert's Hotel paradox proves that actual

[106] Timothy McGrew, Lydia McGrew and Eric Vestrup, "Probabilities and the Fine-Tuning Argument: a Sceptical View," *Mind*, 110 (2001): pp. 1027-1037.
[107] Bradley Monton, "God, Fine-tuning, and the Problem of Old Evidence," *British Journal of Philosophy of Science* 57 (2006): pp.405-424.
[108] Jeffrey Koperski, "Should we care about Fine-Tuning?" *The British Journal for the Philosophy of Science* 56 (2005): pp.303-319.
[109] Ibid.

infinities do not exist.[110] The view is that infinity (∞) is merely a mathematical device but not physically real in nature. If actual infinities do not exist, then the probability defined in Equation (3.5) can be possible because the probability is normalizable.

Although the actual infinities do not exist in our real nature, the coarse-tuning problem still exists if the area A_w is extremely large. This is because we do not have a clear boundary to constrain how small of the life-permitting region is said to be fine-tuned. In the following, I suggest a useful way so that the coarse-tuning objection can be addressed. Suppose we can really define the probability of getting the fine-tuned values. Is fine-tuning a problem if we get $P = 0.1$ only? What if we get $P = 0.01$, do we need to explain it? According to the definition of fine-tuning in chapter 1, the phenomenon can be regarded as a fine-tuning problem when P is small. How small should it be? From the above example, if the life-permitting universe needs $0.006 \leq \varepsilon \leq 6000$, the probability of getting this range is also very small, probably smaller than 0.00001, because the actual parameter space is very large. However, we know that the fine-tuning problem is more serious if the range of ε is much smaller. Therefore, it is not very useful in defining the problem by using the probability defined in equation (3.5). In other words, the actual value of P is not important. The most important is how to assess whether fine-tuning problem is serious or not (the degree of seriousness). Therefore, Holder suggests that the probability should be regarded as quantifying the rational degree of belief rather than proportions in an ensemble.[111] Suppose a value S is defined to measure the "seriousness of the fine-tuning problem" (S is large means that the fine-tuning problem is very serious). It is obvious to note that S is large when A is small and vice versa. Let's suggest an intuitive relation

$$S \propto \frac{1}{A}. \tag{3.6}$$

This relation depends on A, but not A_w. The proportionality constant can be any arbitrary number as the value S is arbitrary. If the life-permitting range is small, then we have small A and large S. Therefore, it is possible for us to distinguish the coarse-tuning and fine-tuning by comparing their respective values of S.

Moreover, one can define a ratio R, which is defined as the ratio of possible variance $\Delta\varepsilon$ (the variation of the life-permitting range) to the mean measured value ε_0:

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[110] Please refer to William Craig, 'The Kalam Cosmological Argument', in Chad Meister (ed.), *The Philosophy of Religion Reader* (NY: Routledge, 2008), chapter 18 and Jeffrey Koperski, "Should We Care about Fine-Tuning?" *The British Journal for the Philosophy of Science* 56 (2005): pp.303-319.

[111] Rodley Holder, *God, the Multiverse, and Everything: Modern Cosmology and the Argument from Design* (VT: Ashgate, 2004), p.50.

$$R = \frac{\Delta \varepsilon}{\varepsilon_0} . \tag{3.7}$$

For example, for our universe, $\Delta \varepsilon = 0.001$ and $\varepsilon_0 = 0.007$ for life-permitting. Therefore, the ratio is $R = 0.142$. We know that S would be large if R is small. We can now relate the probability of getting the fine-tuned value by using R such that $P \propto R$. Although we do not have the actual value of P, we can qualitatively describe the fine-tuning problem by using the value of R. Therefore, when we say that the probability (rational degree of belief) of getting the life-permitting range is small, that means the variable range is small, and thus the ratio R is small too. In general, we can have the following relation:

$$P \propto R \propto \frac{1}{S} \propto A . \tag{3.8}$$

From the above relation, it is not necessary for us to consider the A_w and the actual value of P. More importantly, instead, we should consider how small the variance of the anthropic value is. In other words, we should be surprised when we notice that the change in the ratio of the gravitational force to the electromagnetic force by as little as 1 part in 10^{40} would have dramatic consequences for the types of star which occur, but not asking how large is the parameter space.[112] Also, we can arbitrarily define the fine-tuning phenomenon as serious if the corresponding R is smaller than a certain value, says, 10. By using this criterion, one can determine a constant is fine-tuned or coarse-tuned. Regarding all the fine-tuned fundamental constants discussed in the above sections, all R values are smaller than 10. Certainly one can arbitrarily define the fine-tuning problem as serious when R is smaller than 10^{-1000}. However, it can only be justified subjectively by our experience and knowledge. In fact, most scientists and philosophers have already claimed that the current fine-tuning problem is serious for many fundamental constants. A consensus has already been reached by considering a reasonable value for R. Although R is a better indicator for the fine-tuning problem, we will still say that a constant or condition is fine-tuned because the probability P of getting such constant or condition is small.

3.6.3 Objection to Principle of Indifference

As mentioned above, the discussion in the section 3.6.2 is based on the Principle of Indifference. Is this principle right at all? Monton thinks that we need not rely on the Principle of Indifference.[113] It is open for us to assign zero probability to some possible values of constant and non-zero probability to other

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[112] Ibid, p.35.
[113] Bradley Monton, "God, Fine-tuning, and the Problem of Old Evidence," *British Journal of Philosophy of Science* 57 (2006): pp.405-424.

possible values. This suggestion is trying to solve the non-normalization problem in probability. However, what is the criteria for choosing some regions and discard some other regions? Some argue that there may be a probabilistic density distribution function f that characterizes the probability such that it is finite for infinite large parameter space:

$$\int_0^\infty \dots \int_0^\infty f(x_1, x_2, \dots, x_n)\, dx_1 dx_2 \dots dx_n = \text{finite} , \tag{3.9}$$

where x_1, x_2,…,x_n are the possible fundamental constants in the parameter space. For example, Jaynes suggests the probabilistic distribution function can be obtained by using the "Principle of Maximum Entropy".[114] This principle can be applied in cosmology to determine some relations between different fundamental constants. These relations indicate that the probabilities of getting these fundamental constants are dependent on each other. Therefore, if it is true, the Principle of Indifference may not be a good approximation to the problem. However, we still do not have enough knowledge to determine the exact probabilistic density distribution f and many of the derived distributions are highly model-dependent.[115] Holder states that the measures derived from Jaynes's principle are not unique. There is an inherent ambiguity.[116]

Therefore, the Principle of Indifference is the most intuitive and basic one that is based on our prior knowledge. For example, we often assign a uniform probability for a die that looks perfectly normal (even if it is loaded).[117] Similarly, it is always possible that the "cosmological dice" may be loaded. However, according to our general beliefs that our universe is isotropic and homogeneous, it is reasonable for us to assume that the Principle of Indifference applies.

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[114] Rodley Holder, *God, the Multiverse, and Everything: Modern Cosmology and the Argument from Design* (VT: Ashgate, 2004), pp.184-188.
[115] Jeffrey Koperski, "Should We Care about Fine-Tuning?" *The British Journal for the Philosophy of Science* 56 (2005): pp.303-319.
[116] Rodley Holder, *God, the Multiverse, and Everything: Modern Cosmology and the Argument from Design* (VT: Ashgate, 2004), p.188.
[117] Jeffrey Koperski, "Should We Care about Fine-Tuning?" *The British Journal for the Philosophy of Science* 56 (2005): pp.303-319.

3.6.4 Arguments from Stenger

Particle physicist V. J. Stenger wrote a book "The fallacy of fine-tuning" to present his arguments against the fine-tuning thesis.[118] In the following I will briefly describe some of his important arguments on fine-tuning and respond to them.

In his book, he says "*They make fine-tuning claims based on the parameters of our universe and our form of like, ignoring the possibility of other life-forms*". This statement is not true. We can predict by science that in which conditions life would exist. For example, if some physical constants are changed such that hydrogen atoms cannot be formed. In our understanding, if water and hydrocarbon molecules cannot be formed, this also makes life impossible. As mentioned above, silicon-based life may be possible to exist. However, this possibility also depends on the fine-tuning of physical constants such as N, ε, etc. It is always logically possible that there exists some unknown atomic formation mechanisms in the nature. But we cannot falsify the fine-tuning argument by pointing to some unknown mechanisms. Based on our current knowledge, there is no other anthropic elements' formation mechanism other than that we have discussed above.

Second, he says that the strength of the electromagnetic force and gravitational force cannot be universally defined. They all depend on some more fundamental constants such as strong coupling constant, mass of proton and electron. All these values can be derived from well-established physics. Therefore, no fine-tuning is required for these forces. These statements are partly correct. You can always write the strength of these forces in terms of other constants such as proton mass and force coupling constants. However, these constants have to be fine-tuned too if you transform in this way. Stenger mentions that the Higgs' mechanism and gauge theory can naturally get all the masses of particles and force coupling constants respectively. This is not correct! It may be true that Higgs' mechanism can generate the masses of particles, but this mechanism requires the unification of weak and strong forces, which is not clearly known nowadays. It is still very far from predicting these masses from physical laws alone. Actually, Stenger agrees that "*Theories in which the electroweak and strong forces are unified are called the grand unified theories (GUTs), but none of these are established empirically*".[119] In fact, what he wants to argue is that "*… for my purposes I do not need to know that theory. I just have to show that we have a plausible explanation for the force strengths, and the burden is on the theist to show why these are necessarily fine-tuned*".[120] Therefore, he argues against the fine-tuning thesis by raising some

[118] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011).
[119] Ibid, p.188.
[120] Ibid, p.187.

unknown mechanisms. However, the burden of proof should be on Stenger's side because he needs to provide the details of these unknown mechanisms. Otherwise, everything can be doubted in this way because there is always some unknown possible explanation. Besides, the calculations of proton and neutron mass require the mass of quarks. Recent studies indicate that the quark mass is also fine-tuned.[121] This means that the fine-tuning of proton and neutron mass is just displaced by other fine-tuned constants.

Stenger states that "*All the claims of the fine-tuning of the forces of nature have referred to the values of the force strengths in our current universe. They are assumed to be constants, but, according to established theory (even without supersymmetry), they vary with energy*".[122] It is true that the constants are related to energy. However, the constants at high energy levels are irrelevant to the fine-tuning problem as fusion in stars etc. are at low energy regime.[123] Besides, the relation between the constants and energy involves some other numbers which would be needed to fine-tune.[124] Again, the fine-tuning problem is just displaced by another problem.

Stenger also makes a general argument against the fine-tuning problem by stating that "*The examples of fine-tuning given in the theist literature ... vary one parameter while holding all the rest constant. This is both dubious and scientifically shoddy. As we shall see in several specific cases, changing one or more other parameters can often compensate for the one that is changed*".[125] This statement means that when we say the allowing range of ε is 0.006-0.008, we need to consider the other constants unchanged. He gives an example that the variation of the strong coupling constant should also be involved in considering the life-allowing region. See Figure 2, the life-allowing parameter space seems to be larger when we include one more parameter α (the strong coupling constant).[126] Therefore, a wider range of the fine-tuned constant is obtained if another constant is also allowed to vary. This is a delusion. The fact is that if you involve more parameters, on the contrary, the probability of the life-allowing region would be smaller. The probability calculated by varying only one parameter is actually an overestimation of the probability

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[121] Evgeny Epelbaum et al., "Viability of Carbon-Based Life as a Function of the Light Quark Mass," *Physical Review Letters* 110 (2013): 112502.

[122] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.189.

[123] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.

[124] Ibid.

[125] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.70.

[126] Ibid, p.185.

calculated using more parameters. [127] Barnes illustrates this by assuming the full life-permitting criterion that defines the area is

$$1 - e \leq \frac{\varepsilon}{\varepsilon_0} \leq 1 + e \qquad (3.10)$$

where e is a small number quantifying the allowed deviation from the value of ε in our universe with N fixed and ε_0 is the number that we have actually measured.[128] Then the probability of a life-permitting universe is 2e if we only consider ε. If we calculate the probability by involving one more parameter N, the probability of getting the life-permitting region (the triangular area) for $N \leq N_0$ and $\varepsilon \leq \varepsilon_0(1+e)$ becomes (see Figure 2)

$$P = \frac{\frac{1}{2}N_0\varepsilon_0[(1+e)-(1-e)]}{N_0\varepsilon_0(1+e)} \approx e , \qquad (3.11)$$

which is smaller than just considering one parameter. This probability would be much smaller if we consider all possible N and ε (we haven't considered $N > N_0$ and $\varepsilon > \varepsilon_0(1+e)$). The reason is that when we open up more parameter space in which life can form, but simultaneously also open much more parameter space in which life cannot form. [129] In fact, Rees and Tegmark have already considered multiple parameters in his argument of fine-tuning problem instead of varying only one parameter.[130]
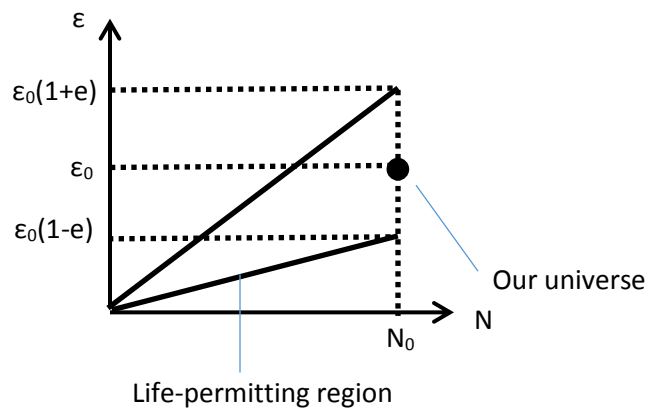
Figure 2. The allowed parameter space for two parameters N and ε.

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[127] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.
[128] Ibid.
[129] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.
[130] Max Tegmark and Martin Rees, "Why is the Cosmic Microwave Background Fluctuation Level 10 -5?" *The Astrophysical Journal* 499 (1998): pp.526-532.

Stenger also comments on the traditional fine-tuning resonant energy level of carbon atom in nuclear fusion. He suggests that the resonant energy level is not fine-tuned at 7.65 MeV by quoting a research result from Livio et al. which showed that the energy level can be increased by as much as 0.277 MeV to 7.933 MeV.[131] Also, an excited state anywhere from this energy down to near the minimum energy would produce adequate carbon for life.[132] Therefore, the possible range of the resonant energy level should be about 7.4 MeV-7.9 MeV. For the other resonant energy level of oxygen at 7.12 MeV, he just quotes an argument from physicist Craig Hogan which states that this resonant energy level is a natural result of a symmetry rather than a tuning.[133] Therefore, four helium atoms are tightly bound because of its symmetry in quantum mechanics, which does not produce similar resonant states. No fine-tuning is required to produce sufficient carbon for life.[134] For the first argument, the problem of fine-tuning may be alleviated to some extent due to a larger possible range obtained. However, this is just a few percent variations, which is still quite narrow range. For the second argument, it is just a rough idea suggested by Stenger. Oberhymmer et al. have performed rigorous calculations based on this theory and suggested that fine-tuning is required:[135]

"*Even with a change of 0.4% in the strength of force, carbon-based life appears to be impossible, since all the stars then would produce either almost solely carbon or oxygen, but could not produce both elements.*"

Therefore, the arguments suggested cannot solve the fine-tuning problem.

All the above arguments made by Stenger concern mainly the constants N and ε. Stenger continues his arguments and claims that the matter content Ω, initial quantum fluctuations Q and cosmological constant λ need not to be fine-tuned.

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[131] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.171 and M. Livio, D. Hollowell, A. Weiss and J. Truran, "The Anthropic Significance of an Excited State of ^{12}C", *Nature*, 340(1989): pp.281-284.
[132] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.171.
[133] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.172 and C. Hogan, "Why the Universe is Just So," *Reviews of Modern Physics* 72 (2000): pp.1149-61.
[134] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.172.
[135] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.

For matter content Ω, he invokes the inflation model to address the fine-tuning of Ω.[136] As mentioned above, this is just displaced by another fine-tuned value in the inflation model. Therefore, this argument is not valid.

For the initial quantum fluctuations Q, Stenger states that "*heroic attempts by the best minds in cosmology have not yet succeeded in calculating the magnitude of Q, inflation theory successfully predicted the angular correlation across the sky that has been observed*."[137]This is wrong. A given inflationary model will predict Q, and it will only predict a life-permitting value for Q if the parameters of the inflation potential are suitably fine-tuned.[138] Further to this argument, Stenger suggests that a Cold Big Bang model can avoid the fine-tuning of Q. The Cold Big Bang model suggests that our universe starts at zero temperature and all particles are in thermal equilibrium. If our universe is expanding according to the Cold Big Bang model, then life is still possible when the initial quantum fluctuation is less than 10^{-7}.[139] Therefore, a wider range of Q is obtained and fine-tuning is not required. It is commonly believed that the expansion of our universe is according to Hot Big Bang scenario but not the Cold Big Bang. The Hot Big Bang suggests that our universe starts with high temperature after the inflation. This model is strongly supported by observational data such as the cosmic microwave background radiation and the observed ratio of helium to hydrogen in the universe. Stenger actually agrees with that by stating "*This is now widely accepted as the standard cosmological model because of its good agreement with observational data. That does not mean that all alternatives have been ruled out of consideration*".[140] This is true only if the alternatives have been supported by some strong evidence. A proposition with no evidence should be ruled out when compared with another highly supported scenario. Unfortunately, there is no evidence to support the Cold Big Bang model although it is logically possible. Since Stenger knows that the Cold Big Bang model cannot explain the isotropic cosmic microwave background radiation, he therefore suggests the existence of Population III objects in the early universe. These objects can help to thermalize the background and yield the required observations.[141] Scientists believe that Population III stars (first generation star) might exist in the early time, but this is not enough to show that the cosmic microwave background radiation detected can be matched with this scenario. Besides, this suggestion cannot explain

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[136] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), pp.281-282.
[137] Ibid, p.206.
[138] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.
[139] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.210.
[140] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.209.
[141] Ibid, p.210.

the relative abundance of hydrogen and helium in the universe. Suggestions of such unverified models (Cold Big Bang model and Population III objects) should not be treated as arguments to falsify the fine-tuning problem.

For the cosmological constant λ, Stenger shows by calculations that current quantum theories cannot obtain this value.[142] In quantum physics, vacuum is not really vacuum but full of creation and annihilation of virtual particles. Quantum mechanics show that the ground state energy is not zero for vacuum. This is known as the vacuum energy. However, the calculated λ by using this vacuum energy is much larger than the observed one.[143] Then, Stenger claims that "*the standard calculation of this parameter is grossly wrong and should be ignored. Viable possibilities exist for explaining its value, and until these are all ruled out, no fine-tuning can be claimed*".[144] Barnes replies this by stating that a calculation is wrong does not show that the cosmological constant is not fine-tuned.[145] The calculation being much larger than the measured value may be due to some cancelations by virtual bosons and fermions which we didn't take into account. [146] This is already known by most particle physicists. Stenger argues that the cosmological constant should be zero by suggesting the existence of a "ghost particle" conjectured by Sakharov.[147] However, this suggestion has not been confirmed by any experiments and observations. If the cosmological constant is zero, then we need an explanation for the accelerating universe. Stenger suggests using the theory of quintessence, which is another form of energy with negative pressure. There exists a parameter w to distinguish the cosmological constant (w = -1) and the quintessence (-1 < w < 0). Although this theory has not been ruled out yet, recent studies from observation indicate that w = -0. 99 ± 0.06, which strongly favours the model of cosmological constant but not quintessence.[148] Even if the theory of quintessence is true, quintessence models must be also fine-tuned in exactly the same way as the cosmological constant.[149] Therefore, the fine-tuning problem for λ still exists.

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[142] Ibid, p.282.

[143] Ibid, p.220.

[144] Ibid, p.284.

[145] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.

[146] See Bradley Carroll and Dale Ostlie, *An Introduction to Modern Astrophysics* (San Francisco: Pearson, 2007), p.1241.

[147] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.222.

[148] Adrian Cho, "What is Dark Energy?" *Science* 336 (2012): pp.1090-1091; S. Postnikov, M. G. Dainotti, X. Hernandez, and S. Capozziello, "Nonparametric Study of the Evolution of the Cosmological Equation of State with SNeIa, BAO, and High-redshift GRBs" *Astrophysical Journal* 783 (2014): 126 (11 pp.).

[149] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.

In a chapter of his book, he writes down some important constraints for life and allows four free parameters (the coupling constant for electromagnetic force α, the strong coupling constant $α_s$, the mass of electron and proton) to vary. By using simulations, he discovers that a considerable amount of life-permitting universe is generated. The variation of parameters can be as large as ten times or two orders of magnitude.[150] Therefore, he claims that fine-tuning is not necessary for life. In fact, he does not include all the constraints. He includes 14 constraints in his calculations, but not the constraints of molecular stability, proton stability, pair creation of electrons, bound state of diproton, stability of deuteron, stability of carbon production, etc.[151] Many more constraints should be included in the calculations. The life-allowing parameter space would be much larger even if you just omit one constraint. Some careful studies about these four parameters have been carried by Tegmark, which indicate that only an extremely tiny parameter space is allowed for life.[152] Some more arguments such as using Bayesian method to disprove the fine-tuning problem have been suggested by Stenger. I will discuss these arguments in later chapters.

To conclude, none of the suggested arguments from Stenger seem reasonable to address the fine-tuning problem. In fact, the existence of fine-tuning is widely accepted in the scientific community. Barnes quotes many famous scientists that support the idea of a fine-tuned universe for life.[153] Even if we accept all the arguments from Stenger that the existence of stars and anthropic elements need not be fine-tuned, he still needs to explain the secondary fine-tuning in the nature, such as the thermal properties of water and carbon dioxide. All these constraints would limit these physical constants to a narrow region. In the later chapters, I will continue to discuss some more constraints on the initial conditions and fundamental constants, especially in our environment and biological evolution. That will make the fine-tuning problem even more seriously.

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[150] Victor Stenger, *The Fallacy of Fine-Tuning: Why the Universe is not Designed for Us* (NY: Prometheus Books, 2011), p.244.
[151] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): pp.529-64.
[152] Ibid.
[153] Ibid.

Chapter 4   Fine-tuning of the initial conditions and life formation

In the previous chapter, I have reviewed the facts about some important fine-tuned constants in nature. Some of the constants such as N, ε and masses of elementary particles are related to physical laws. Strictly speaking, all primary and secondary fine-tuning are based on four fine-tuned fundamental constants of forces (electromagnetic, gravitational, weak and strong forces). Nevertheless, these constants are not the only way to govern the consequences. All subsequent motions of particles are governed by two things: physical laws and initial conditions. Basically, given some required initial conditions, physical laws can tell you all the subsequent motions. For example, in Newtonian mechanics, the motions are mainly governed by Newton's second law, which is a second order differential equation:

$$F = m\frac{d^2x}{d^2t} \tag{4.1}$$

where F, m, x, t are the force on the particle, mass of the particle, displacement function (position) and time respectively. Mathematical theorem states that at least two initial conditions should be given to a second order differential equation so that a subsequent motion can be well-defined. Usually, given the initial position and velocity of a particle, the future trajectory of the particle can be derived. Therefore, initial conditions are very important in knowing the particle behaviors. In the evolution of our universe, the primordial fluctuation Q, matter content Ω and the cosmological constant λ can be regarded as the initial conditions.

Life is highly dependent on the environmental changes. Our Earth is not habitable if there are too much cosmic rays attacking life or the surface temperature of the Earth is a few Celsius degrees higher. All the environment changes are governed by physical laws and initial conditions. A slight change in the initial conditions and physical laws may give rise to a drastic change in the environment, in which life cannot live anymore. For example, Venus is a similar planet to Earth, in many physical compositions. Its temperature is about 400℃ due to severe greenhouse effect. Obviously, no life known can be living in such environment. In addition, evolution of life also sensitively depends on the environmental changes. For example, mammals become a dominant force in nature because the fall of dinosaurs due to drastic change in environment. The evolution series would be greatly altered if there were no such environmental changes in the past. Therefore, initial condition is a very important parameter that should be considered in life evolution.

In this chapter, we will describe the importance of the location of our Earth in Milky Way and how the initial conditions caused changes in the environment. It is not necessary to trace all the conditions back to the beginning of the universe, even though they actually affect the initial conditions of the Earth. All the

initial conditions of the universe such as Ω (or the inflation field), λ and Q, have been discussed in the previous chapter. Here we mainly examine whether fine-tuning exists in the initial conditions at the beginning of the Earth. In the following, by using the fact that initial conditions can sensitively affect the environment, I will show that the beginning of life and biological evolution are fine-tuned process. Here, as well as the previous chapter, we simply assume that all life forms come from natural processes. In this chapter, I call the environment that is hospitable for life the "anthropic environment".

4.1 The location of Earth in Milky Way

Recent studies in Astrobiology indicate that the location of a planet in a galaxy is essential for life evolution. The region that a planet located in a galaxy such that it could evolve complex life is called the Galactic Habitable Zone (GHZ). A region that can be regarded as GHZ should have 1) an appropriate supernova rate nearby and 2) appropriate amount of heavy elements.[154]

4.1.1 Supernova rate

As mentioned in the previous chapter, supernovae are essential for life formation because some of the anthropic elements can only be made through supernova processes. However, the nearby supernova rate cannot be too high. Since supernovae would produce a large amount of cosmic rays, which can deplete our ozone layer so that our Earth would be exposed to the sun's radiation. This effect is called the Supernovae Sterilization. If the rate of nearby supernovae is as large as 4 times the solar neighborhood rate, no life would be formed in our Earth.[155] Therefore, the location of our Earth is fine-tuned such that the supernova rate is not too high to prohibit life.

4.1.2 Metallicity

The amount of heavy elements (metallicity) in a planetary system is also crucial for planet formation. If no habitable planets can be formed, no life would evolve. Recent studies show that no planet can be formed if the metallicity in a system is too low. Also, if the metallicity is too high, only giant planets

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[154] M. G. Gowanlock, D. R. Patton, and S. M. McConnell, "A Model of Habitability Within the Milky Way Galaxy," *Astrobiology* 11 (2011): pp.855-873.
[155] Ibid.

would be produced, and most likely this kind of planets would either be ejected out from the planetary system or fall into the host star due to gravitational attraction. Fortunately, the metallicity of our solar system is suitable for making habitable planet – Earth.

In general, the space of GHZ is not very large in a typical galaxy. To produce life, the host planet must be located inside GHZ and need to satisfy many other different conditions and constraints, which will be discussed below.

4.2 Initial conditions and the environmental changes

Environmental changes and climatic changes are inter-related. All climatic changes are governed by atmospheric science, which is composed by some physical and chemical laws. In principle, given all the initial conditions and scientific laws, all climatic changes can be predicted. However, this is not the actual case. We notice that weather forecasting is not always precise. For example, no one can precisely determine whether any typhoons would be created after one month. The reason is that the physical laws (or the equations) that govern the climatic changes are highly non-linear. Non-linear physics is hardly predictable. Mathematically, the solutions of the non-linear equations are sensitively dependent on initial conditions. Errors would be accumulated, and grow with time. Even a very tiny difference in the initial condition would generate a great difference. The "butterfly effect" – a movement of butterfly's wing may result in a storm in another continent - is one of the famous results related to non-linear physics.

In atmospheric science, we need several initial conditions to specify the climatic change. These conditions include temperature, pressure, density of air, chemical composition of air, velocity of air, energy supply from Sun and water content in air.[156] All these parameters are correlated to each other. In the following, I will briefly review how these conditions should be fine-tuned for life.

4.2.1 Composition of Earth

Our Earth can be roughly divided into two parts: "air" and "ground (including sea)". For the ground, we have 92 naturally found elements, in which 25 are presently considered essential for life.[157] Many of them have been discussed in the previous chapter. No complex life would exist if any one of them is missing.

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[156] Murray Salby, *Physics of the Atmosphere and Climate* (Cambridge: Cambridge University Press, 2012).

[157] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.74.

Some of these elements (carbon, oxygen) are generated from stars' nuclear fusion; and the remaining elements (cobalt, copper) are generated from supernovae. Therefore, only a right amount of explosion from supernovae may result in this specific composition. However, some elements that are not directly essential for life (no role in metabolic reactions) are also crucial for life. They are radioactive elements. In general, radioactive elements are harmful to life because they will emit high energy radiation which can cause cancers. Surprisingly, recent studies show that a considerable amount of radioactive elements are essential to generate life. They provide heat by radioactive decay which can warm the interior of the earth shortly after its formation. This effect causes differentiation of elements in Earth which is important in life evolution because the elements crucial for life can rise to an upper region to increase the probability of generating life. Also, the differentiation process can cause some radioactive elements to float to the surface in order to prevent overheating of the Earth's core. These processes are sensitively dependent on the amount of the radioactive elements. Too much radioactive elements would melt the Earth while no differentiation would happen if there were too few radioactive elements.[158]

Moreover, the presence of radioactive elements helps the movement of Plate Tectonics.[159] The Plate Tectonic movement recycles carbonate and silicate rock through the planet's interior, which can also stabilize the atmosphere over geologic time. The mass of a planet that can undergo plate tectonics should be within 0.5-10 Earth masses.[160]

Besides, our atmosphere is also fine-tuned for life. The atmospheric pressure of Earth in the past was ranging from 500 mmHg – 1000 mmHg, which is quite stable in history. If it were 10 times smaller, body fluids would vaporize at 38℃. If it were 10 times smaller, the respiration would be prohibitive.[161] Therefore, the atmospheric pressure in Earth is fine-tuned. Moreover, one of the most important gases in the air, oxygen, also has some fine-tuned properties. Oxygen provides ozone (O_3), which can prevent harmful ultraviolet radiation to reach the Earth. Also, the oxygen content level (about 21% now) is at a point where risk and benefit nicely balance.[162] If there were too much oxygen (above 25%), very little land vegetation could survive. The probability of a forest fire being ignited by lightning increases by as much as 70 percent for every 1 percent increase in the oxygen level.[163] If there were too little oxygen, not enough energy would be generated for complex life and the diversity of life would be largely decreased. In fact, the oxygen content and atmospheric pressure are controlled by a complex set of feedback

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[158] Ibid, pp.81-83.
[159] Ibid, pp.83-84.
[160] N. Haghighipour, "Binary Stars with Habitable Planets," *American Scientist* 96(2008): p.294
[161] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.128.
[162] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.121.
[163] Ibid, p.121.

mechanisms involving complex interactions between the hydrosphere, biosphere and the material making up the crust of Earth.[164] The interactions between different cycles in different spheres are related to chemical properties of anthropic molecules, which will be discussed later. Moreover, it has been shown that various cycles (oxygen, carbon, and nitrogen cycles) are also regulated by microbes, not just by the physical environment. For example, cyanobacteria produce oxygen and remove hydrogen sulfide. Nitrogen fixing bacteria converts usable nitrogen from air to food.[165] Therefore, not only the physical conditions give a hospitable environment for the microbes, the microbes also help to regulate the environment. In order to make an equilibrium condition, these complicated mechanisms and cycles must be fine-tuned. In fact, since these mechanisms depend on the results of biological evolution, the processes of biological evolution must also be fine-tuned. We will discuss this issue in the next chapter.

Besides these fine-tuned cycles, one of the major fine-tuned values is the mass of Earth. As mentioned above, the mass of Earth controls the plate tectonics. It also controls the oxygen content and the atmospheric pressure. A few percent changes in the mass of Earth may result in a drastic change in the oxygen content and the atmospheric pressure.

4.2.2 Maintenance of constant content

In most metabolisms, oxygen is consumed and carbon dioxide is released. Therefore, one can imagine that oxygen content is decreasing and carbon dioxide content is increasing. If so, after a long history, lacking of oxygen and greenhouse effect would become more serious which make life impossible. Fortunately, it is not the case because some cycles help to balance the content of essential chemicals over the past 4 billion years!

There are many essential cycles to life, such as carbon cycle, oxygen cycle, nitrogen cycle, phosphorous cycle, sulfur cycle, calcium cycle, iron cycle and sodium cycle. Most of the cycles are interdependent.[166] Breaking down of any cycles may result in significant changes in other cycles, which would make life impossible. Moreover, these cycles also depend on temperature, tectonic cycle, etc. These cycles would generate new essential chemicals by some feedback mechanisms or chemical processes when these chemicals were consumed by organisms. For example, the content of carbon dioxide is regulated by a negative feedback system via the weathering of silicate rocks. The silicate rocks would increase the

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[164] Ibid, p.129.
[165] Lynn Margulis and Michael Dolan, "Gaia: Cosmic Beginnings, Nonhuman Ends," in *Cosmic Beginnings and Human Ends*, eds. Clifford N. Matthews and Roy A. Varghese (Illinois: Open Court Publishing, 1995), p. 192.
[166] Michael Denton, *Nature's destiny* (New York: The Free Press, 1998), pp.88-89.

uptake rate of the carbon dioxide if the carbon dioxide content is increased. This helps to stabilize the carbon dioxide content and the temperature of the Earth.[167]

Interestingly, cycles stabilize the chemical content in Earth, but also allow some variations, which are not fatal to life. I call it "globally stable but locally fluctuating". These fluctuations and variations do not overwhelm the overall stability, but provide enough forces to generate diversity. Without these variations, no diversity would be produced and evolution might not be possible (to be discussed in the next chapter). However, too much variation would make the environment unstable for life. Therefore, these cycles, the fundamental constants and initial conditions involved, are fine-tuned.

4.3 Origin of life

In the 19th century, scientist Louis Pasteur showed that if a broth or solution was properly sterilized and excluded from contact with micro-organisms, it would remain sterile indefinitely. This experiment disproved that life could be generated spontaneously.[168] If it were the case, where did the first life come from? In the bottom-up scenario, the first life evolved from some simple molecules by natural processes. It is known as chemical evolution. According to this scenario, all major building blocks of life such as protein, RNA, DNA were formed from more basic chemicals by chemical reactions. A collection of these basic chemicals is called the prebiotic soup. These chemicals include water, lipids, sugars, amino acids, phosphate and nitrogenous bases. Besides natural processes, some believe that the first life could be made by some other intelligent life or supernatural being. In the following, I will mainly follow the bottom-up scenario and discuss the probability of getting the first life.

4.3.1 Prebiotic soup

It is commonly believed that only simple molecules (e.g. water, oxides) were formed when the formation of Earth was just complete. More complex molecules such as amino acids and phosphate need to be generated from chemical processes. In the early 1950s, Stanley Miller generated some important complex molecules that are essential for life by experiment. He used a flask of water to represent the primordial ocean and another flask containing water vapour, methane, ammonia and hydrogen to represent the

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[167] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.90.
[168] Mark Sephton, "Origin of Life", *An Introduction to Astrobiology,* eds. Iain Gilmour and Mark Sephton (Cambridge: Cambridge University Press, 2003), p.1.

primordial atmosphere. By using a continuous electrical discharge that represents lightning, the gases interact and reaction products would be formed. One week later, he found that amino acids were formed after the experiment.[169] However, recent geochemical evidence shows that the primordial atmosphere should contain carbon dioxide, nitrogen, water vapour and oxygen, but not the gases used in the Miller's experiment.[170] Models of atmospheric evolution indicate that a methane- and ammonia-rich reducing atmosphere would be easily destroyed by sunlight. Therefore, the synthesis proposed by Miller is highly improbable. Even if the experimental result is right, many amino acids generated (e.g. pipecolic acid) from the experiment are not found in proteins on Earth.[171] Now, many scientists believe that the prebiotic soup could not be generated from the primordial atmosphere through chemical processes because of its extremely low probability. Therefore, the initial conditions or the environment must be extremely fine-tuned in order to create the prebiotic soup from simple molecules naturally.

Another theory states that the prebiotic soup is mainly generated from extra-terrestrial objects. In 1969, a town called Murchison in Australia was shattered by a carbon-rich meteorite.[172] Scientists discovered that this meteorite contained organic molecules including amino acids, lipids, monosaccharides, phosphate and nitrogenous bases.[173] It indicates that the early Solar System must have been a place in which organic chemistry was taking place. However, there are still some essential organic molecules for life that could not be found in the Murchison meteorite, such as polysaccharides, proteins, nucleic acids.[174] These large organic molecules might be polymerized by some mechanisms that would achieve the properties of life.[175] By using statistics, we can estimate the minimum time to accumulate enough organic materials for life. The total accumulated carbon content is given by

$$x_c = \sum_i P_i a_i m_i t \tag{4.2}$$

where P_i, a_i, m_i are the impact probability, carbon content ratio, mass of particular meteorite i respectively, and t is the estimated time. The value of a_i is well known, and the values of P_i and m_i can be obtained from statistics. The mass of carbon in the biosphere is about 6×10^{14} kg and the estimated $\sum_i P_i a_i m_i$ is 0.32×10^6 kg.[176] Therefore, the required time is about 1.9 billion years, which is quite close to the first

[169] Ibid, p.19.
[170] Stephen Meyer, *Signature in the Cell* (New York: HarperOne, 2009), p.224.
[171] Mark Sephton, "Origin of Life", *An Introduction to Astrobiology,* eds. Iain Gilmour and Mark Sephton (Cambridge: Cambridge University Press, 2003), p.21.
[172] Ibid, p.20.
[173] Ibid, p.23.
[174] Ibid, p.23.
[175] Ibid, p.20.
[176] Ibid, pp.24 and 304.

life appeared since the Earth formed (about 1 billion year). Many scientists start to believe that the prebiotic soup or life may come from the extra-terrestrial objects. In the above calculation, we can notice that the probability P_i is a fine-tuned value. If P_i is ten times smaller, the required time t for carbon accumulation would be 19 billion years, which is impossible for life because the Sun is already dead. If P_i is ten times larger, our Earth would be too easy for impact from meteorites, which is fatal for most complex life. This fine-tuned P_i mainly depends on the size and the relative gravitational strength of Earth. Moreover, the initial conditions of the Solar System have to be fine-tuned. For example, the location of the meteorites should not be too close to or too far away from Earth. Otherwise the impact probability would be either much higher or smaller. Also, the mass of the meteorites should not be too large or too small. Otherwise, either extinction of life would be happened or no life would be created.

To conclude, in order to generate the prebiotic soup, there are two possible scenarios. Both scenarios need to have some fine-tuned conditions.

4.4 Macro-organic molecules

Scientists believe that the macro-organic molecules, such as protein, RNA, DNA, etc. could be formed from the prebiotic soup. However, the actual mechanisms are very poorly understood. It is because some specified structures make these molecules difficult to be produced naturally. Some fine-tuned conditions must be needed. In the previous chapter, I have outlined some fine-tuned chemical properties of protein and DNA molecules. In the following, I will briefly describe the formation of the specified structures of three most important macro-organic molecules for life, protein, RNA and DNA.

4.4.1 Protein

Proteins are polymerized amino acids. A very small protein can contain about 150 amino acids, which has 10^{195} possible sequence combinations.[177] In general, not all the amino acids can form chains by chemical bonds to become protein molecules. Only for those amino acids that can form a peptide bond would fold into a protein. When amino acid mixtures are allowed to react in a test tube, the probability of getting

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[177] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), p.205.

peptide bonds is about ½.[178] In other words, for simple protein that contains 150 amino acids, the probability of getting this protein by random is $(1/2)^{149} = 10^{-45}$, which is very low.[179]

Moreover, molecules with identical chemical formulae may have difference structural arrangements. For example, in amino acids, there are two different forms, left-handed and right-handed. This chemical property is called chirality.[180] Out of 20 amino acids used in forming protein, 19 can exist as left-handed and right-handed forms. In the absence of life, the chemical reactions from amino acids generally create equal numbers of left- and right-handed forms. However, what is remarkable is that all life on Earth uses only the left-handed forms of amino acids for producing proteins. [181] Therefore, the probability of creating a protein with 150 amino acids randomly is $(1/2)^{150} = 10^{-195}$. Combined with the probability of forming peptide chain, the total probability of creating a protein with 150 amino acids randomly is 10^{-240}. This is an extremely small probability. If this protein has to be created randomly from nature, some fine-tuned conditions must be satisfied. Nevertheless, many practical proteins for life need more than 150 amino acids, and the required fine-tuning is much more serious.

One possible mechanism for generating left-handed amino acids in nature has been postulated. The amino acids found from meteorites show an excess of the left-handed amino acids.[182] One possibility is that the excess left-handed amino acids are formed by the ultraviolet circularly polarized light (UVCPL). The electric field direction rotates along the beam which destroys one form of the molecules (right-handed) more readily than the other form (left-handed).[183] These UVCPL might come from the star-forming regions in space. If this is true, the probability of generating a protein molecule naturally may increase significantly. However, there should be a fine-tuned condition such that the UVCPL is pointing to the Solar System, and these radiations should have enough intensity to increase the amount of left-handed amino acids. Therefore, the mechanism that can generate excess left-handed amino acids also requires fine-tuning. In any case, the probability of getting a protein is still very low.

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[178] Ibid, p.206.
[179] Ibid, p.206.
[180] Mark Sephton, "Origin of Life", *An Introduction to Astrobiology,* eds. Iain Gilmour and Mark Sephton (Cambridge: Cambridge University Press, 2003), p.24.
[181] Ibid, p.27.
[182] Ibid, p.27.
[183] Ibid, p.27.

4.4.2 DNA and RNA

DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are two very important structures in life that store genetic information and transcribe the genetic information to synthesize protein respectively. The DNA molecules consist of four nucleotide bases Adenine (A), Cytosine (C), Thymine (T) and Guanine (G) while the RNA molecules consist of the same three bases A, C, G and one different base, Uracil (U). Basically, the genetic information stored in DNA is represented by the sequence of bases, for example, ACTGGTCAACGGCTGG…. Then, the RNA molecules will 'translate' the code and instruct the cell to make proteins. However, proteins are needed to catalyse the reaction. Therefore, protein cannot reproduce without the help of the DNA and DNA cannot produce protein without the help of proteins. If so, how could the first DNA exist without the RNA and protein? This is similar to the 'chicken and egg' paradox.[184]

Scientists later discovered the RNA molecules can perform some enzymatic functions needed for replication. RNA could store genetic information and act as catalysts, which would make proteins for simple life.[185] This "RNA-first model" is commonly accepted by most biological scientists. Although this suggestion can alleviate the 'chicken and egg' paradox, some questions are still not yet addressed. Meyer has summarized 5 major problems in the RNA-first model.[186] Firstly, the RNA building blocks are hard to synthesize and easy to destroy. Experiments show that it is extremely difficult to synthesize and maintain the essential RNA building blocks (ribose and the nucleotide bases). As mentioned above, we didn't find any nucleotide acids from the meteorites. These nucleotide bases must be created through naturalistic processes. However, the life-times for these bases are relatively short (less than 20 years), which is not long enough for life to evolve.[187] Secondly, the RNA can only perform a small handful of the thousands of functions performed by modern proteins.[188] That means RNA is just a very poor substitute for proteins in terms of catalyzing properties, which makes life difficult to evolve. Thirdly, no plausible explanation is given how primitive self-replicating RNA molecules might have evolved into modern cells that rely on a variety of proteins to process genetic information and regulate metabolism.[189] Fourthly, the origin of genetic information cannot be explained in this model. All genetic codes stored in DNA (or RNA) are specified. Not all the codes are meaningful (useful for generating suitable proteins), but just a few specified codes can synthesize useful proteins. As there is no chemical affinity between the nucleotide

[184] Ibid, p.35.
[185] Ibid, p.35.
[186] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), pp.301-320.
[187] Ibid, p.302.
[188] Ibid, p.304.
[189] Ibid, p.305.

bases in the same strand of DNA, the codes in the DNA can be in any sequences. In other words, there is no restriction on the sequence of the DNA. If these sequences were generated randomly, the probability of getting a meaningless sequence (cannot form specified proteins for life) is much greater than the meaningful one (can form specified proteins for life). Therefore, the probability of getting correct genetic information for life is extremely low. Lastly, current scientists cannot create any fully functional RNA-based RNA polymerase from anything else, unless you provide some directions to enhance function of some common types of ligases.[190] The above five problems indicate that a functional and information-rich RNA is extremely difficult to create.

In view of these difficulties, the problem of genetic information stored in DNA or RNA is the most serious. Many proposals have been suggested to address this problem. In 1977, Prigogine and Nicolis suggested that highly ordered pattern can be formed when energy is flowing into a system under non-equilibrium conditions.[191] However, Yockey pointed out that highly ordered pattern is not equivalent to specified information.[192] Even if a sequence can be generated by some unknown biological forces (laws) in nature, the resulting sequence should be periodic or repetitive pattern (e.g. ACGTACGTACGTACGT…) rather than specified (aperiodic but meaningful) because natural laws describe events that repeatedly and predictably recur under the same conditions.[193] Therefore, the DNA sequence possesses specified complexity, not just a highly ordered pattern.[194] Later, Kauffman suggests that the specified information problem can be solved by a self-organizational process – a self-reproducing metabolic system might emerge directly from a set of low-specificity catalytic peptides and RNA molecules in a prebiotic soup (chemical minestrone).[195] However, Meyer points out that Kauffman's model merely transfers the information problem from the molecules into the soup.[196] In other words, Kauffman presupposes that his system will work only once it had been fine-tuned.[197]

Although the RNA-first model is the most reasonable one to explain the existence of proteins, DNA and RNA, many fine-tuned conditions in this model are required, especially the information stored in the DNA and RNA. For organic synthesis in laboratory, the right materials must be taken from the right

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[190] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), p.319.

[191] G. Nicolis and I. Prigogine, *Self-Organization in Nonequilibrium Systems* (New York: Wiley, 1977), pp.339-353, 429-447.

[192] Please refer to Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), p.255.

[193] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), p.258.

[194] Ibid, p.250.

[195] Stuart Kauffman, *At Home in the Universe* (Oxford: Oxford University Press, 1995), p.274.

[196] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), pp.262-264.

[197] Ibid, p.269.

bottles and mixed and treated in an appropriate sequence of operations.[198] This indicates that even simple organic synthesis requires fine-tuned process. For organisms that involve particular enzymes for catalytic processes, right sequence of DNA for storing information and specific proteins for biological functions, the fine-tuning problem is much more serious.

4.5 Fine-tuning of cell

All cells in organisms require some fine-tuned properties. These properties work well with some other independent fine-tuned properties.

4.5.1 Lipid

Lipids are important molecules that play many critical roles in cells. They are a major source of cellular energy. They function as electrical insulators and as detergents. They form the waxes which coat the feathers of birds.[199] The solubility of lipid molecules in water is fine-tuned. Lipid molecules cannot carry out biological functions if they are either too soluble or insoluble in water. This requires the number of carbon atoms in lipid molecules to be 16-18. If the number of carbon atoms is larger than 18, it would be too insoluble for biological functions – they cannot be mobilized at all in water. If the number of carbon atoms is smaller than 16, it would be too soluble so that all constituents would merely dissolve away.[200] In addition, the lipid can form bilayer to serve as an electrical insulator to avoid the loss of potassium and sodium ions. These ions generate an electrical potential between inside and outside of the cell which helps to transit the nerve impulses.

4.5.2 Cell adhesion

Another important fine-tuned property is the affinity bond between two cells. The strength of these affinity bonds is made up of the sum of the various weak chemical bonds between two cells.[201] Recent studies show that only between 1-10 affinity bonds are sufficient to hold two cells together against most

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[198] G. Cairns-Smith, "Fine-Tuning in Living Systems: Early Evolution and the Unity of Biochemistry," *International Journal of Astrobiology* 2 (2003): pp.87-90.
[199] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.213.
[200] Ibid, p.214.
[201] Ibid, p.218.

of the common forces in biological systems.[202] If the bonds are weaker, the specific cell-cell binding would be impossible. If the bonds are stronger, it would be very difficult for cells to detach themselves from one another.[203] The strengths of these bonds are mainly characterized by the chemical compositions of cells and the value of the fundamental constant of electromagnetic force.

4.5.3 Crawling

Crawling means continual changes to its shape which is formed by deformable cytoplasm. Crawling plays an essential role in all developmental processes in higher organisms. This property requires an appropriate viscosity of cytoplasm. The cell's contents would be immobilized if the viscosity is too high. This phenomenon is characterized by various weak chemical bonds, and the forces of these chemical bonds should be finely balanced in order to make crawling possible.[204]

To conclude, the fine-tuning of cells requires several coincident primary and secondary fine-tunings. These fine-tuned properties make the cells possible to carry out many crucial biological functions in organisms.

4.6 Conclusion

The origin of life is a mystery. Two possible scenarios of creating prebiotic soup – chemical evolution and accumulation from extra-terrestrial objects – require fine-tuned conditions, such as suitable size of Earth, chemical composition, probability of meteorite impact and initial conditions. Even if the prebiotic soup could be generated naturally, it is very difficult for them to evolve into proteins, RNA and DNA. As mentioned above, since the structures of proteins, RNA and DNA have some specific properties, the probabilities of generating these macro-molecules naturally are extremely low. Therefore, some fine-tuned conditions must be satisfied in order to create them through natural processes. Even if all RNA, DNA and proteins are generated, life would exist only when certain environment is hospitable for life, such as chemical composition of Earth, atmospheric pressure and oxygen content level. Some initial conditions must be fine-tuned in order to get these anthropic environments.

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[202] Ibid, p.219.
[203] Ibid, p.220.
[204] Ibid, p.221.

In this chapter, I have discussed the fine-tuned conditions for life. Some of these conditions are dependent on fundamental constants. These fine-tuned conditions are mainly secondary fine-tuning. Nevertheless, many fine-tuned properties are based on complex behavior of molecules and environments, which are highly non-linear and dependent on initial conditions. Suppose the probability of getting these fine-tuned initial conditions P(c) is independent of the primary and secondary fine-tuning. By using equation (3.4), the total probability of getting all these fine-tuned anthropic fundamental constants and conditions is given by

$$P(c \ and \ s \ and \ p) = P(c) \times P(s \ and \ P) \leq P(c) \times P(s) \times P(p). \tag{4.3}$$

This probability is extremely low. The fine-tuning problem is getting worse if we consider the fine-tuned initial conditions.

Smith and Szathmary generalize seven crucial transitions from prebiotic soup to human life through natural processes. They are self-organization (generating protocells), synthesis (RNA formation), RNA to DNA, Endosymbiosis (formation of Algae), Asexual to sexual, cell differentiation (animals, plants and fungi formation), and language (human intelligence).[205] We have now discussed three of them, and all need fine-tuned conditions. In the next chapter, we will discuss the remaining crucial steps and show that all require fine-tuned conditions.

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[205] M. McCabe and H. Lucas, "On the Origin and Evolution of Life in the Galaxy," *International Journal of Astrobiology* 9(2010): pp. 217-226 and John Smith and Eörs Szathmary, *The Major Transitions in Evolution* (Oxford: Oxford University Press, 1995).

Chapter 5   Global fine-tuning – guidance of evolution

The theory of evolution was proposed by a biological scientist Charles Darwin in the 19th century. He stated that life evolved from basic life to complex life through a long period of natural processes. The evolution of complex life is mainly based on a mechanism called Natural Selection. This mechanism suggests that all organisms in the nature undergo competitions (food searching). Due to the scarcity of resources, some inferior organisms lose in the competition (killed or eaten by the others), and the more superior organisms survive. This process continues and the nature will favor the more superior organisms. As a result, an equilibrium will be reached - many complex life and only some simple organisms remained. Therefore, the theory of evolution mainly consists of two general components: natural selection and the survival of the fittest. In other words, the environment and competitions (or cooperation) determine the evolution history.

However, this theory does not suggest a possible mechanism why life would evolve from simple to complex life. In the 20th century, scientists discovered genes and noticed that genes would change in time due to mutations. The DNA sequence in organisms would have a slight change due to some external effects such as cosmic radiations. These changes could be accumulated by passing to the next generation. Therefore, the genetic change in DNA provides a possible mechanism of evolution.

Although the theory of evolution is far from complete due to many missing links in the evolution series, most scientists have already come to a consensus that complex life evolved from simple life by evolution. The fact of evolution is mainly based on the geological distribution of fossils (simple organisms mainly found in the early crusts) and genetic variations among the organisms.[206] Intelligent life (human) also evolved from simple life by evolution. The ancestor of modern human evolved from the common ancestor of humans and apes 6-7 million years ago.[207] By the way, not only the biological evolution (evolution of body, organs, etc.) is important, the evolutions of languages, social behavior are also very important.

In this chapter, we will briefly discuss the fine-tuned condition for biological evolution. It requires the fine-tuning of global environment and conditions. I call it the "global fine-tuning". Also, we will discuss the fine-tuning of materialistic mind generations in evolution. Lastly, we will focus on the fine-tuning of evolution of human beings (intelligent life).

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[206] Jerry Coyne, *Why Evolution is True* (New York: Penguin Group, 2009).
[207] Kenneth Kardong, *An Introduction to Biological Evolution* (New York: McGraw-Hill, 2008), p.277.

5.1 Global environmental fine-tuning

Evolution is highly dependent on the driving force, the surroundings and the environmental changes. In the previous chapter, I have discussed how environment is related to initial conditions and how life formation is sensitive to the "background environment" of our Earth (such as oxygen content). In this section, I will mention some crucial global environmental changes that lead to some significant changes in evolutionary history.

Most evolution biologists believe that the evolution series would be different if the environmental changes were different in the past. Moreover, a slightly different environment in different areas causes variations in the organisms. This generates diversity. When a great change occurs in the Earth, such as meteorite impact or volcano eruption, a large amount of organisms become extinct and some other organisms start to dominate the world. As a result, the driving force becomes different and the evolution series would be totally different. Many Biologists used to believe that the "punctuated equilibrium" in evolution theory characterizes the burst of intense evolution and speciation. Now, recent studies indicate that the effect of punctuated equilibrium in evolutionary history may not be so significant. Instead, global episodes may have a crucial role in evolution.[208] In this section, I will outline how global events affect the evolution. I will also briefly describe the fine-tuning in evolution and the importance of diversity and cooperation.

5.1.1 Mass extinction episodes

In the evolutionary history, the number of families in the Earth is not strictly increasing. There exist at least five mass extinction episodes. They occurred at, in chronological order, late Ordovician, late Devonian, late Permian, later Triassic and late Cretaceous. A large amount of families were destroyed due to different global events. Simultaneously, those organisms who survived in these episodes started to grow and change their morphology. Here I will describe two most important episodes in the history that totally change the world.

The first most important episode occurred at late Permian (251 million years ago). An estimated 95% of all species on the Earth became extinct.[209] It is commonly believed that global warming caused by some

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[208] M. Pagel et al., "Large Punctuational Contribution of Speciation to Evolutionary Divergence at the Molecular Level," *Science* 314 (2006): pp.119-121.
[209] Marten Scheffer, *Critical Transitions in Nature and Society* (New Jersey: Princeton University Press, 2009), p.172.

massive volcanic eruption was the main reason. Life came close to complete annihilation and it took about 100 million years for global biodiversity to return to pre-extinction levels.[210]

Another crucial episode happened in the best-known period in late Cretaceous during which the extinction of dinosaurs occurred. It is widely accepted that this extinction is caused by a huge asteroid impact. There may be some massive volcano eruptions which further enhance the effect.[211] We now notice that this extinction event facilitate the start of mammals, which leads to the development of human beings later.[212] Without the extinction of the dinosaurs, mammals would not be the dominant forces in the nature and human beings may probably not be developed through evolution.

These two crucial episodes require some global events such as massive meteorite impact or volcano eruptions. The probability of these global events depends on many factors, such as the size of the meteorite, the thickness of our atmosphere and the size of the Earth. Statistics show that the approximate frequency (probability) of meteorite impact depends on the size of meteorite (or the energy given out by the meteorite). The frequency is about one time in one to ten million years for the global catastrophe caused by meteorite impact.[213] Therefore, the number of possible global events is not so small compared with the long life history (few billion years). However, the massive meteorite impact that makes dinosaurs extinct occurred at a right time with a right amount of power. If it is somewhat larger in power, all organisms in the Earth might be dead. If the power is much smaller, the extinction would not be occurred and human beings would not be able to appear. In fact, statistics show that the frequency of meteorite impact is dependent on the size (power) of the meteorite.[214] Therefore, these global episodes should be under some fine-tuned conditions such that the events appeared at the right time and gave out the right amount of power.

5.1.2 Fine-tuning in evolution

The evolutionary series is governed by biological rules (genetic variations, natural selections, etc.). Simple organisms can become complex organisms by following these rules through a very long time. As mentioned above, fine-tuned environments and global changes should be made in order to get highly

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[210] Ibid, p.173.
[211] See Marten Scheffer, *Critical Transitions in Nature and Society* (New Jersey: Princeton University Press, 2009), p.176; D. Huddart and T. Stott, *Earth Environments* (Oxford: Wiley-Blackwell, 2010), p.821.
[212] Marten Scheffer, *Critical Transitions in Nature and Society* (New Jersey: Princeton University Press, 2009), p.177.
[213] Michael Seeds, *Foundations of Astronomy* (Belmont: Wadsworth, 2005).
[214] Ibid.

complex organisms. These changes require very specific fine-tuned conditions, which are highly improbable to be generated randomly. Apart from these fine-tuned conditions, evolution itself might intrinsically be an important fine-tuned process.

Recently, some computational biologists start to simulate evolution by using computer algorithms. They try using computer program to see whether it can generate complex structures from simple structures. The first famous attempt is the program called "Game of Life" invented by Conway.[215] He starts with a simple figure - square array - and sets some rules to determine next generation. For example, a live square with two or three live neighbours survives and the cell will be dead if it has more than three neighbours. After numerous generations, some complex "life" is formed. During the late 1980s, Dawkins and Küpper simulate natural selection by using computer algorithm. They provided a target sequence and let the program to run from some primordial sequences. Variation is generated randomly. The computer would preserve those sequences that are close to the target sequence and then repeat the process. Finally, the program really produced the target sequence.[216] Later, a better algorithm called "Avida Algorithm" has been used to simulate the effect of random mutation and natural selection. The program would generate some random variation and change the input function to the new output function (act as random mutation). The computer would first compare the input and output functions and then replicate those functions that have logical relationships (act as natural selection). As a result, the program would generate some complexity after numerous processes.[217] This algorithm does not have any target sequence or possible future functions. It seems that these algorithms are able to generate some complex structures originated from simple structures. However, all these algorithms were designed by human beings. Robert Marks points out that these evolutionary algorithms are continuously adding information to the system.[218] Therefore, it is not surprising why complex structures would be generated. The information adding processes have been input to the algorithms artificially by the program designers. Basically, these results indicate that some fine-tuned conditions must be satisfied in order to get complex structures. In the simulations, all the program languages are fine-tuned. We should use correct computer languages, functions and algorithms to get the results. Secondly, the computer logics are fine-tuned. We should have some specific logics for replicate and dispose the useful and useless structures respectively in order to simulate the natural selection. If wrong functions or logics are used, no stable results would be generated. What you should do is to write a better program by using other logics to generate the required output. It would not be possible for a computer to generate complexity by randomly typing any letters into the

[215] Stephen Hawking and Leonard Mlodinow, *The Grand Design* (New York: Bantam Books, 2010), p.172.
[216] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), p.281.
[217] Ibid, p.286.
[218] Stephen Meyer, *Signature in the Cell* (New York: Harper One, 2009), pp.284-285.

simulations. Therefore, the success of these evolutionary algorithms suggests that evolution itself is a fine-tuned process.

On the other hand, diversity is generated by evolution due to different driving forces in different areas. Interestingly, the success of evolution should also be based on diversity. Competitions in evolution rely strongly on the food chains. The prey and predators interact with each other to form complex food circles. In other words, evolution itself provides a positive feedback mechanism to keep its stability. As mentioned in the previous chapter, the globally stable but locally variable environment maintains this stability in evolutionary history. This also suggests that evolution itself is a fine-tuned process.

5.1.3 Gaia hypothesis

In 1979, scientist James Loverlock realized that if the Earth's atmosphere were at chemical equilibrium, it would be very similar to that of Venus and Mars. However, observations show that the atmospheric content of Earth is quite different from that of Venus and Mars.[219] On the other hand, observations also indicate that the salt content in sea is somewhat smaller than that obtained from theoretical predictions. It shows that the sea is at a chemical disequilibrium.[220] Therefore Lovelock argues that the presence of organisms is a key to set up the chemical equilibrium in our atmosphere (see section 4.2.1).[221]

Lovelock summarizes the above facts and proposes the Gaia hypothesis, which holds that "*the atmosphere, the oceans, the climate and the crust of the Earth are regulated at a state comfortable for life because of the behavior of living organism. Specifically, the Gaia hypothesis said that the temperature, oxidation state, acidity, and certain aspects of the rocks and waters are at any time kept constant, and that this homeostasis is maintained by active feedback processes operated automatically and unconsciously by the biota*".[222] In other words, life affects environment, and environment affects life. This is a non-linear process because a certain change in the life forms might severely affect the environment (because the regulation of cycles changes). Consequently, the changes in the environment might severely affect the evolution of life. In order to achieve a stable equilibrium, the structures of organisms need to be fine-tuned in order to give a positive feedback to the environment. Since the structures of organisms are highly dependent on the biological evolution, we can conclude that both the

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[219] James Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 1979), p.39.
[220] James Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 1979), p.36.
[221] Ernest Lucas, *Science and the New Age Challenge* (Leicester: Apollos, 1996), p.120.
[222] James Lovelock, *The Ages of Gaia: A Biography of Our Living Planet* (New York: W. W. Norton, 1988).

environmental conditions and the evolution processes need to be fine-tuned. Otherwise, a vicious cycle would be easily generated to destroy the chemical equilibrium.

Note that the Gaia hypothesis discussed here is a scientific explanation, but not a personal explanation (the definitions of scientific explanation and personal explanation can be seen in p.73). Some advocates of this hypothesis (especially the advocates of the New Age Movement) treat our natural world as a living thing. Some of them interpret the interaction between the natural world and the living organisms as evidence for a living Gaia (or gods). Here, we do not take this view as the interaction can be completely understood by scientific explanation. Otherwise, the existence of a supernatural being would be implicitly assumed.

5.1.4 Adaptive mutation

It is commonly believed that mutation is a random process. However, recent studies in micro-organisms suggest that some environmental stress can direct the mutation process. This kind of mutation is called Adaptive mutation.[223] The existence of adaptive mutation suggests that the mutation might be sensitive to the environmental changes. Since mutation is an essential element in biological evolution, the process of evolution itself is also sensitive to the environmental changes. Therefore, a certain degrees of fine-tuning might exist in the evolution process.

Recently, scientific investigations in Escherichia coli cells reveal a possible mechanism for the adaptive mutation. The adaptive mutation is regulated by the SOS response, a complex, graded response to DNA damage that includes induction of gene products blocking cell division and promoting mutation, recombination, and DNA repair.[224] SOS is the prototypic cell cycle check-point control and DNA repair system. In general, the adaptive mutation is a complicated mechanism that involves different genes and molecules. It is a tightly regulated response, controlled both positively and negatively by the SOS system.[225] It seems that this mechanism is highly fine-tuned in order to respond to the environmental changes. Moreover, recent studies also indicate that the adaptive mutation may increase mutation rates under adverse conditions.[226] This might provide another favorable route to facilitate the rate of evolution because it is believed that most mutations are deleterious.

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[223] P. L. Foster, "Adaptive Mutation: The Uses of Adversity," *Annual Review of Microbiology* 47(1993): pp.467-504.
[224] G. J. McKenzie et al., "The SOS Response Regulates Adaptive Mutation," *Proceedings of the National Academy of Sciences of the United States of America* 97(2000): pp.6646-6651.
[225] Ibid.
[226] P. L. Foster, "Adaptive Mutation: Implications for Evolution," *Bioessays* 22(2000): pp.1067-1074.

Therefore, the existence of adaptive mutation suggests that mutation can be a fine-tuned process, which might control the rate of evolution.

5.2 Fine-tuning in cooperation

Most scientists believe that natural selection is the most important driving force in evolutionary history. However, recent studies indicate that cooperation is another important driving force in evolution. Even from the first cell evolved to human beings, cooperation plays a crucial role in the evolutionary history.[227] Interestingly, competitions in naturally selection favour the selfish behavior of organisms while cooperation favours the selfless behavior. Although organisms cooperating with each other may enjoy some privilege in competitions, the origin of some organisms switching from being selfish to giving helping hands is still a mystery. Studies have shown that the bats remember which bats have helped them in times of need, and when the day comes that the generous bat finds itself in need of food, the bat it helped earlier is likely to return the favour.[228] Altruism, which is commonly found in animals and human beings, may be generated through selfless behavior in cooperation. This selfless behavior is very important in developing the intelligence of human beings. It is an essential component of the social behavior of human beings. If all human are selfish, then no cooperation and no social connection would exist. Development of languages would also be impossible because we need not communicate with each other.

Suppose the selfless behavior is generated by pure materialistic mechanisms (not by free wills), such as the genetic properties of an organism. Due to some unknown reasons, some genes are changed so that the organism starts to have some selfless behavior and cooperate with the others. Here, we assume that the mind involved in the cooperation is materialistic and deterministic. In other words, these minds can be described by some deterministic natural laws.

Since the cooperation may give organisms some survival advantages, the genetic properties that govern the selfless behavior would pass to the next generation. However, evolutionary simulations indicate that cooperation is intrinsically unstable.[229] That means selfless behavior would easily get lost after some generations. This is because the competitions in the nature would force you to become selfish again even if you have some selfless behavior. There is no strong reason for an organism to sustain its selfless

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[227] M. A. Nowak, "Why We Help," *Scientific American* 307 (July 2012): pp.36-39.
[228] Ibid.
[229] Ibid.

behavior as this behavior only gains some direct and short-term survival advantages. Although the altruistic spirit may rebuild again in some generations later, it does not guarantee this spirit would pass from generations to generations forever. Since this is an unstable process, some fine-tuned conditions must be satisfied so that the altruistic spirit can accumulate from different generations and become the dominant power in the communities of some organisms. This stability should be maintained by some fine-tuned process. For example, the genes that characterize this selfless behavior have to be relatively stable.

The cooperation in evolution is very important. Since some cooperation in animals may maximize the survival advantages according to the Game Theory, it makes the evolution process faster. Also, scientists believe that this behavior is crucial in the development of social behavior in human beings.[230] This generally affects the evolution of intelligence of human beings.

5.3 Evolution of Intelligence

Although human beings evolved from the other animals, we are quite different from them with numerous unique properties. There are six adaptations being crucial to the unique success of our species: (1) high intelligence, (2) linguistic communications, (3) highly developed visual ability, (4) possession of a superb manipulative tool – the hands, (5) our upright stance, and (6) our being a highly social species.[231] The developments of these adaptations depend on several independent evolutionary series, such as the evolution of brain, vocal apparatus, eyes, hands and muscles. In the following, I will describe how these crucial independent evolutionary series have to be fine-tuned in order to achieve all the adaptations.

5.3.1 Brain

Although we know that brain size alone seems to bear little direct relationship to intelligence, the human's brain is generally larger than many other organisms. For example, the brain of a fly is about 1mg while the human brain weighs about 1.4 kg.[232] The evolution of brain is generally getting larger and heavier. Nowadays, we know that the human brain is the most complex in the animal kingdom and it may

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[230] Ibid.

[231] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.238.

[232] Ibid, p.256.

be the end of the road for brain evolution.[233] Therefore, through a long series of evolution, our brain has evolved to get enough power to have cognitive functions, which may be already the end of the evolution.

5.3.2 Language

The language ability in human depends not only on the cognitive abilities, but also on our appropriate organs for generating complex sound patterns. Nonhuman primates have supralaryngeal vocal tracts in which the larynx exits directly into the oral cavity while in human the larynx exits directly into the pharynx.[234] This difference enables human to generate a far richer phonetic repertoire than that available to the other animals.[235] Moreover, recent studies reveal that FOXP2 gene on chromosome 7 plays an important role in language. This single gene with a subtle misspelling could cause profound language deficits without other obvious consequences.[236] Surprisingly, this sequence of this same FOXP2 gene has been remarkably stable in nearly all mammals while two significant changes have occurred in the coding region of the gene in human. These changes might contribute to the development of language in human beings.[237]

5.3.3 Vision

There are several independent evolution series for eye's evolution. For example, some organisms possess camera-lens eyes (found in vertebrates and octopuses) and some have curved reflector eyes.[238] The evolutionary history of eye is very long, and can be traced back to the Cambrian explosion. Interestingly, human eye is already close to optimum for a camera type of eye using biological cells as photodetectors. That means our visual acuity cannot be improved to any significant degree by making changes in its absolute size or the relative size of its components.[239]

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[233] M. Ward, "End of the Road for Brain Evolution," *New Scientist* 153 (1997): p.14.
[234] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.240.
[235] P. Lieberman, "On the Evolution of Language: A Unified View," in *Primate Functional Morphology and Evolution*, ed. Russell Tuttle (The Hague: Mouton Publishers, 1975), pp. 504-510.
[236] Francis Collins, *The Language of God* (New York: Free Press, 2006), p.140.
[237] Ibid, p.140.
[238] Alister McGrath, *A Fine-Tuned Universe* (Kentucky: Westminster John Knox Press, 2009), p.193.
[239] Michael Denton, *Nature's Destiny* (New York: The Free Press, 1998), p.240.

5.3.4 Hands and human body

Hands are the most efficient manipulative tool for art works, scientific acquisition, writing, etc. One of the most important functions that can be carried out by hands only is making fire. In fact, the utility of hands is dependent to a large extent on our upright stance and bipedal gait.[240] Besides, the strength of muscle is also a crucial component for us to participate in these activities. It controls the movement of our limbs, pumping of blood, respiration, and the maintenance of the upright posture.[241] Moreover, in order to make the smallest fire, the height of our body should be about 1.5-2 m with mobile arm about 1 m long ending in manipulatively tools.[242] All these parts require different evolutionary routes.

5.3.5 Concordance evolution for intelligence

All the above adaptations are controlled by different organs, which were evolved independently. Interestingly, all these adaptations rely on each other in order to help human becomes intelligent beings. Without good visual ability, we can't make fire or write. Without language ability, we can't cooperate efficiently. Without cognitive development, we can't invent tools and develop language. Without upright stance, we can't use our hand efficiently. Therefore, all these independently evolved adaptations have to cooperate with each other. It seems that all these adaptations simultaneously evolved through a right time interval (takes similar long time) and to a right ability so that human beings can give rise to technological development. In other words, evolution gets these six adaptations simultaneously.[243]

5.4 Conclusion

In the previous two chapters, we discussed the fine-tuning of fundamental constants and the initial conditions. In this chapter, I briefly describe the intrinsic fine-tuning in evolution and the fine-tuning of global events that significantly altered the evolutionary history. These fine-tuned conditions are highly independent of the fine-tuning of initial conditions in Earth and the primary and secondary fine-tuning. Therefore, the total probability of fine-tuning P(FT) by considering all these evidences becomes

$$P(FT) = P(G) \times P(Ev) \times P(c \text{ and } s \text{ and } p), \qquad (5.1)$$

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[240] Ibid, p.242.
[241] Ibid, pp.245-248.
[242] Ibid, p.243.
[243] Ibid, p.239.

where P(G) and P(Ev) are the probabilities of global events' fine-tuning and the fine-tuning in evolution respectively. The resulting probability P(FT) is much lower after multiplying the global factor and the fine-tuning in evolution. The probability of evolving human intelligence is equal to or less than getting all these necessary conditions – right fundamental constants, right initial conditions, right conditions for global events and right evolutionary series – simultaneously. In fact, I have not discussed all factors that have contributed to the evolution of human intelligence such as the evolution of some other essential organs and systems in a body. All these factors involve some complex interactions between individual components. Certain fine-tuned conditions must be satisfied to carry out some essential functions for human. Nevertheless, by just looking at the evidences mentioned above, the evolution of human intelligence is already highly improbable through naturalistic processes. Therefore, we can conclude that the evolution of human intelligence is an extremely fine-tuned process in our universe. In the next chapter, we will discuss some major ideas to address this interesting fine-tuning phenomenon.

Chapter 6   Philosophical arguments about the fine-tuning phenomena

In the previous chapters, we have a thorough discussion of the fine-tuning phenomena. Observational evidence indicates that the existence of intelligent life is highly improbable unless some fine-tuned fundamental constants, initial conditions and mechanisms in evolution exist. There is already a consensus, from many scientists and philosophers, that fine-tuning phenomena are real in nature.[244]

If the fine-tuning phenomena are real (the probability of the evolution of intelligent life on background knowledge is extremely low), do they need an explanation? An intuitive answer to this question is yes. According to the strong version of the Principle of Sufficient Reason (S-PSR), for every proposition, p, if p is true, then there is a proposition, q, that explains p.[245] However, we still do not have a proof why we must accept this principle. There is another weak version of the Principle of Sufficient Reason (W-PSR), which states for any proposition, p, if p is true, then we presume that there exists a proposition, q, such that q explains p.[246]

If we accept W-PSR, we should seek any possible explanation until we cannot find an explanation. Therefore, we have the presumption that every phenomenon presupposes a rational explanation. For those true propositions which do not have an explanation (after seeking all possible explanations), we may regard them as the brute facts. If we deny W-PSR, it is equivalent to saying that we need not presume an explanation for any phenomenon. If it is the case, science would break down because we do not presume any explanation for the natural events. For example, when we observe a ball is accelerating under free fall, if we deny W-PSR, we need not account for it and no Newtonian mechanics can be formulated. Besides, it also contradicts to our daily experience. When my money deposited in the bank disappears, if we deny W-PSR, we do not need to seek any explanation. Obviously, the consequences of denying W-PSR would be disastrous. Therefore, in the following discussion, we follow W-PSR and first seek a possible and reasonable explanation for the fine-tuning phenomena before we can simply regard the fine-tuning phenomena as brute facts.

In fact, there are many hypotheses suggested to explain the fine-tuning phenomena (see Fig. 6.1 for the classification of the hypotheses). In this chapter, I will briefly describe all the major hypotheses and

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[244] For the consensus from scientific community, see Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): 529-64. For the philosophical community, see Antony Flew, *There is a God* (New York: HarperCollins, 2007).
[245] Richard Gale and Alexander Pruss, "A New Cosmological Argument," *Religious Studies* 35(1999): 461-476.
[246] Ibid.

illustrate how they can explain the fine-tuning phenomena. Finally, I will compare and evaluate all the major hypotheses.

Explanation of fine-tuning phenomena
- Naturalistic
  - Multiverse
    - Non-generated
    - Generated
  - One universe
    - Chance
    - Super-law
    - Others
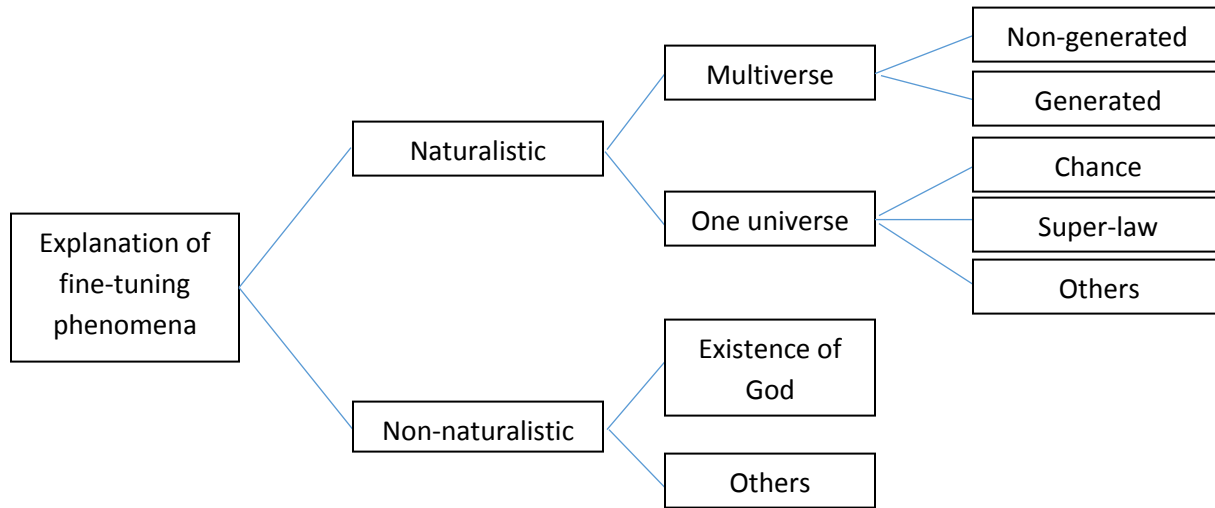- Non-naturalistic
  - Existence of God
  - Others

Fig. 6.1. Classification of the major hypotheses.

Traditionally, philosophers usually categorize a cause of an event into either a teleological cause or an efficient cause. A teleological cause gives a purposive explanation whereas an efficient cause gives a causal explanation. However, there is another way to categorize an explanation of an event into either a personal explanation or a scientific explanation. A personal explanation explains why some proposition is true in terms of the intentional action of an agent and a scientific one in terms of some conjunction of law-like propositions, be they deterministic or only statistical, and one that reports a state of affairs at some time.[247]

In this thesis, we follow this categorization (personal or scientific explanation) to discuss the major available hypotheses which can explain the fine-tuning phenomena. Here, the naturalistic hypotheses are the hypotheses which use only scientific explanations to explain the fine-tuning phenomena. Some believe that the fine-tuning phenomena can still happen by chance, though the probability is very low. W. H. Wong is one of the representative philosophers to support this argument. Some believe that the existence of a super-law such as the string theory can explain the fine-tuning phenomena. Many famous physicists, such as Edward Witten, are now working on it. On the other hand, some believe that our universe is just one of the many universes. They suggest that the existence of multiverse can explain the fine-tuning phenomena. There are two possibilities, the multiverse is generated by a "universe generator" or the existence of multiverse is a brute fact. The former one is the most popular hypothesis as there are

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[247] Ibid.

many famous scientists, including Stephen Hawking, supporting it. The latter one is a logical possibility, which states that our Universe contains infinitely many universes and our universe is just one of them.

The non-naturalistic hypotheses are the hypotheses which use some sort of personal explanations or assume the existence of a supernatural being to explain the fine-tuning phenomena. We will mainly focus on the God hypothesis, which suggests that God creates the fine-tuned universe. Richard Swinburne is one of the major representative philosophers to support this argument. We will also discuss some other minor hypotheses, such as Pantheism, Panentheism and some other forms of naturalistic theism. The former one proposes that the divine and the universe are identical while the latter one proposes that the divine interpenetrates every part of the universe and extends beyond it.

6.1 Chance-alone hypothesis

Some argue that it is not necessary to give any further explanation for the fine-tuning phenomena. Although the chance of fine-tuning is extremely low, it is still a non-zero probability, $P(FT|Chance) \neq 0$. Low probability does not mean that we have to give up this chance-alone hypothesis. For example, the probability of getting a prize from a lottery is very low. However, it is not necessary for us to give any special explanation other than chance why the winner gets the prize. Another example is that even though there are 300 million citizens in America and the chance of becoming a president is just 10^{-9}, someone has to be the president.[248] Therefore, these examples illustrate that it is not necessary for us to give any special explanation for the fine-tuning phenomena. The chance-alone hypothesis is already enough to explain the fine-tuning phenomena. Recently, Wong provides another argument to show that our fine-tuned universe is just a result from the 'cosmic lottery'.[249] Since winning a lottery has no significant difference from losing a lottery, similarly, a fine-tuned universe is not significantly different from a non-fine-tuned universe. His argument is that

"*the universe is life-permitting requires an explanation only if (a) non-life-permitting possible universes are not significantly different from one another so that all possible universes should be divided into two groups, namely, 'life-permitting' and 'non-life-permitting', or (b) the life-permitting possible universe stands out as far as being the actual universe is concerned, even though non-life-permitting possible universes are significantly different from one another.*"[250]

[248] Alister McGrath, *A Fine-Tuned Universe* (Kentucky: Westminster John Knox Press, 2009), p.121.
[249] W. H. Wong, "The Cosmic Lottery," *International Journal for Philosophy of Religion*, 66 (2009): 155-165.
[250] Ibid, p.162.

He thinks that we should not divide all possible universes into life-permitting and non-life-permitting. It is because this view is anthropocentric. This would mislead us because it may blind us to the fact that all possible universes are significantly different.[251] Therefore, in Wong's argument, the criterion (a) is not satisfied. Also, being life-permitting may not be a rare cosmic feature. It is reasonable to conceive that many other non-life-permitting possible universes also have rare cosmic features. It is similar to drawing a ball randomly from an urn in which there are one thousand balls, each of which is marked with a number. It does not require an explanation if you draw a ball that is marked number '1'. It is because the number-1 ball does not have any special features that are significantly different from the other balls with other numbers. Therefore, Wong thinks that "*having a rare cosmic feature thus does not make life-permitting possible universes stand out in such a way that a life-permitting possible universe being the actual universe requires an explanation.*"[252] The criterion (b) is also not satisfied. Since the criteria (a) and (b) are not satisfied, the existence of fine-tuning does not require a special explanation. The chance-alone hypothesis is enough to explain the fine-tuning phenomena.

It is true that something could occur even if the probability is very low. However, the above two examples are somewhat misleading. In the first example, there may be many people participating in the lottery which makes the overall probability of getting at least one winner much higher. However, our universe has only one time to "choose" the fine-tuned values. The overall probability of getting these fine-tuned values is extremely low. In the second example, a president must be elected, while in the evolution of our universe, the existence of life is not necessary.

For Wong's argument, it is dubious why the criterion (a) is correct. Suppose that there are two possible non-life-permitting universes. One is full of black holes and the other one is full of neutron stars. These two non-life-permitting universes are significantly different from each other. We don't see why this entails that our universe is life-permitting does not require an explanation. Whether life-permitting universe requires an explanation or not does not depend on the natures of the non-life-permitting universes. Therefore, the criterion (a) is irrelevant. For the criterion (b), it relies heavily on assuming that life-permitting universe is not significantly different from the non-life-permitting universe. By saying life-permitting just being a rare cosmic feature basically undermines the importance of life. In general, living things tend to be highly organized at any given level of description and so differ from objects like stones, which tend to have uniform or random structures.[253] Moreover, as mentioned in Chapter 4-5, our fine-tuned universe not only can evolve life, but also evolve intelligence that can communicate, create new

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[251] Ibid, p.163.
[252] Ibid, p.163.
[253] Benjamin Jantzen, *An Introduction to Design Arguments* (Cambridge: Cambridge University Press, 2014), p.226.

things, make tools, understand science, etc. These abilities make us significantly different from the other non-life-permitting universes. In other words, our universe is fine-tuned such that the evolution of intelligence is possible. In fact, we usually view our universe anthropocentrically because life is too mysterious and marvelous. Life can produce life, and life can create many possibilities. However, Wong says that "*suppose a possible universe U has a rare cosmic feature (or set of features) F that is necessary for the existence of Xs. If U were the actual universe, then the actual universe would appear to be fine-tuned for the existence of Xs. No matter what F is, such apparent fine-tuning does not require an explanation given that many other possible universes have other rare cosmic features.*"[254] Wong's argument is reducing life to certain life-permitting fundamental constants and conditions, which are not different from the non-life-permitting fundamental constants and conditions. However, this view is counter-intuitive. Leslie argues that, "*please ask how you would react to the man who, catching a fish, next discovered that his fishing apparatus would accept only fish of exactly that length, to one part a million, and who still saw absolutely no ground for believing in a fish-creating benefactor or in multiple fish.*"[255] He thinks that such a surprising coincidence requires an explanation, but not explained by chance.

In fact, the chance-alone hypothesis itself is not really a good explanation. We use chance to explain an event because (i) the occurrence of the event is indeterministic or stochastic, or (ii) the occurrence of the event involves complicated processes so that it is hard to determine by natural laws. For example, the probability of getting "1" by throwing a fair dice is about 1/6. Strictly speaking, it is possible to determine the motion of the dice and predict the result. However, throwing a dice involves many physical processes and factors such as the initial conditions, wind, friction, air resistance, etc., which are very difficult to be determined. Therefore, we use "chance" to explain why the frequency of getting "1" is about 1/6 of the total attempts. Back to the fine-tuning phenomena, we do not really know whether these fine-tuning phenomena are deterministic or indeterministic. Also, we do not know the mechanism how these fine-tuning conditions can be generated. Therefore, using chance to explain the fine-tuning phenomena is not a good explanation.

Secondly, Schlesinger thinks that a significant surprising improbable event is different from a normal improbable event. He says "*a significant surprise, of the sort that is relevant to confirmation theory, is one which licitly demands an adequate explanatory hypothesis showing that in fact nothing puzzling has*

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[254] W. H. Wong, "The Cosmic Lottery," *International Journal for Philosophy of Religion*, 66(2009): 155-165 (in p.164).
[255] John Leslie, *Universe* (New York: Routledge, 1989), p.156.

taken place. Now an appropriate explanation has to provide a plausible reason why a given event, rather than something else, has actually occurred."[256] He further uses an example to illustrate this idea. Scientists now know that the inertial mass of an object is equivalent to its gravitational mass. Schlesinger supposes that the inertial and gravitational masses are not equivalent, but one is precisely 17.35 times greater than the other. It is safe to assert that in that case scientists would not feel an overwhelming urge to search for a theory to explain this ratio. However, it turns out that the ratio between two masses is 1, and this has been a source of acute concern. Scientists want to find a theory to explain why the ratio is exactly 1.[257] Einstein worked for many years to develop General Relativity to explain the ratio 1.[258] In other words, the ratio "17.35" is not a special number while the ratio "1" is. Although these two numbers are equally improbable out of infinitely many numbers, but the ratio "1" has an extremely special kind of value and it should be very puzzling if no unifying explanation can be found based on our background knowledge. The major difference between "1" and "17.35" is that the former number is exactly an integer while the latter one is just a ratio. Also, the integer "1" here indicates that the inertial mass may be identical to the gravitational mass. Therefore, as mentioned by Schlesinger, our background knowledge serves as the basis for judging the acceptability of a suggested explanation. If a man wins 1000 consecutive gambling games in a casino and earns a lot of money, we would believe that he is cheating rather than he wins by chance. It is because this significant surprising improbable event can be explained easily by another explanation (he is cheating). Similarly, since the life-permitting conditions have a special kind of value – making life possible, it is still puzzling if we use the chance-alone hypothesis to "explain" the fine-tuning phenomena. Therefore, we should seek another better explanation, and later we will see that there exists some better explanations to explain the fine-tuning phenomena.

In fact, since the probability of getting the fine-tuned values randomly is extremely small, the chance-alone hypothesis suggests that all constants and conditions should probably lie outside the anthropic region. In other words, the chance-alone hypothesis does not help to raise the prior probability of the fine-tuning evidence to a higher value, i.e. $P(FT|Chance) \approx P(FT)$. Therefore, by equation (2.2), we get $P(Chance|FT) \approx P(Chance)$, which means that the chance-alone hypothesis cannot be confirmed according to the confirmation theory. However, since $P(Chance|FT) \neq 0$, it could still be a possible solution if there is no other better hypothesis.

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[256] George Schlesinger, *New Perspectives on Old-time Religion* (Oxford: Clarendon Press, 1988), p.127.
[257] Isaac Newton asked this question too when he discovered this. He treated this ratio 1 to be a coincidence.
[258] George Schlesinger, *New Perspectives on Old-time Religion* (Oxford: Clarendon Press, 1988), p.128.

6.2 The existence of a Super-law

It is possible for our nature to have a "super-law" such that it "forces" all the fundamental constants into the life-allowing region. If this is true, the fine-tuning phenomena could be simply explained by a single physical law.

As mentioned in chapter 3, there are four fundamental forces in the nature. We now know that at certain energy scales, these forces may combine together and become unified. The unification of electromagnetic force and weak force is known as the electroweak force. Many predictions from the electroweak theory have been verified. Later, theoretical physicists start to unify the strong force and the electroweak theory to form a theory called Grand Unified Theory (GUT). Some predictions have been made but not yet confirmed. For example, the life time of proton predicted by GUT is 10^{32} years while the recent experimental bounds put it to be greater than 10^{34} years.[259] Although the GUT is not favored by the observations, one can still further unify the strong force, electroweak theory and the gravitational force into a single framework theoretically. However, this is much more difficult because when we focus on very small scale within a particle, the uncertainty in energy becomes large due to the Uncertainty Principle in quantum mechanics, and the gravitational effect would be very large predicted by the General Relativity. This is known as the "normalization problem". Nevertheless, if we do not treat particles as point particles but something like one-dimensional strings or higher dimensional objects, the normalization problem can be solved. This theory is called the string theory.

The string theory is now a well-developed theory. Although none of its predictions have been verified, string theory itself is highly self-consistent. After the first revolution of string theory, there are five different models that can explain the main features of the standard model in particle physics. These models are "Type I theory", "Type IIA theory", "Type IIB theory", "Heterotic SO(32)" and "Heteotic $E_8 \times E_8$ theory".[260] Later, Edward Witten proves that all these five different models are indeed five different equivalent versions of a single theory called M-theory. These five models are related to each other through the M-theory. However, we do not know much about the content of the M-theory. What we now know is that there may exist a most fundamental theory called M-theory which has a potential to explain everything in physics.[261] Therefore, it has been suggested that if we can obtain the M-theory, we might be able to derive the observed fundamental constants from this "super-law" (M-theory). In other words, the values of the fundamental constants might not be contingent, but "decided" by natural laws.

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[259] Stephen Hawking and Leonard Mlodinow, *The Grand Design* (New York: Bantam Books, 2010), pp.111-112.
[260] S.-T. Yau and S. Nadis, *The Shape of Inner Space* (Taipei: Yuan-Liou Publishing, 2012).
[261] Ibid.

However, based on the current scientific evidence, the string theory is not yet confirmed by experiment. Even for its supporting theory, the supersymmetry theory, is not favored by Large Hadron Collider experiments.[262] In fact, the string theory is still developing. We do not have any idea how the fundamental constants can be derived from the string theory. According to the DN-model in scientific explanation, since the string theory does not have any empirical content to explain the observed fundamental constants, it should not be qualified to become an explanation.

Furthermore, even if string theory is true and it really explains the fine-tuning phenomena, we still need to ask why we have such a super-law such that many physical constants are fine-tuned. It is because the super-law must involve some particular content (in specific mathematical forms) so that the physical constants must be those observed values. In other words, the super-law should also be fine-tuned in such a way that we can get all those fine-tuned constants. Therefore, invoking super-law to explain the fine-tuning phenomena is just moving the need for explanation to an upper level.

In view of this, Flew points out that "*the important point is not merely that there are regularities in nature, but that these regularities are mathematically precise, universal, and tied together… The question we should ask is how nature came packaged in this fashion.*"[263] Also, Davis thinks that a threefold-question should be asked: "*Where do the laws of physics come from? Why is that we have these laws instead of some other set? How is that we have a set of laws that drives featureless gases to life, consciousness and intelligence?*"[264] It means that the existence of any precise laws definitely requires an explanation, unless we accept that the existence of the super-law is a brute fact. At least, the existence of a supernatural being might be able to provide an explanation to the existence of natural laws. We should not simply accept that the existence of the super-law is a brute fact.

Besides, the initial conditions should be independent of the super-law. Therefore, the super-law cannot "control" the initial conditions such that it is fine-tuned for life. As mentioned in previous chapters, many initial conditions are fine-tuned for the existence of life. Lewis had already pointed out that natural laws are more or less like the rule of addition.[265] Natural laws tell you that if you save $1,000 a month, you will have $3,000 after three months. Natural laws cannot guarantee you have $3,000 in the bank if you did not deposit any money. The actions (put money into the bank) together with the laws (addition rule) enable

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[262] Supersymmetry theory predicts that there are many supersymmetry particles. However, none of the particles is seen in the Large Hadron Collider experiments.

[263] Antony Flew, *There is a God* (New York: HarperOne, 2007), p.96.

[264] The original article has been removed from the internet. Reader may refer to Antony Flew, *There is a God* (NY: HarperOne, 2007), p.108.

[265] C. S. Lewis, *Miracles* (London: Fontana, 1974).

your money to accumulate correctly.[266] Similarly, initial conditions together with natural laws enable our universe to be created.[267] All the natural laws require initial conditions such as specifying the initial entropy, the initial (primordial) quantum fluctuations, and the initial inflation field. Natural laws, including the string theory, cannot generate these conditions.

Therefore, the explanation of the fine-tuned constants and conditions cannot be addressed by natural super-law itself. Science can only push this problem to a more fundamental level, but can never fully address this issue. In fact, it is quite easy for us to confuse the terms "cause" and "agency". Natural laws can tell you the cause of an event, given that all initial conditions are known. However, natural laws will not tell you who or what makes the laws (the agency).[268] For example, natural laws can tell you how a steam engine works, but not who makes the steam engine.[269] Similarly, natural laws can only tell you "how" but not "who" or "why".[270] Therefore, it is hopeless to invoke natural laws to explain the fine-tuned fundamental constants and conditions.

6.3 Anthropic principle and observational selection effect

6.3.1 The anthropic principle

The anthropic principle states that we should not be surprised in observing the fine-tuning phenomena. It is because if all the fundamental constants or initial conditions were not within the life-permitting region, we would not exist and would not be able to observe them. Therefore, the argument becomes:

$\sim$ (life-permitting condition) $\rightarrow$ $\sim$ (we exist)

$\therefore$ (we exist) $\rightarrow$ (life-permitting condition)[271]

Therefore, our existence guarantees that all the fundamental constants and initial conditions must fall into the life-permitting region. This is known as the anthropic principle. In fact, this principle has different versions. The "weak anthropic principle" states that a theory must be compatible with evidently true data of observation. The "strong anthropic principle" states that the constants and laws of nature must be such

[266] J. C. Lennox, *God and Stephen Hawking: Whose Design Is It Anyway?* (Oxford: Lion Hudson, 2011).
[267] Details of the argument can be seen in Man Ho Chan, "Can Natural Laws Create Our Universe?" *Perspectives on Science and Christian Faith*, 66(2014): 35-39.
[268] Ibid.
[269] R. J. Asher, *Evolution and Belief* (Cambridge: Cambridge University Press, 2012), p.5.
[270] R. J. Asher, *Evolution and Belief* (Cambridge: Cambridge University Press, 2012), pp.14-15.
[271] Here, A $\rightarrow$ B means "A entails B".

that life can exist.[272] These two different versions insist that our existence and the life-permitting conditions are inter-related.

Therefore, some philosophers claim that P(FT|existence) = 1, which means that the probability of fine-tuning is not very low, but a necessary outcome. For example, Stenger states that since P(FT|natural law and our existence) = 1, the apparent fine-tuning phenomena also supports naturalism.[273] His statement is just another equivalent form of the anthropic principle. Therefore, they claim that this anthropic principle can already give a good explanation for the fine-tuning phenomena. However, some argue that the compatibility of the fine-tuning effect and our existence does not amount to an explanation. Leslie gives an example (example of the prisoner) to illustrate this:

"On a certain occasion the firing squad aim their rifles at the prisoner to be executed. There are twelve expert marksmen in the firing squad, and they five twelve rounds each. However, on this occasion all 144 shot miss. The prisoner laughs and comments that the event is not something requiring any explanation because if the marksmen had not missed, he would not be here to observe them having done so. But of course, the prisoner's comment is absurd; the marksmen all having missed is indeed something requiring explanation; and so too is what goes with it – the prisoner's being alive to observe it. And the explanation will be either that it was an accident (a most unusual chance event) or that it was planned (e.g., all the marksmen had been bribed to miss). Any interpretation of the anthropic principle which suggests that the evolution of observers is something which requires no explanation in terms of boundary conditions and laws being a certain way (either inexplicably or through choice) is false."[274]

This example illustrates that the survival of the prisoner relies on some fine-tuned conditions (unusual chance event or the marksmen intend to miss) but not that the fine-tuned conditions rely on the survival of the prisoner. Therefore, the relation of the fine-tuning phenomena and our existence should be "(fine-tuning) → (we exist)" but not "(we exist) → (fine-tuning)". The former one should be the correct causal relationship. Moreover, the fundamental constants and initial conditions fall into the life-allowing region does not mean that they must be fine-tuned. In general, coarse-tuning of the constants and conditions can also allow life to exist. Therefore, our existence does not entail that our universe is fine-tuned. In other words, we still need to seek an explanation for fine-tuning phenomena because there should be something else which has caused the fine-tuning. The above mentioned weak anthropic principle is just showing the

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[272] Richard Swinburne, "Argument from the Fine-Tuning of the Universe," *Modern Cosmology and Philosophy*, ed. J. Leslie (NY: Prometheus Books, 1998), p.171.

[273] Victor Stenger, *The Fallacy of Fine-tuning: Why the Universe is not Designed for Us* (New York: Prometheus Books, 2011), p.254.

[274] This story has many different versions. Here I refer to the one appeared in Elliot Sober, "The Design Argument," *The Blackwell Guide to the Philosophy of Religion*, ed. W. E. Mann (Oxford: Blackwell Publishing, 2005), p.137.

relation and consistency between the life-permitting conditions and our existence, but not a valid explanation of fine-tuning.

In fact, the consistency shown by the anthropic principle cannot be regarded as an explanation. An explanation is an adequate description of underlying causes helping to bring about the phenomenon to be explained.[275] As mentioned above, there are two kinds of explanation – personal explanation and scientific explanation. Clearly, the anthropic principle is not a personal explanation. We have to determine whether it is a scientific explanation. What makes a scientific explanation explanatory is that it tells us why an event had to occur, why the event was necessary once the basis is there and the laws are accepted.[276] Based on the pattern of scientific explanation, Hempel suggests that the explanandum must be logically deducible from the information contained in the explanans. Also, the explanans must contain general laws and have empirical content.[277] Therefore, the anthropic principle definitely cannot serve as a scientific explanation of fine-tuning. This principle does not have any information and empirical content. Also, the existence of life can only entail the constants and conditions are life-allowing, but not fine-tuned. It is logically possible that the life-allowing conditions are coarse-tuned.

6.3.2 The observational selection effect

Sober suggests an effect called "the observational selection effect" (or anthropic bias) to explain the fine-tuning phenomena. It is an improved version of the anthropic principle which involves one more assumption. He suggests that our existence may provide some bias on observing the fundamental constants. He follows the idea from Bostrom who argues that any special features of the universe which we might observe may be ultimately illusory, because of our restricted viewpoint.[278] Sober further elaborates this effect by using an analogy:

"Suppose I catch 50 fish from a lake, and all the fish I caught were more than 10 inches long (observation O). You may conclude that all the fish in the lake are more than 10 inches long (hypothesis

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[275] Richard Miller, *Fact and Method: Explanation, Confirmation and Reality in the Natural and the Social Sciences* (Princeton: Princeton University Press, 1987), p.60.

[276] David-Hillel Ruben, *Explaining Explanation* (London: Routledge, 1990), p. 27.

[277] Carl Hempel, *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science* (New York: The Free Press, 1965), pp.247-248.

[278] Nick Bostrom, *Anthropic Bias: Observation Selection Effects in Science and Philosophy* (New York: Routledge, 2002), pp.11-58.

F). However, you then discover that the net can't catch fish smaller than 10 inches because of the sizes of its holes (assumption A). Therefore, the probability of getting 10 inches fish is P(O|F and A) = 1." [279]

In other words, Sober argues that the very nature of our existence as observers introduces a bias into our evidence. He also responds to the example of the prisoner by using the observational selection effect. He mentions that the issue isn't whether the prisoner's survival requires explanation, but whether this observation provides evidence as to whether the marksmen intended to spare the prisoner or shot at random.[280] He suggests that we should compare the prisoner's reasoning with that of a bystander who witnesses that the prisoner survives from the firing squad. It is reasonable for the bystander to conclude that the prisoner's survival is due to the marksmen's intention (P(the prisoner survived|the marksmen intended to miss) > P(the prisoner survived|the marksmen fired at random)) because he/she is independent of the prisoner's survival. However, the prisoner is subject to the observational selection effect, which should be P(the prisoner survived|the marksmen intended to miss and the prisoner survived) = P(the prisoner survived|the marksmen fired at random and the prisoner survived) = 1. Therefore, the prisoner and the bystander are in different epistemic situations. [281]

In view of this, he applies a concept called "blindspots" proposed by Sorensen.[282] A proposition p is a blindspot for an individual S just in case, if p were true, S would not be able to know that p is true.[283] If p is a blindspot for S, then if S marks an observation to determine the truth value of p, the outcome must be that not-p is observed. The prisoner, but not the bystander, has "the prisoner does not exist" as a blindspot.[284] Moreover, Sober thinks that it is not possible to determine the probability that a prisoner will survive because he does not have information about the estimation of probability. A probability should be calculated based on counting the total number of outcomes compared with the total trials. Therefore, a single survivor cannot know that the marksmen's intention is more likely than chance.[285]

To summarize, Sober suggests that (P1) we have a restricted viewpoint because "we do not exist" is a blindspot; and (P2) an observer has blindspot so that he/she does not share a bystander viewpoint.

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[279] Elliot Sober, "The Design Argument," *The Blackwell Guide to the Philosophy of Religion*, ed. W. E. Mann (Oxford: Blackwell Publishing, 2005), p.133.

[280] Elliot Sober, "The Design Argument," *The Blackwell Guide to the Philosophy of Religion*, ed. W. E. Mann (Oxford: Blackwell Publishing, 2005), p.137.

[281] Ibid, p.138.

[282] Roy Sorensen, *Blindspots* (Oxford: Oxford University Press, 1988).

[283] Elliot Sober, "The Design Argument," *The Blackwell Guide to the Philosophy of Religion*, ed. W. E. Mann (Oxford: Blackwell Publishing, 2005), p.138.

[284] Ibid, p.139.

[285] Ibid, p.139

Therefore, our observations of the fine-tuned conditions are biased. We need not be surprised by the fine-tuning phenomena. No special explanation is needed.

Based on the definition of the blindspot, Sober's premise (P1) is correct. While for the premise (P2), he assumes that the viewpoints from the prisoner and the bystander are radically different, is questionable. Weisberg argues that based on enough physical knowledge and human experience, the third person (bystander) and first person (observer) can have identical epistemic starting points and epistemic inputs.[286] It is because the prisoner and the bystander can share similar physical knowledge and experience. A rational agent has rational power to think objectively. Unless the required knowledge or experience are totally subjective, it is not reasonable to separate the viewpoints from different persons. Based on our evaluation of the fine-tuning phenomena, the discussion so far is objective. Therefore, there is no difference between the "bystander" and the "observer". Since the bystander does not have any observational selection effect, similarly, the observer should also not be subject to any observational selection effect either. This view can be justified by using an example. Human beings were evolved through biological evolution many years ago. Strictly speaking, we are observers of the evolution. If observational selection effect exists, all evolution biologists suffer from their "blindspots" and all of their observations are biased. This view is obviously wrong. Biologists can objectively study evolution and the related mechanisms. We can understand how evolution occurs and investigate the processes. We do not say due to the observational selection effect, the evolution of human beings is not very special and we need not seek any special explanation. Similarly, we still need to seek a special explanation for the fine-tuning phenomena.

Therefore, the anthropic principle can only show the consistency between the observed life-permitting conditions and our existence, but not the explanation of fine-tuning. Also, it is not justified why the viewpoints from a bystander and an observer are radically different. Based on the above arguments, the anthropic principle and the observational selection effect cannot provide a viable explanation for the fine-tuning.

6.4 God hypothesis

God hypothesis is one of the major hypotheses to explain the fine-tuning phenomena. Based on the definition of God in chapter 1, He is omnipotent, omniscient and perfectly good. It is logically possible

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[286] Jonathan Weisberg, "Firing Squads and Fine-Tuning: Sober on the Design Argument," *British Journal of Philosophy of Science*, 56(2005): 809-821.

that God creates the nature by fine-tuning all the initial conditions and fundamental constants. Although it is very difficult for us to know how He fine-tuned the conditions and constants, it does not affect the validity of the argument. He might initially set the right constants and conditions to let the world and intelligence evolve naturally, or He might intervene in the nature by changing the conditions if something is not on the right track.

According to the confirmation theory, a theory T can be regarded as confirmed if P(T|E) > P(T). This is satisfied if and only if P(E|T) > P(E). Therefore, the necessary condition is that the theory T renders E probable (T raises the probability of getting E). In this context, the theistic solution requires P(FT|God) > P(FT), i.e. the existence of God raises the probability of getting a fine-tuned universe. This is true if we have[287]

$$P(FT|God) > P(FT| \sim God). \hspace{3cm} (6.2)$$

6.4.1 Formalism

Swinburne suggests that if God is perfectly good, in the sense of always doing the best action or an equal best kind of action, there is quite a probability that God will create humans:

"He has good reason to cause the existence of souls join them to bodies, in the goodness of the existence of embodied animals and human beings who can have enjoyable sensations, satisfy their desires, have their beliefs about what the world is like, and form their own purposes in the light of these beliefs which make a difference to the world."[288]

Moreover, it is a good choice if God creates intelligent humans such that they can communicate with God and understand the great creation from God. On the other hand, if there is no God, as mentioned above, the probability of getting fine-tuned universe by random processes and our existence is extremely low. Since God is omniscient, He knows that fine-tuning the parameters and condition can make our existence possible. Since God is omnipotent, He can rightly set all the fundamental constants and initial conditions in order to achieve His plan. Therefore, the three basic properties of God, omnipotent, omniscient and perfectly good, make it quite probable for God to create human beings by fine-tuning the fundamental

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[287] Since $P(FT) = P(FT|God)P(God) + P(FT|\sim God)P(\sim God) = P(FT|God)[1 - P(\sim God)] + P(FT|\sim God)P(\sim God)$, we have $P(FT|God) - P(FT) = [P(FT|God) - P(FT|\sim God)]P(\sim God)$. See Bradley Monton, "God, Fine-tuning, and the Problem of Old Evidence," *British Journal of Philosophy of Science* 57(2006): 405-424.

[288] Richard Swinburne, *Is There a God?* (Oxford: Oxford University Press, 2010), p.80.

constants and initial conditions. As a result, the existence of God would raise the prior probability of fine-tuning P(FT) to a higher value of P(FT|God). Since P(FT|God) > P(FT), we have P(God|FT) > P(God). The fine-tuning phenomena support the existence of God, and the God hypothesis is confirmed.

6.4.2 Theodicy

In the above discussion, we assume that the creation of intelligent humans is an overall good decision. This is equivalent to saying that the existence of intelligent humans is better than the non-existence of intelligent humans. However, if the total amount of evils or sufferings is much greater than that of goods, the creation of intelligent humans might not be an overall good decision. Therefore, a theodicy is required to show that there is a significant probability that any evil on earth is such that by allowing it to occur, a perfectly good God forwards some good purpose which could not be forwarded in any better way.[289] Swinburne suggests that it is not morally wrong for God to create or permit the various evils, normally on the grounds that doing so is providing the logically necessary conditions of greater goods.[290] For example, it is a good thing that there exist free agents (human beings), but a logically necessary consequence of their existence is that their power to choose to do evil actions may sometimes be realized. Swinburne thinks that "a world in which no one except the agent was affected by his evil actions might be a world in which men has freedom but it would not be a world in which men has responsibility."[291] Therefore, it is a price (existence of evils) which must be paid if they are to have those responsibilities.

In fact, theodicy is one of the most controversial issues in philosophy of religion. We do not have the space to discuss this issue rigorously in this thesis. Nevertheless, numerous sophisticated versions of theodicy may show that the creation of a perfectly free, responsible, and intelligent human may well be an overall good decision, though a certain amount of evils are permitted.[292] God would possibly want us to

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[289] Richard Swinburne, "Bayes, God, and the Multiverse", *Probability in the Philosophy of Religion*, eds. Jake Chandler and Victoria Harrison (Oxford: Oxford University Press, 2012), pp.102-123.

[290] Richard Swinburne, "A Theistic Response to the Problem of Evil", *Introduction to Philosophy: Classical and Contemporary Readings* (Belmont, California: Wadsworth, 2000), p.219.

[291] Richard Swinburne, "A Theistic Response to the Problem of Evil", *Introduction to Philosophy: Classical and Contemporary Readings* (Belmont, California: Wadsworth, 2000), p.222.

[292] For example: John Hick, "Solutions to the Problem of Evil", *Philosophy for a New Generation*, eds. A. K. Bierman & J. A. Gould (London: Macmillan, 1980), pp.474-479; Richard Swinburne, "A Theistic Response to the Problem of Evil", *Introduction to Philosophy: Classical and Contemporary Readings* (Belmont, California: Wadsworth, 2000), pp.216-230; Peter van Inwagen, *The Problem of Evil* (Oxford: Oxford University Press, 2006); William Hasker, *The Triumph of God over Evil: Theodicy for a World of Suffering* (IL: InterVarsity Press, 2008); Richard Swinburne, *Is There a God?* (Oxford: Oxford University Press, 2010), chapter 6; Eleonore Stump, *Wandering in Darkness: Narrative and the Problem of Suffering* (Oxford: Clarendon Press, 2010).

learn responsibilities and become more mature. That might be His goals and plans. Here we just assume that these possibilities have not yet been disproved.

Even if we cannot find an appropriate theodicy to solve the problem of evil, this would not affect too much our conclusion. What we need to do is to fine-tune the God hypothesis and assume a deity is omnipotent, omniscient and not perfectly good. Even we can postulate that an evil deity creates humans to suffer in the universe. As a result, this revised hypothesis can still explain the fine-tuning phenomena. Therefore, whether the deity is good, partly good or evil can be treated as a degree of freedom. The major point is that the fine-tuning phenomena seem to challenge the naturalistic worldview and may indicate some form of supernaturalism. In other words, in so far it poses a challenge to naturalism.

6.4.3 Prior probability of God hypothesis

Based on the confirmation theory, we need to check whether P(God) is non-zero. If P(God) is zero, the posterior probability P(God|FT) must be zero no matter how high the likelihood probability is. The prior probability P(God) is zero if the concepts in the God hypothesis are incoherent. Based on the formalism, we assume that God is omnipotent, omniscient and perfectly good. Are the three concepts coherent? We have discussed the concept of perfect goodness in the above section. As mentioned above, an appropriate theodicy can show that the existence of a perfectly good God is compatible with a world with evil. Therefore, the concept of perfect goodness is coherent. How about the other two?

Throughout the history, many philosophers propose that omnipotence is an incoherent concept. Some of them used a famous paradox – the stone paradox – to indicate the problem. It questions "can God make a rock so heavy that he cannot lift it?"[293] It seems that no answer to it could be satisfactory. If God cannot make the rock, then He is not omnipotent. If He can make it, He would not be able to lift it and hence He is not omnipotent. To deal with this problem, Swinburne defines the term omnipotence as follow: A person P is omnipotent at a time t if and only if he is able to bring about any logically contingent state of affairs after t, the description of which does not entail that P did not bring it about at t.[294] According to this definition, if God really exercises His ability to bring about the existence of the stone that He cannot

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[293] Michael Murray and Michael Rea, *An Introduction to the Philosophy of Religion* (Cambridge: Cambridge University Press, 2008), p.15.
[294] Richard Swinburne, *The Coherence of Theism* (Oxford: Oxford University Press, 1993), p.156.

lift, He will cease to be omnipotent. Nevertheless, God may remain omnipotent forever because he never exercises His power to create that stone.[295] Therefore, the concept of omnipotence is a coherent concept.

How about the concept of omniscience? As Swinburne argues, persons obviously can know much. It is definitely possible for a person to know all true propositions.[296] However, we should notice that the concept of omniscience may be incompatible with free wills. Swinburne states that "*God does not foreknow anything. He knows it as it happens, but there is no moment at which he does not know it. Hence He is omniscient in the sense which I have been considering, because all things are present to him.*"[297] Here, the meaning of omniscience does not include controlling others' free wills or foreknowing everything. Therefore, if God is not a timeless God, the concept of omniscience can be a coherent concept.

If there is no incoherent concept in the God hypothesis, P(God) is non-zero. Furthermore, this prior probability can be raised if we have other evidence which shows the existence of God is at least somewhat probable. In the following, I outline another argument, the Kalam Cosmological Argument, which can increase the value of P(God).

The Kalam Cosmological Argument can be formulated as follow:[298]

P1: Whatever begins to exist has a cause of its coming to exist.

P2: The universe began to exist.

C: The universe has a cause of its coming to exist.

The conclusion C derived from the two premises P1 and P2 needs an explanation. It is commonly believed that the existence of God is the ultimate cause or explanation.[299]

Is the premise P1 always true? Modern quantum physics allows particles to be created from "nothing" (vacuum). The Hawking's radiation can be generated around a black hole through this process. The only "cause" for these created particles is quantum fluctuations, which is a random process without any specified conditions. However, it is not very precise to say that the particles are really created from

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[295] Ibid, p.161.
[296] Ibid, p.167.
[297] Ibid, pp.178-179.
[298] Michael Murray and Michael Rea, *An Introduction to the Philosophy of Religion* (Cambridge: Cambridge University Press, 2008), p.143.
[299] William Craig, "The Kalam Cosmological Argument", *The Philosophy of Religion Reader*, ed. C. Meister (New York: Routledge, 2008), chapter 18.

"nothing". Quantum mechanics shows that both the minimum energy and the energy fluctuation are not zero for vacuum. Some energy is extracted from the vacuum to create the particles and these particles annihilate to return the energy back to the vacuum. These particles are virtual particles, and the cause of these particles is the energy fluctuation. Besides, the creation of these particles must follow the rules from quantum physics, though the rules are indeterministic.[300] In general, if an event occurs randomly, its cause is called a stochastic cause.[301] Therefore, the creation of particles from vacuum is just an example of a stochastic cause. It is still reasonable to say that P1 is true.

The premise P2 can be verified. Recent studies in the cosmological microwave background indicate that the age of our universe is about 13.7 billion years old.[302] This evidence is independent of the fine-tuning phenomena. However, Hawking has pointed out that our universe may not have a beginning. He supposes that the beginning of the universe was like the South Pole of the earth, with degrees of latitude playing the role of time. As one moves north from the South Pole, the circles of constant latitude, representing the size of the universe, would expand. The universe would start as a point at the South Pole, but the South Pole is much like any other point. Technically speaking, Hawking is suggesting the time at the very beginning is an imaginary number rather than a real number (no "t = 0" exists).[303] Therefore, if our universe is considered in this way, it has no boundary in space and time.[304] I agree with Hawking that the South Pole is not so special in this analogy. However, this analogy only states that the starting time t = 0 is not a special time, but it does not explain why we have a beginning of time t = 0. In other words, even if Hawking's suggestion is true, there would exist a transition such that time is changing from an imaginary value to a real value. However, the proposed imaginary time epoch is ontologically unreal and unintelligible.[305] Holder thinks that there are some difficulties involved in ontologizing imaginary time. If there is an imaginary time, then how can time flow? How can anything change?[306] Since there is a particular moment for the transition (from imaginary time to real time), our universe is transformed from an ontologically unreal state to an ontologically real state. If the transition exists, strictly speaking, our

[300] Michael Murray and Michael Rea, *An Introduction to the Philosophy of Religion* (Cambridge: Cambridge University Press, 2008), p.144.

[301] Richard Johns, "Inference to the Best Explanation", http://faculty.arts.ubc.ca/rjohns/ibe.pdf.

[302] D.N. Spergel *et al.*, "Three-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Implications for Cosmology," *Astrophysical Journal Supplement* 170(2007): 377-408.

[303] An imaginary number is usually expressed as z = a + bi, where $i = \sqrt{-1}$ and a, b are real numbers.

[304] Stephen Hawking and Leonard Mlodinow, *The Grand Design* (New York: Bantam Books, 2010), pp.134-135.

[305] William Craig and James Sinclair, "The Kalam Cosmological Argument", *The Blackwell Companion to Natural Theology*, eds. W. L. Craig and J. P. Moreland (Oxford: Wiley-Blackwell, 2009), p.179,

[306] Rodney Holder, *God, the Multiverse, and Everything: Modern Cosmology and the Argument from Design* (Hampshire: Ashgate, 2004), p. 59.

universe began to exist and something has to cause its existence.[307] In fact, recently, Craig and Sinclair examine most of the popular models which can generate an eternal universe. However, they find that none of them can really get a beginningless universe.[308] In other words, our universe is very likely to have a beginning.

Therefore, there is no strong reason why premises P1 and P2 are wrong. If these premises are true, then the universe has a cause of its coming to exist. The probability of getting this cause with God is higher than without God, P(universe exists|God) > P(universe exists|$\sim$ God). Therefore, P(God|universe exists) > P($\sim$ God|universe exists). This result raises the value of P(God) before consideration of the fine-tuning phenomena.

6.4.4 Criticisms of the God hypothesis

Sober thinks that if we say God is omnipotent, He is not predictable.[309] How can we know God would create humans and thus fine-tuned our universe? He believes that nothing can be said about design without independent evidence as to the putative designer's goals and abilities.[310] Later, Saward argues that it is not possible to generalize the conclusion about which hypothesis is better. The explanatory power of a hypothesis is strongly dependent on the actual content of the hypothesis. For example, there are many choices of God such as evil-god, good-god, etc. One cannot generalize about all the God hypotheses to arrive at any conclusion.[311]

Although we do not know everything about God, we can still assume some properties of God based on our thoughts. For example, most religious believers thought that God is omnipotent, omniscient and perfectly good. This enables us to postulate a hypothesis – the God hypothesis. Based on these limited properties, we can assess whether God would create human or not. Moreover, McGrew suggests that the knowledge of design can be inferred from a human designer. Although a human designer is not the same as God, we still have some knowledge about God based on their common characteristics.[312] As Aquinas

[307] Man Ho Chan, "Can Natural Laws Create Our Universe?", *Perspectives on Science and Christian Faith* 66(2014): 35-39.

[308] William Craig and James Sinclair, "The Kalam Cosmological Argument", *The Blackwell Companion to Natural Theology*, eds. W. L. Craig and J. P. Moreland (Oxford: Wiley-Blackwell, 2009), chapter 3.

[309] Elliot Sober, "The Design Argument", *The Blackwell Guide to the Philosophy of Religion*, ed. William Mann (Oxford: Blackwell Publishing, 2005), pp.117-147.

[310] Ibid, pp.117-147.

[311] Mark Saward, "Fine-Tuning as Evidence for a Multiverse: Why White is Wrong," *International Journal for Philosophy of Religion* 73 (2013): pp.243-253.

[312] Timothy McGrew, "Testability, Likelihoods and Design", *Philo* 7(2004): 5-21.

argues that the likeliness between God and human beings (the creatures) is established by God in the act of creation.[313] In the God hypothesis, God as a being creates human beings. By using the analogy of being, it is natural to claim that human beings are similar to God to some extent. Therefore, the use of analogies based on creatures to refer to God is thus not arbitrary, but is ultimately grounded in creation itself.[314] In fact, modern science also uses analogies to build new theories. For example, although the correct form of the "super-symmetry theory" is not known, most physicists develop "super-symmetry theory" based on the symmetry found in other theories, such as the electro-weak theory. It is because physicists believe that these theories should share some similarities in the formalism.

Certainly, based on our pure thoughts and common experience, the assumptions in the God hypothesis may be wrong. Nevertheless, treating God in analogy with the human designer is the simplest and plausible way for us to establish the God hypothesis for assessment. The evidence in the assessment would tell us whether the hypothesis is confirmed or not. In principle, we can create any God hypothesis to test. For example, as mentioned in 6.4.2, we can assume that God is evil. If we really find that our universe is full of inexplicable evils, then we can conclude that the evil-god proposal is confirmed. Therefore, it is not necessary for us to fully understand the nature of God. We can generally postulate any properties which are coherent and then do the assessment.

Let's further discuss this point by an example in modern science. Recently, scientists claim that Higgs particle is discovered. How do we know that the particle discovered is really the Higgs particle? Before the discovery of Higgs particle, we do not know much about it. However, based on some extended theories from Standard Model, we are able to predict some (or a few) behaviors of a Higgs particle such as its decay channel and range of mass. These predictions are not certainly correct because we do not have a confirmed theory about the extended Standard Model. Fortunately, based on this unconfirmed model, we discover an unknown particle in the experiment such that the observed decay channels and range of mass are consistent with the theory. In other words, the experimental observations support the Higgs hypothesis as well as the extension of Standard Model. Therefore, the confirmation of Higgs particle need not rely on any other independent evidence of Higgs particle. This story tells us that it is not necessary for us to know much about God before we can confirm the God hypothesis. A few characteristics based on some assumptions are enough for setting up a hypothesis to be tested even if these characteristics might be wrong. Certainly, there may be more than one hypothesis that can explain

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[313] Thomas Aquinas, *Summa contra Gentiles*, trans. Anton C. Pegis (Notre Dame: University of Notre Dame Press, 1975), vol. 1, pp.138-139.
[314] Alister McGrath, *The Foundation of Dialogue in Science and Religion* (Oxford: Blackwell, 1998), p.181.

the observations. In order to choose a best hypothesis, we have to compare the explanatory powers and the prior probabilities of different hypotheses. This comparison can be done by using the confirmation principle or inference to the best explanation.

Let's use one more example to illustrate that it is not necessary for us to know the exact properties of God. Consider an astronaut in Mars discovers a machine which can generate water when he puts sands in it. It is reasonable for him to conclude that this is a product of intelligence. Although he doesn't know who creates it and the properties of the creator, based on our common sense, we can safely conclude that the machine is designed by intelligent beings. Similarly, although we do not know all the properties of God, we can still assess whether the fine-tuning universe is designed by God.

Thus, by assuming some properties of God based on our limited knowledge or imagination, we can still assess the God hypothesis, even though we do not have other independent evidence for the exact goals or abilities of God. This is similar to the confirmation of Higgs particle based on our limited knowledge on extended Standard Model and Higgs particle. We don't say that Higgs particle is not confirmed because we have no other independent evidence to verify the existence and properties of Higgs particle. Therefore, in general, we can postulate different kinds of God hypothesis to see whether they can explain the fine-tuning phenomena.

Another objection to the God hypothesis is the problem of "who designs the designer", which was suggested by Hume many years ago.[315] Some philosophers suggest that any designer involved in explaining complexity in the universe will feature complexity of its own.[316] This requires an explanation in terms of design. Scientist Dawkins thinks that if God exists, God is intelligent and complicated beyond all imagination.[317] Therefore, God should be internally complex and hence requires a designer. If we don't know who designs the designer, how can we accept the existence of God? The problem of "who designs the designer" severely affects the persuasiveness of the design argument.

Basically, the complexity here involves two concepts: complexity of designer and complexity of designer's ideas. In view of this problem, Collins thinks that God is the simplest being who does not have any internal complexity.[318] Craig suggests that God Himself is a remarkably simple thing.[319] Moreover,

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[315] David Hume, *Dialogues Concerning Natural Religion* (Cambridge: Cambridge University Press, 2007), p.37.
[316] Lloyd Strickland, "The `Who Designed the Designer' Objection to Design Arguments", *International Journal for Philosophy of Religion* 75(2014): 87-100.
[317] Richard Dawkins, *The God Delusion* (London: Bantam Press, 2006), p.150.
[318] Robin Collins, "The Teleological Argument." In *The Routledge Companion to Philosophy of Religion*, eds. C. Meister and P. Copan (New York: Routledge, 2007), pp.351-361.
[319] William Craig, "Design and the Anthropic Fine-Tuning of the Universe", *God and design*, ed. N. A. Manson (London: Routledge, 2003), p.174.

Richmond and Barr both deny the complexity of God's thought.[320] They think that God has an infinite idea or thought. God can hold many things together in a single insight. Therefore, since the omniscient and omnipotent God is not a finite being, He is the simplest thing without any internal complexity. His infinite idea of thought involves no complexity in His ideas. As Leslie says, infinity is simpler than "five million and seventy".[321] In other words, no special explanation about the complexity of God is required.

Even if the creator of our universe is not an ultimate origin, it does not affect the assessment of the God hypothesis here. Swinburne mentions that the design argument is still valid even if we do not know the origin of the creator.[322] As the example mentioned above, the machine that the astronaut discovered can be confirmed as a product of intelligence, even though he doesn't know the origin of the intelligent being. In this thesis, we are going to ask whether the God hypothesis can explain the fine-tuning phenomena. If the creator is created by someone, it does not affect the truth that the creator creates the fine-tuned universe. In other words, whether the creator is created does not affect our conclusion.

6.4.5 Other non-naturalistic or theistic hypotheses

In our postulated God hypothesis, God is a transcendent being. However, recently some proposals suggest that God is not a transcendent being, but continuously interacting with the nature or identical to the nature. These theistic proposals can be regarded as "naturalistic theism" or "theistic naturalism". Generally speaking, there are various proposals and theories about naturalistic theism as there are many religious beliefs all over the world. In the following, we will discuss three major proposals, Pantheism, Panentheism and Confucianism.

6.4.5.1 Pantheism

Pantheism suggests that God is identical to the natural world (or universe). In this view, God is not a transcendent being. Therefore, God can't intervene with the natural world and the natural laws. If God cannot change the natural laws, it is doubtful if He can fine tune the fundamental constants and

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[320] See P. Richmond, "Richard Dawkins' Darwinian Objection to Unexplained Complexity in God", *Science and Christian Belief* 19(2007):pp.99-116 and Stephen Barr, "Stephen M. Barr." In *Open questions: Diverse Thinkers Discuss God, Religion, and Faith*, ed. L. F. Rodrigues (Santa Barbara: Praeger, 2010), pp.1-14.
[321] John Leslie, *Universe* (New York: Routledge, 1989), p.23.
[322] Richard Swinburne, "The Argument from Design", *Philosophy* 43(1968): 199-212.

conditions. Also, in Pantheism, God is not a personal God. It is difficult to justify why He wants to create human beings because the nature of human beings is totally different from a non-personal God.

Besides, if God is identical to the natural world, theistic account of the fine-tuning would be equivalent to the naturalistic account of the fine-tuning. In this sense, Pantheism can be thought of a naturalistic hypothesis, but not a non-naturalistic hypothesis. Therefore, it is not necessary for us to consider Pantheism.

6.4.5.2 Panentheism

Panentheism is closely related to "process theism" which states that God or a number of gods interpenetrate every part of the universe, including the atoms and molecules. The power of God is not coercive but persuasive. The direct influence of God is analogous to the power of thought over thought, of feeling over feeling, but never suppress all freedom. It implies that entities from quarks to atoms to cells and all the way up to humans have their own degree of freedom and self-determination.[323] In other words, God is not omnipotent and not omniscient.

In some sense, God is not totally supernatural because God can only "persuade" the nature but not control it. If it is true, we don't know whether He can fine-tune the fundamental constants and conditions because atoms have "freedom" to "reject" God's will. Since He is not omniscient, we don't know whether He can predict the evolution of human beings when the conditions are fine-tuned. Also, since He is not a personal God, it is difficult for us to use analogy to describe the will of God. Therefore, due to many uncertainties, it is not easy for us to logically deduce all the consequences and make prediction based on Panentheism. Although we cannot reject this proposal, it cannot be confirmed by using the confirmation principle.

6.4.5.3 Confucianism

Confucianism can be regarded as a form of naturalistic theism. It has a concept "heaven" (or Tian), which has some characteristics that overlap the category of deity.[324] However, different versions of Confucianism might have different descriptions about the properties of the "heaven". Therefore, whether Confucianism is a better option depends on the empirical content of the concept "heaven". In some

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[323] Charles Birch, *Science and Soul* (Philadelphia: Templeton Foundation Press, 2008), pp.161-162.
[324] Ronnie Littlejohn, *Confucianism: An Introduction* (New York: I.B. Tauris, 2010), pp.34-36.

original forms of Confucianism, the concept of "heaven" expresses a form of Pantheism.[325] If it likes a form of Pantheism, then, as mentioned above, it can be treated as a completely naturalistic theory. If the concept "heaven" is not identical to the natural world, then it would be close to Panentheism or the God hypothesis. If the "heaven" wants to create human beings and it can freely "control" the fine-tuned values and conditions, Confucianism can be regarded as a possible hypothesis to account for the fine-tuning phenomena. This general rule can also be applied to other forms of theism.

6.5 Multiverse hypothesis

Besides the God hypothesis, there are some hypotheses that are based on natural causes. Although these natural causes are still compatible with the existence of God (God can use these methods to create our universe), as mentioned in chapter 1, we regard all these as atheistic hypotheses in the following discussion (we will discuss the compatibility of the naturalistic causes and the existence of God in chapter 7).

So far we have discussed one of the possible naturalistic causes, the super-law explanation. However, as mentioned above, it cannot satisfactorily explain the fine-tuning phenomena. Another spectacular solution to the fine-tuning phenomena is the multiverse hypothesis. Multiverse hypothesis suggests that there are many universes which are independent of each other and may have different properties. If there are many universes in the nature, each has a particular set of fundamental constants and initial conditions, and we are just living in one of them, we should not be surprised why our universe is fine-tuned. It is because it may be more probable to have a universe in a multiverse such that it has the required anthropic fundamental constants and anthropic initial conditions. These right constants and initial conditions are chosen randomly from numerous universes. This is similar to a person winning a lottery randomly out of many participants. Therefore, the existence of multiverse may provide a satisfactory explanation of the fine-tuning phenomena. In general, a four level taxonomy of multiverse cosmologies has been proposed:[326]

Level 1: The infinite Ergodic universe – a universe that has many Hubble volumes with all possible initial conditions but homogeneous laws (same fundamental constants).

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[325] Homer Dubs, "Theism and Naturalism in Ancient Chinese Philosophy", *Philosophy East and West* 9 (1959): 163-172.

[326] See Max Tegmark, "The Multiverse Hierarchy," *Universe or Multiverse*? ed. B. Carr (Cambridge: Cambridge Universe Press, 2007), pp.99-100, and Colin Coleman, "Cosmic Fine Tuning and the Multiverse Hypothesis," arXiv: 1207.5396.

Level 2: Bubbles' universe – many different universes with different laws and fundamental constants.

Level 3: Metaphysical universes – many different universes based on the many-worlds interpretation of quantum mechanics. These universes exist in an infinite dimensional Hilbert space rather than real physical space.

Level 4: Multiverse motivated by a principle of mathematical democracy – any universe that is possible in mathematical structure exists in reality.

For the level 1 multiverse, it means that our universe (just one universe) consists of many observable universes, but not many different universes.[327] In principle, all the observable universes must have the same set of fundamental constants, but different initial conditions. In other words, the level 1 multiverse can only use chance-alone hypothesis to address the fine-tuning phenomena because there is only one set of fundamental constants. Since it is very unlikely to get the fine-tuned fundamental constants by chance, in the following discussion, we will just focus on the level 2, 3 and 4 multiverse theories.

For the level 2 multiverse, it is predicted by most currently popular models of inflation and string theory. According to this theoretical framework, nearly infinitely many bubble universes could be generated.

For the level 3 multiverse, it is usually called the "Many World Interpretation (MWI)". It is first developed by Everett and is stimulated by the quantum mechanics. [328] In quantum mechanics, a wave function ψ is invoked to describe the evolution of a system. The function ψ can be a superposition of infinitely many base functions ψ_i such that

$$\psi = \sum_i a_i \psi_i \,, \tag{6.3}$$

where a_i characterizes the probability of getting the base function ψ_i when a measurement is made on the system. Similarly, if the fundamental equations of physics are unitary, one may imagine our universe keeps dividing into parallel branches. Whenever a quantum event appears to have a random outcome, all outcomes should occur, one in each branch.[329] Therefore, our "Universe" is composed by infinitely many different small branch universes which are described by different state functions. These state functions

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[327] It is because we can only observe a finite size of space due to the finite speed of light. The actual size of our universe is much larger than the distance that we can observe. The region bounded by the observable distance is called observable universe.

[328] Hugh Everett, "`Relative State' Formulation of Quantum Mechanics," *Reviews of Modern Physics* 29(1957): 454-462.

[329] Max Tegmark, "The Multiverse Hierarchy," *Universe or Multiverse*? ed. B. Carr (Cambridge: Cambridge Universe Press, 2007), p.109.

may have different physical laws, fundamental constants, and initial conditions. We are only in one of those universes and so only observe the values realized in our universe.[330]

For level 4 multiverse, it involves the idea of mathematical democracy, in which universe governed by other equations are equally real.[331]

Generally, all the multiverse theories can be divided into two different kinds: 1. the multiverse just exists (it is a brute fact), and 2. the multiverse is generated by some fundamental laws or mathematical structures (it is generated by a "universe generator"). The difference between these two is that some simpler fundamental propositions exist in the second kind of multiverse but not in the first kind.

6.5.1 Type 1: The existence of multiverse as a brute fact (non-generated multiverse)

For this type, we assume that there are infinitely many universes, which are beginningless and exist eternally. These universes are not generated by fundamental laws or agents. Their existence can be considered as a brute fact. Although the probability of getting a fine-tuned universe is extremely low, the huge numbers of trial make the low probability event possible. Therefore, the theory of the type-1 multiverse (non-generated multiverse, NG multiverse) renders the evidence of fine-tuning probable, i.e. $P(FT|NG\ multiverse) > P(FT)$. The hypothesis can be confirmed according to the confirmation theory, $P(NG\ multiverse|FT) > P(NG\ multiverse)$.

Since the existence of the NG universe is not derived from any fundamental principles, the existence of the NG universes is merely an assumption. We will further discuss this issue in a later section.

6.5.2 Type 2: The generated multiverse

In the generated multiverse scenario, the existence of nearly infinitely many universes itself is not an assumption, but a derived result of some more fundamental physics or mathematics. As mentioned above, the string theory together with some eternal inflation theories can generate multiverse, though both theories are not yet confirmed.

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[330] Richard Swinburne, *Is There a God* (Oxford: Oxford University Press, 1996), p.175.
[331] Max Tegmark, "The Multiverse Hierarchy," *Universe or Multiverse*? ed. B. Carr (Cambridge: Cambridge Universe Press, 2007), p.116.

The basic content of the string theory or M-theory is related to six-dimensional manifolds (Calabi-Yau manifolds). According to the string theory, a particular Calabi-Yau manifold may represent a particular set of fundamental constants in the nature. Mathematical estimation shows that there are 10^{500} possible types of Calabi-Yau manifold, and the number of possible types should be finite.[332] In other words, if there are really many universes, and each universe is characterized by a particular Calabi-Yau manifold, there would be about 10^{500} universes which exist in the nature.[333]

However, string theory only mentions that the mathematical structure allows 10^{500} possible universes. We need another physical environment (initial conditions) to really generate these possible universes. As mentioned in chapter 3, our universe has probably undergone inflation. This inflation is probably triggered by a scalar field. If a scalar field exists eternally, an eternal inflation would occur and may generate many different universes. In other words, string theory plus the eternal inflation provide a possible mechanism and theoretical framework to generate the multiverse.[334]

If there is only one universe, the probability of getting a fine-tuned universe is extremely small. However, if there are really 10^{500} universes, even though the probability is extremely small, it is more probable for us to have an anthropic universe. As a result, the theory of generated multiverse can raise the probability of getting a fine-tuned universe, P(FT|generated multiverse) > P(FT). Therefore, we get P(generated multiverse|FT) > P(generated multiverse) and this theory can be confirmed according to the confirmation theory.

It is important to note that P(FT|generated multiverse) ≠ 1. This would be true only if there are really infinitely many universes with infinitely many possible set of fundamental constants and initial conditions without "logical gap". However, since the set of fundamental constants is constrained by the mathematical structures, it is not possible to have infinitely many possible set of fundamental constants without logical gap (see the discussion in 6.6.1). As mentioned above, a rough estimation gets 10^{500} possible sets of fundamental constants. Although this is a great number, if the probability of getting the fine-tuned universe is much smaller than 10^{-500}, P(FT|generated multiverse) would still be very small.

6.6 Comparison of the hypotheses using confirmation principle

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[332] S.-T. Yau and S. Nadis, *The Shape of Inner Space* (Taipei: Yuan-Liou Publishing, 2012).
[333] Stephen Hawking and Leonard Mlodinow, *The Grand Design* (New York: Bantam Books, 2010), p.118.
[334] Douglas Watson, "On the Anthropic Principle in the Multiverse: Addressing Provability and Tautology", ArXiv: 1103.6044.

In this section, we are going to evaluate which hypothesis is the best to explain the fine-tuning phenomena. According to the classification diagram shown in Fig. 6.1, we have already introduced all the known naturalistic hypotheses and the God hypothesis. As discussed above, the chance-alone hypothesis does not provide a satisfactory account for the fine-tuning phenomena. Also, the super-law explanation and the observational selection effect do not provide enough information and content to serve as an explanation. Therefore, these hypotheses and theories will not be evaluated in this section. The only available competitive hypotheses are the God hypothesis and the two kinds of multiverse hypotheses.

In chapter 2, we have discussed two major methodologies in evaluating the best hypothesis – the confirmation principle and the inference to the best explanation. According to the confirmation principle, the best hypothesis should have the highest value of P(T|E) or S(T,E). On the other hand, by using the inference to the best explanation, we can use several criteria discussed in chapter 2 to evaluate the best hypothesis. We will first do the assessment by using the confirmation principle.

6.6.1 Likelihood

Now, we first compare the likelihood functions of the three different hypotheses – God hypothesis, type-1 multiverse hypothesis and generated multiverse hypothesis. The posterior probabilities are respectively given by P(FT|God), P(FT|NG multiverse) and P(FT|generated multiverse). As mentioned above, God would have some reasons to create human beings in order to make a better world. Swinburne suggests that humans are such good things that he attributes the value P(FT|God) = 0.5.[335] For the NG multiverse hypothesis, we discuss the most extreme case that there are infinitely many possible universes without "logical gap" and each has a unique set of fundamental constants and initial conditions, the probability of getting at least one life-permitting universe is close to 1. Therefore, we can assign P(FT|NG multiverse) = 1. However, for the generated multiverse, the probability of getting the fine-tuned value is very small. This is because, according to the calculations by Roger Penrose, the probability of all the necessary conditions sufficient to allow the formation of planets coming together (a necessary condition for life) just by chance is $10^{-10^{123}}$.[336] For the most robust theory of generated multiverse theory, there are only 10^{500} different universes and possible sets of fundamental constants. Therefore, the total number of possible outcome of getting the right planets coming together to evolve life is around $10^{-10^{121}}$, which is still an

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[335] This is a conservative value. See the discussion in Richard Swinburne, "Bayes, God, and the Multiverse", *Probability in the Philosophy of Religion*, eds. Jake Chandler and Victoria Harrison (Oxford: Oxford University Press, 2012), pp.102-123 (at p.118).
[336] Roger Penrose, *The Emperor's New Mind* (Oxford: Oxford University Press, 1990), pp.343-344.

extremely small number. It is important to note that we haven't considered the secondary fine-tuning and the fine-tuning in evolution and the environment of the Earth. This number would be much smaller if all these factors are taken into account. Therefore, this finite set of generated multiverse is not enough to explain the fine-tuning problem. As a result, we can safely assign P(FT|generated multiverse) ≈ P(FT) in this case.

Some may argue that the estimation of possible sets of fundamental constants is very rough. Indeed, this number may be much larger if we know more possible Calabi-Yau manifolds. If there were more than $10^{10^{123}}$ possible types of Calabi-Yau manifolds, the probability of getting the fine-tuned universe would be much larger. In fact, Linde and Vanchurin propose a slow-roll inflation model such that there can be approximately $10^{10^{10^7}}$ universes, which is much larger than $10^{10^{123}}$.[337] Nevertheless, the actual number of universes is still uncertain. In the following, let's assume that there are infinitely many possible Calabi-Yau manifolds to see whether this scenario can probably generate the fine-tuned universe. Strictly speaking, the existence of infinitely many possible Calabi-Yau manifolds does not mean that there must be a set of fundamental constants that can fall into the anthropic region. For example, there are infinitely many solutions (x ,y) that can satisfy the equation x + y = 1. However, clearly (1, 1) is not a solution to the equation. In fact, there are also infinitely many (x, y) that cannot satisfy the equation. Under a constraint x + y = 1, the possible set of solution {x, y} is just a small set in all real number set R. If there is one more constraint, say x ≥ 1, the set of solution {x, y} would be smaller than before, but it still has infinitely many solutions. Therefore, just talking about the number of possible solutions is not useful. We should also consider whether the set of solutions includes the fine-tuned values or not. If the possible solutions of the fundamental constants of the multiverse hypothesis do not overlap with the fine-tuned set, then the hypothesis cannot explain the fine-tuning phenomena. This problem would not arise in the NG multiverse theory because these universes exist without any causes. There are no constraints on the fundamental constants as no physical laws govern the formation of the universes. Technically speaking, it has no "logical gap" in the parameter space of the fundamental constants and initial conditions.[338] However, in the generated multiverse scenario, all universes are generated by a fundamental law (string theory) and a scalar field (inflation field). Also, the string theory is not an arbitrary theory, but based on some specified assumptions (e.g. particles behave like strings) and some higher-dimensional geometry. Since the shape of a Calabi-Yau manifold is not arbitrary, it has to follow some geometrical properties

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[337] Andrei Linde and Virtaly Vanchurin, "How Many Universes are in the Multiverse?", *Physical Review D* 81(2010): 083525.

[338] W. David Beck and Max Andrews, "God and the Multiverse: A Thomistic Modal Realism", *Philosophia Christi* 16(2014): 101-115.

(constraints). For example, the simplest form of 5-dimensional Calabi-Yau manifold (quantic threefold) is given by $z_1^5 + z_2^5 + z_3^5 + z_4^5 + z_5^5 = z_1 z_2 z_3 z_4 z_5$, where z_1, z_2, z_3, z_4, z_5 are the coordinates in 5-dimensional geometry.[339] A slight variation in the coefficients would not be able to generate the manifold. Due to many specified conditions and constraints, the possible set of the fundamental constants that can be generated by the string theory is much smaller compared with the set of all real number space R (even though it has infinitely many possible solutions). In other words, there are many logical gaps in the parameter space of fundamental constants and initial conditions due to the constraints in geometry and string theory. These available values are very unlikely to overlap with the anthropic fine-tuned fundamental constants unless the conditions and constraints in the string theory are fine-tuned. Therefore, the popular generated multiverse theory may not be able to significantly raise the prior probability of the fine-tuned universe.

This proposition can be verified by a recent simulation by Gil and Alfonseca. They perform a computer simulation and discover that if we want to provide a satisfactory explanation for the fine-tuning phenomena by using the most general type of multiverse theory (level-4 multiverse in Tegmark's taxonomy), the physical laws required are complicated and show certain time dependence.[340] These requirements are not consistent with the physical laws in our living universe. Since it is contradictory to our observations, the multiverse theory is probably wrong, i.e. P(multiverse) ≈ 0. Therefore, if we want to increase the value of P(FT|multiverse), the value of P(multiverse) would be simultaneously decreased because some more assumptions have to be added to satisfy the constraints. Page also believes that the most general type of multiverse is not possible. He says that "*different mathematical structures can be contradictory, and contradictory ones cannot co-exist. For example, one structure could assert that spacetime exists somewhere and another that it does not exist at all. However, these two structures cannot both describe reality*".[341] In other words, since different contradictory mathematical structures co-exist in the ultimate reality, it is logically impossible to have a level-4 multiverse.

There is another method to raise the probability P(FT|multiverse). If the constraints under the string theory and the eternal inflation are specified to match the fine-tuned value, the probability of getting the fine-tuned values would be higher. However, that means the multiverse theory has to be fine-tuned in order to get the fine-tuned universe. Collins points out that if we eliminate or modify one of the fields or law in the fine-tuned universe generator by just a little bit, no life-permitting universes would be

[339] S.-T. Yau and S. Nadis, *The Shape of Inner Space* (Taipei: Yuan-Liou Publishing, 2012).
[340] Francisco Gil and Manuel Alfonseca, "Fine Tuning Explained? Multiverses and Cellular Automata", *Journal of General Philosophy of Science* 44(2013): 153-172.
[341] D. N. Page, "Predictions and Tests of Multiverse Theories." In *Universe or Multiverse?* ed. B. Carr (Cambridge: Cambridge University Press, 2007), pp.411-430 (at p.424).

produced.[342] In other words, the requirement of the fine-tuned universe is that the universe generator should also be fine-tuned. This may move the issue of fine-tuning up one level to the higher-level fine-tuning.[343] In fact, there are only 5 possible versions of string theory instead of many possible versions. This may suggest that only certain fine-tuned or highly constrained string theory can explain our universe.

To conclude, the likelihood analysis gives P(FT|God) = 0.5, P(FT|NG multiverse) = 1 and P(FT|generated multiverse) ≈ P(FT).

6.6.2 The prior probability

The calculations of the prior probability depend on two major factors: 1. Simplicity of a hypothesis, and 2. Compatibility with background knowledge. As mentioned in chapter 2, the simplicity of a hypothesis can be evaluated by six criteria (see section 2.1.2). In the following, we evaluate all three hypotheses by using these criteria.

6.6.2.1 Simplicity

Criterion 1: Number of things

All the things postulated in each of the hypothesis are summarized in Table 6.1. We can see that the God hypothesis postulates the fewest things.

	God hypothesis	NG multiverse	Generated multiverse
Things postulated	One God	Infinitely many universes	Many universes (finite)

Table 6.1: Number of things postulated.

[342] Robin Collins, "The Teleological Argument", *The Routledge Companion to Philosophy of Religion*, eds. Chad Meister and Paul Copan (New York: Routledge, 2007), pp.351-361.
[343] Michael Murray and Michael Rea, *An Introduction to the Philosophy of Religion* (Cambridge: Cambridge University Press, 2008), p.154.

Criterion 2: Number of entities and properties of entities

All the required kinds of things and properties of entities in each of the hypothesis are summarized in Table 6.2. We can see that the God hypothesis postulates fewer kinds of things. Some philosophers argue that naturalism (or materialism) only postulates physical things while theism postulates both physical things and mind. Therefore, theism should be more complicated. First, theistic proposals only postulate God as the ultimate source of things. The physical things are created by God so that only mind exists at the very beginning. In other words, there are two kinds of things but only one ultimate source of things. The finite matter and energy are created by and dependent on God. However, for naturalism, it is not proven that mind can be reduced to physical things. Dualism, suggested by Descartes a few centuries ago, has in recent years found a number of able defenders, though not always in exactly Descartes's form.[344] For example, Nagel argues that physical sciences will not enable us to understand the irreducibly subjective centres of consciousness that are such a conspicuous part of the world.[345] Burge mentions that actual successful mentalistic explanations, commonsense or scientific, do not appear, on their face, to refer to material compositions of mental states.[346] Swinburne argues that "*a man's having mental life must be understood as a non-bodily part of the man, his soul, having a mental life*."[347] Chalmers develops a systematic framework and shows that the conclusion that consciousness is not logically supervenient on the physical, and therefore cannot be reductively explained. He argues for a form of dualism on which consciousness is seen as a non-physical property that supervenes on the physical by a lawful connection.[348] Furthermore, Baker and Goetz list out several outstanding problems in Cognitive science, including the problem of qualia, the problem of intentionality, the problems of free will and morality, the problem of abductive reasoning and the binding problem, that suggest mind may not be reducible.[349] If mind is not reducible, naturalism has to postulate two things: mind and the physical things. In other words, the number of things postulated based on naturalism is as least the same as that based on theism. Nevertheless, only one ultimate source of things postulated by theism while there is no ultimate source of mind and the physical things postulated by naturalism.

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[344] Edward Feser, *Philosophy of Mind: A Beginner's Guide* (Oxford: Oneworld, 2006), p.47.

[345] Thomas Nagel, *Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature is Almost Certainly False* (Oxford: Oxford University Press, 2012), p.42.

[346] See Tyler Burge, *Foundations of Mind* (Oxford: Oxford University Press, 2007), p.230; B. W. Kobes, "Burge's Dualism", *The Waning of Materialism*, eds. R. C. Koons and G. Bealer (Oxford: Oxford University Press, 2010), p.225.

[347] Richard Swinburne, *The Evolution of the Soul* (Oxford: Clarendon Press, 1997), p.174.

[348] David Chalmers, "Toward a theory of Consciousness", Ph.D thesis, The Indiana University, 1993.

[349] The details of the problems please see Mark Baker and Stewart Goetz, "Introduction", *The Soul Hypothesis: Investigations into the Existence of the Soul*, eds. M. C. Baker and S. Goetz (New York: Continuum, 2011), p.9.

	God hypothesis	NG multiverse	Generated multiverse
Kinds of things postulated	1. God – Infinite mind 2. Finite matter/energy (created by and dependent on God)	1. Infinitely many universes 2. Different universes having different fundamental constants 3. Different universes having different initial conditions 4. Finite minds evolved from matter	1. A universe generator which can generate many universes 2. Different universes having different fundamental constants 3. Different universes having different initial conditions 4. Finite minds evolved from matter

Table 6.2: Number of entities and properties of entities involved.

Criterion 3: More readily observable properties

Many atheists claim that God is not observable. However, the word "observable" here should not be limited to sensible properties. God can manifest in visions and voices, which are observable in reality. This is commonly known as religious experience. Therefore, strictly speaking, God can be observable if we do not exclude religious experience. Nevertheless, the multiverse theories have a serious problem. It is not possible for us to observe the other universes because the universes will not interact with each other. Also, the distance between the other universes and our universe is far beyond our limit of observation. Scientist Ellis says that "*I do not believe the existence of those other universes has been proved – or ever could be.*"[350] Even if the other universes might produce some observable effects on our universe, we can never confirm this objectively because we are subject to our own set of fundamental laws and views. Therefore, multiverse is not a readily observable thing while we can at least possible to "observe" God based on religious experience.

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[350] G. F. R. Ellis, "Does the Multiverse Really Exist?" *Scientific American*, 305(2011): 38-43.

Criterion 4: Number of laws

All the required laws in each of the hypothesis are summarized in Table 6.3. Note that no specific laws are required to govern an omnipotent God. As mentioned above, He can do all logically possible things, and no laws (except logic) would prohibit him from doing anything. The only principle required is the moral principle for a perfectly good God. Obviously, the number of laws required is the fewest for the God hypothesis.

	God hypothesis	NG multiverse	Generated multiverse
Required laws or principles	1. Creation of human is overall a good action	1. Quantum law of the universes 2. There exists a law that can give different fundamental constants without logical gap 3. There exists a law that can give different initial conditions without logical gap	1. A ultimate law exists to generate all universes 2. There exists a law that can give different fundamental constants which yield life-permitting set 3. There exists a law that can give different initial conditions which yield life-permitting set

Table 6.3: Number of laws and principles required.

Criterion 5: Variables involved in the required laws

For the God hypothesis, God creates human beings through fine-tuning the fundamental constants and initial conditions. Therefore, the only variables involved are the fine-tuned fundamental constants and initial conditions in our actual universe. However, for multiverse hypotheses, many more variables have to be involved. Since each universe would have a unique set of fundamental constants and conditions, the total number of variables involved is much greater than that in the God hypothesis. As a result, the God hypothesis has the fewest variables involved in the required laws.

Criterion 6: Mathematical formulation

All the hypotheses cannot be easily quantified by mathematical formulation. Therefore, it is difficult for us to judge by using this criterion.

In summary, the overall simplest hypothesis is the God hypothesis. It has postulated the fewest entities, properties among the entities and variables involved.

6.6.2.2 Compatibility with other knowledge

For the compatibility with other knowledge, although we have no observational evidence for the existence of God, as mentioned above, religious experience of some people do suggest some information about God. Swinburne argues that we ought to believe that things are as they seem to be (in the epistemic sense) unless and until we have evidence that we are mistaken. He calls this the principle of credulity.[351] By using this principle, religious experiences are treated as prima facie evidence for the existence of God until there are reasons for doubting them.[352] Therefore, the only way to defeat the claims of religious experience will be to show that the strong balance of evidence is that there is no God.[353] However, for the NG multiverse hypothesis, it is not derived from any fundamental physics but is postulated to be a brute fact. We do not have any independent experience or knowledge to support this hypothesis.

For the generated multiverse hypothesis, it can be roughly divided into two sub-divisions: 1. Quantum interpretation (level 3), and 2. Due to eternal inflation (level 2 and level 4). For the level-3 multiverse, it is proposed solely based on quantum physics, which suggests that a system is comprised of infinitely many possible states. When the system is being measured, it would collapse into a certain state according to a probability, which is determined by the coefficients that characterize the states. In general, this theory has three major assumptions:

A1: Our universe behaves like a quantum system that has infinitely many possible states.

A2: Each possible universe should have different fundamental constants and initial conditions.

A3: The time evolution of the wave-function of universe is unitary[354].

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[351] Richard Swinburne, *Is there a God?* (Oxford: Oxford University Press, 1996), p.115.

[352] K.-M. Kwan, *The Rainbow of Experiences, Critical Trust, and God* (New York: Bloomsbury, 2011), p.6.

[353] Richard Swinburne, *Is there a God?* (Oxford: Oxford University Press, 1996), p.118.

[354] The determinant of a unitary matrix is 1.

For the assumption A1, these infinitely many possible states are not real, but manifest in infinite-dimensional Hilbert space.[355] The Hilbert space is an imaginary space based on quantum mechanics, and it is a theoretical term rather than an observational term. Generally speaking, it is a mathematical tool to connect the indeterministic behavior in quantum mechanics to the deterministic observational real world. Since the Hilbert space may not be a real space, it is doubtful that these universes would evolve independently and one of them (our universe) has finally evolved to produce intelligent life. The second assumption A2 is purely imaginary. Although different states in a system would have different properties, it does not entail that all properties would be different. For example, a vibrational mode of a string can be described by a superposition of infinitely many possible resonant states with different frequencies. However, the travelling speeds of wave in these states are the same. Therefore, it is logically possible that all different universes (if really exist) have different initial conditions but the same fundamental constants. The last assumption A3 is also doubtful. Although experimenters have encountered no departures from unitary, some theorists who work on quantum gravity suggest that evaporating black holes might destroy information, which would be a non-unitary process.[356]

Swinburne rejects this theory because its assumptions are beyond our rational belief and background knowledge. He comments on the level-3 multiverse (many-world interpretation) as follow:[357]

"The postulation of the actual existence of an infinite number of worlds, between them exhausting all the logical possibilities, many of them consisting of an infinite quantity of matter – energy behaving in accord with simple laws over infinite time, which are not caused by anything else, which do not causally affect each other, but which between then exhaust the logical space without any one being qualitatively identical to any other, is to postulate complexity and non-prearranged coincidence of infinite dimensions beyond rational belief."

Scientist Francis Collins states that *"… near-infinite number of unobservable universes strains credulity. It certainly fails Occam's Razor.*"[358]

For the generated level-2 or level-4 multiverse, it is mainly extrapolated based on two more fundamental theories: string theory and the eternal inflation theory. As briefly discussed above, the generated

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[355] Colin Coleman, "Cosmic Fine Tuning and the Multiverse Hypothesis," arXiv: 1207.5396.

[356] Max Tegmark, "The Multiverse Hierarchy," *Universe or Multiverse*? ed. B. Carr (Cambridge: Cambridge Universe Press, 2007), p.113.

[357] Richard Swinburne, "Argument from the Fine-Tuning of the Universe," *Modern Cosmology and Philosophy*, ed. J. Leslie (New York: Prometheus Books, 1998), p.178.

[358] Francis Collins, *The Language of God* (New York: Free Press, 2006), p.76.

multiverse can generate many different initial conditions due to random generation while the string theory constrains that there should be roughly 10^{500} possible sets of fundamental constants.

However, the string theory and the eternal inflation theory are unconfirmed theories. Scientist Ellis comments on the multiverse by stating that:[359]

"A multiverse is implied by some forms of inflation but not others. Inflation is not yet a well defined theory and chaotic inflation is just one variant of it. ... the key physics involved in chaotic inflation (Coleman-de Luccia tunneling) is extrapolated from known and tested physics to quite different regimes; that extrapolation is unverified and indeed inverifiable. The physics is hypothetical rather than tested."

Any extrapolated theories from known physics should be tested or verified until they can be claimed as successful theories. Since you can extrapolate anything from known physics by adding some more assumptions, the uncertainty is large unless some of these assumptions or predictions are verified. However, although there is some positive evidence for inflation, we still have no evidence for eternal inflation. Ellis points out that *"... not all types of inflation go on forever and create an infinite number of bubble universes. Observations do not single out required type of inflation from other types. Some cosmologists such as Steinhardt even argue that eternal inflation would have led to different patterns in the background radiation than we see."*[360] For the string theory, it is not a complete theory and none of the predictions is verified. The present form of string theory is highly dependent on the theory of supersymmetry in physics.[361] The search of supersymmetry particles is now undergoing in Large Hadron Collider in Europe. Unfortunately, no such particles have been observed.[362] It may indicate that the theory of supersymmetry as well as the string theory is not true at all. Since there is no evidence supporting both theories, the prior probability of the generated multiverse theory subject to our background knowledge (i.e. the probability P(generated multiverse) before evaluating the fine-tuning phenomena) is very low.

Moreover, some probabilistic predictions can be made by the multiverse theory. For example, there is a principle called the "principle of living dangerously" which states that if the prior probability for a parameter is a rapidly increasing (or decreasing) function (goes like Q^4 for large Q and goes like exp(Q) for small Q)[363], then we expect the observed value of the parameter to lie near the edge of the

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[359] B. J. Carr and G. F. R. Ellis, "Universe or Multiverse," *Astronomy and Geophysics*, 49(2008): 2.29.

[360] G. F. R. Ellis, "Does the Multiverse Really Exist?" *Scientific American*, 305(2011): 38-43.

[361] Theory of Supersymmetry suggests that every particle must accompany with a partner called supersymmetry particle.

[362] P. de Jong, "Supersymmetry Searches at the LHC," Proceedings of Physics in Collision 2012.

[363] J. Garriga and A. Vilenkin, "Anthropic Prediction for Λ and Q Catastrophe*", Progress of Theoretical Physics Supplement* 163(2006): 245-257.

anthropically allowed range.[364] A particular parameter that satisfies the principle of living dangerously is the primordial quantum fluctuation Q. The anthropic allowed region for Q is $10^{-6} \leq Q \leq 10^{-4}$, while the observed value is 10^{-5}. Therefore it is not close to either edge of the anthropically allowed range.[365] In other words, if there exists infinitely many universes, it would be very high probability that an anthropic universe with Q close to 10^{-4} or 10^{-6}. However, the parameter Q of our universe is a highly improbable value under the multiverse hypothesis. This problem is now known as the "Q-catastrophe". Another probabilistic prediction is that it is highly probable for an anthropic universe to be much less fine-tuned. Modern astrophysics is able to construct some scenarios that are also possible for life. One of them is the Cold Big Bang model (our present universe is evolved under the Hot Big Bang model). This model requires the primordial ratio of photons to baryons $\eta \sim 1$ (it is $\eta \sim 10^9$ in our universe). Some early population of luminous objects can generate heavy elements for life. In this scenario, structure formation is not suppressed by the cosmic microwave background radiation pressure, and thus stars and galaxies require a smaller value of Q.[366] Aguirre claims that this scenario requires $10^{-11} \leq Q \leq 10^{-5}$, which is a much wider range compared with the Hot Big Bang model in our universe ($10^{-6} \leq Q \leq 10^{-4}$).[367] If a life-permitting universe is chosen randomly under the multiverse theory, it would be much more likely that the universe is evolved under the Cold Big Bang model, but not the Hot Big Bang model. Therefore, this result does not favour the multiverse hypothesis. It is important to note that these results do not strictly falsify the multiverse hypothesis because it is still possible (even the probability is extremely small) that our universe is evolving by Hot Big Bang model with a value Q that is not lying near the edge of the anthropically allowed range. However, these results would further decrease the prior probability of the multiverse hypothesis subject to our background knowledge before evaluating the fine-tuning phenomena.

Some argue that there may be some evidence that support the multiverse hypothesis. For example, observations indicate that a void exists in front of the cosmic microwave background cold spot and more than 1000 galaxy clusters are moving with up to 1000 km/s towards Centaurus or Vela. Some suggest that these phenomena are due to the gravitational pull from other universes.[368] However, it is not known whether different universes would interact with each other because they may not have the same

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[364] Luke Barnes, "The Fine-Tuning of the Universe for Intelligent Life", *Publications of the Astronomical Society of Australia* 29(2012): 529-64.

[365] Ibid.

[366] Ibid.

[367] Anthony Aguirre, "Cold Big-Bang Cosmology as a Counterexample to Several Anthropic Argument," *Physical Review D*, 64 (2001): 083508.

[368] Rüdiger Vaas, "Multiverse Scenarios in Cosmology: Classification, Cause, Challenge, Controversy, and Criticism," *Journal of Cosmology* 4(2010): 664-673.

gravitational law. Also, some irregular distribution of mass may also generate these phenomena. Recent researches incline to suggest that the existence of void and cold spot are correlated with an overdense region surrounded by an underdense region at the last scattering surface.[369] Therefore, the alleged evidence for multiverse is just a speculative idea but not confirmed evidence.

To conclude, many scientists and philosophers reject the idea of multiverse because it is not founded on standard physics. Moreover, some of its predictions do not match the observations. Some scientists also think that multiverse theory is only a speculative idea without any explanatory power. Davies writes that "*it is trivially true that, in an infinite universe, anything that can happen will happen… Like a blunderbuss, it explains everything and nothing*."[370] In fact, as mentioned above, the multiverse theory has many limitations. For example, it has a finite set of possible Calabi-Yau manifolds and fundamental constants. The constraints in string theory may restrict the allowed space for the fundamental constants. Last but not least, there are many doubts and questions about the string theory.[371] Clearly, although string theory is a well-defined theory due to its mathematical elegance, it is not a confirmed theory in physics. All these problems and limitations in both string theory and multiverse theory decrease the prior probability of the generated multiverse hypothesis subject to our background knowledge.

Therefore, based on the simplicity and the compatibility of the hypotheses with background knowledge, we conclude that P(God) is the best among all the available hypotheses, and P(NG multiverse) ≈ P(generated multiverse) are very small compared with P(God). Since P(FT|God) = 0.5, P(FT|NG multiverse) = 1 and P(FT|generated multiverse) ≈ P(FT), by using the strength value of a theory S(T,E) = P(E|T)P(T) defined in equation (2.4), we get S(God, FT) = 0.5P(God), S(NG multiverse, FT) = P(NG multiverse), and S(generated multiverse, FT) ≈ P(FT)P(generated multiverse). As discussed above, we can safely assign P(God) > 2P(NG multiverse) and P(God) > 2P(generated multiverse). Since P(FT) < 1, we can get

$$S(God, FT) > S(multiverse, FT), \tag{6.4}$$

where "multiverse" stands for either NG multiverse or generated multiverse. Based on the confirmation principle, the God hypothesis is the best explanation of the fine-tuning phenomena.

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[369] See K. T. Inoue, "On the Origin of the Cold Spot", *Monthly Notices of Royal Astronomical Society* 421(2012): 2731-2736; Y.-C. Cai, et al., "A Possible Cold Imprint of Voids on the Microwave Background Radiation", *The Astrophysical Journal* 786(2014): 110.
[370] This is extracted from Antony Flew, *There is a God* (New York: HarperCollins, 2007), p.118.
[371] See the discussion in S.-T. Yau and S. Nadis, *The Shape of Inner Space* (Taipei: Yuan-Liou Publishing, 2012).

6.7 Comparison of the hypotheses using inference to the best explanation

Now, we use another principle, the inference to the best explanation, to assess all the available hypotheses. In chapter 2, we have discussed the explanatory virtues commonly used by scientists and philosophers. They are explanatory power, degree of testability, simplicity, consistency with background knowledge, informativeness, and fecundity.[372] We have discussed the explanatory power and the simplicity of different hypotheses. The God hypothesis is a simpler hypothesis and has a relatively high explanatory power. For the NG multiverse hypothesis, it also has a relatively high explanatory power but it is a complicated hypothesis. For the generated multiverse, it has the lowest explanatory power and it is also a complicated hypothesis. In the following, we will discuss all the other remaining explanatory virtues of the available hypotheses.

6.7.1 Degree of testability

A testable hypothesis must contain some empirical content (see section 2.2.2). In the following, we are not going to discuss whether the predictions made by a particular hypothesis are satisfied or not by the available empirical observations. We will just compare the "amount of empirical content" in each of the available hypotheses.

In general, it is very difficult for us to give predictions about God's action because we do not have any "laws of divine action". However, in our context, the God hypothesis is not a single hypothesis. Our proposed God hypothesis is in the form "there is a God who wills creation of intelligent human beings". Here, the creation of intelligent human beings is a posited divine goal. Therefore, we can to some degree predict what would happen if God creates human beings. For example, it's likely that God would communicate with us and educate us. These can be some of the predictions. Therefore, there are some empirical contents for the God hypothesis.

For the NG multiverse hypothesis, it can predict everything because this hypothesis has infinitely many parameters without logical gap and it can predict all possibilities. However, as mentioned above, it is equivalent to saying that this hypothesis predicts nothing. Therefore, the NG multiverse hypothesis does not have any empirical content. Although observations (such as using principle of living dangerously) can verify the probabilistic predictions made by the NG multiverse hypothesis (or generated multiverse

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[372] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.112.

hypothesis), such observations can only give us a very few degrees of testability because it is very difficult to determine which particular type of multiverse is true or not true.

For the generated multiverse hypothesis, as mentioned in section 6.6.2.2, it can generate some predictions. Although the predictions generated from this hypothesis do not satisfy the observations, this hypothesis has some empirical content. However, since we are not sure whether the string theory and the chaotic inflation theory are correct or not, the amount of substantiated empirical content is quite little.

Therefore, we can say that the God hypothesis and generated multiverse hypothesis do have some degrees of testability, while the metaphysical multiverse nearly does not have any.

6.7.2 Comprehensibility

This criterion suggests that a good hypothesis should be comprehensible by our background knowledge. For the God hypothesis, although it is difficult for us to imagine how an omnipotent and omniscient God could create our universe with fine-tuned values and conditions, we can still define the meanings of "omnipotent" and "omniscient". Since we have ability and knowledge, what we have to do is to extend the idea of ability and knowledge to an infinite extent. It can be done by our imagination. Similarly, we can also understand the meaning of "perfectly good" based on our experiences. In general, these definitions are comprehensible by our background knowledge and do not have any contradiction.

For the multiverse hypotheses, based on known physics, we can imagine how the universes can be generated through physical processes, though we don't know whether these mechanisms are correct or not. Therefore, all the proposed hypotheses are comprehensible by our background knowledge.

6.7.3 Informativeness

An informative theory should specify some articulated casual mechanism whose description allows us to deduce the precise details of the effect.[373] For the God hypothesis, we have no casual mechanism to describe God's creation. Nevertheless, we also have no casual mechanism to describe how fine-tuned values and conditions could be generated by the multiverse hypotheses. For the NG multiverse, we don't know how these universes could be generated and we are not sure these universes could have different fundamental constants and conditions. For the generated multiverse, we have no theory to describe how

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[373] Peter Lipton, *Inference to the Best Explanation* (London: Routledge, 1991), p.118.

universes could be generated through a universe generator. We are not quite sure whether the possible Calabi-Yau manifolds must have an anthropic set of fundamental constants and conditions. Therefore, all the available hypotheses are not informative for us to judge because there are too many uncertainties and unknowns.

6.7.4 Fecundity

This criterion suggests that a good theory should be able to suggest new lines of research.[374] God hypothesis implies that the creation of human beings and intelligence is overall a good action. We can further investigate this by various disciplines such as sociology, psychology, etc. Also, it makes theology and religious studies possible. For the NG multiverse hypothesis, as mentioned above, it has no predictive power. Therefore, it does not suggest any lines of research. It can just serve as an explanation of fine-tuning. For the generated multiverse, it can suggest a few lines of research such as finding any interactions between the generated universes. It may also give rise to some other lines of research if we could know more details of the hypothesis.

6.7.5 Summary of all explanatory virtues

In table 6.4, we can summarize all the above discussions and use three scales (good, fair, poor) to assess the best hypothesis.

	Explanatory power	Simplicity	Testability	Comprehensibility	Informativeness	Fecundity
T1	Good	Good	Fair	Good	Poor	Fair
T2	Good	Poor	Poor	Good	Poor	Poor
T3	Poor	Poor	Fair	Good	Poor	Fair

Table 6.4. Summary of different hypotheses (T1, T2 and T3 stand for God hypothesis, NG multiverse hypothesis and generated multiverse hypothesis respectively).

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[374] Gregory Dawes, *Theism and Explanation* (New York: Routledge, 2009), p.116.

Obviously, the God hypothesis is the best hypothesis to explain the fine-tuning phenomena. It generates the same conclusion by using the confirmation principle.

6.8 Conclusion

Based on the classification in Fig. 6.1, we have discussed all major available hypotheses that can provide explanation of the fine-tuning phenomena. In fact, there are some other types of multiverse hypotheses, such as oscillating universe. However, the general features of these theories have already been involved in the discussions above. The NG and generated multiverse hypotheses basically have already covered most of the essential features of the other hypotheses, such as the total number of universes, the origin of multiverse and the nature of multiverse (see Tegmark's taxonomy). In particular, since dark energy will dominate the cosmological energy density in the future, it is nearly impossible to have oscillating universe.

Among the available hypotheses, the chance-alone hypothesis, super-law explanation, and observation selection effect are not able to give a satisfactory explanation of the fine-tuning phenomena. Therefore, most of our discussions focus on the God hypothesis and the two multiverse hypotheses. By using the confirmation principle, we conclude that the God hypothesis has the largest value of P(T|E). On the other hand, by using another principle, inference to the best explanation, we still get the same conclusion. Therefore, we can conclude that the theistic worldview can offer the best explanation of the fine-tuning phenomena.

Chapter 7 Compatibility of the hypotheses and the criticisms of the fine-tuning argument

In the previous chapter, we assume that the God hypothesis, metaphysical multiverse hypothesis and generated multiverse hypothesis are mutually exclusive. Nevertheless, in general, they can be compatible with each other. For example, God can use a generated multiverse scenario to allow a fine-tuned universe to evolve human beings. In this chapter, we are going to discuss the implication of the compatibility of the God and multiverse hypotheses. We will also discuss some criticisms of the fine-tuning argument.

7.1 Compatibility of the hypotheses

What if the God hypothesis and multiverse hypothesis are compatible with each other? If the fine-tuning is generated by non-generated multiverse scenario, the probability of fine-tuning does not depend on the existence of God. Therefore we have $P(FT|God \& multiverse) = P(FT|{\sim}God \& multiverse)$. However, if the fine-tuning is generated by a single universe, then clearly we have $P(FT|God \& single\ universe) > P(FT|{\sim}God \& single\ universe)$. If there are only two possibilities – single universe or multiverse, the weighted average of combining these two possibilities gets $P(FT|God) > P(FT|{\sim}God)$.[375] Therefore, even if the God hypothesis is compatible with the multiverse hypothesis, the existence of God is still a better solution to the fine-tuning problem and our conclusion is the same for the most general situation.

The above discussion is an oversimplified version. It assumes that the multiverse hypothesis and God hypothesis are marginally independent and we do not know the multiverse hypothesis is confirmed or not. In chapter 2, we have discussed a methodology in assessing the residual confirmation if two competing hypotheses are considered at the same time. The residual confirmation RC evaluates the effect of the confirmation of hypothesis T_1 if the hypothesis T_2 is confirmed. Let's assume that T_1 is the God hypothesis and T_2 is the multiverse hypothesis. Since there is some observational evidence that disfavours the existence of multiverse, we simply assume that ${\sim}T_2$ is confirmed. From equation (2.8), RC would be positive if $P(E|T_1, {\sim}T_2) > P(E|{\sim}T_1, {\sim}T_2)$. Obviously, the existence of God would render the fine-tuning evidence E more probable then without the existence of God. Therefore, the residual confirmation is

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[375] B. Monton, "God, Fine-tuning, and the Problem of Old Evidence," *British Journal of Philosophy of Science* 57(2006): 405-424.

positive if multiverse and God are marginally independent. This is also consistent with our previous conclusion. But it does not raise the probability.

What if the multiverse hypothesis and God hypothesis are marginally dependent? For example, if one can show that God has some reasons that He would not create multiverse, i.e. $P(\sim T_2|T_1) \approx 1$, what would be the implication? By using equation (2.9) and replacing T_2 by $\sim T_2$, we have

$$RC' = \log\left[P(T_1) + \frac{P(E|\sim T_1, \sim T_2)}{P(E|T_1, \sim T_2)}\frac{P(\sim T_2|\sim T_1)}{P(\sim T_2|T_1)}P(\sim T_1)\right]^{-1}$$

$$\approx \log\left[P(T_1) + \frac{P(E|\sim T_1, \sim T_2)}{P(E|T_1, \sim T_2)}P(\sim T_2|\sim T_1)P(\sim T_1)\right]^{-1},$$

(7.1)

where RC' is the degree of residual confirmation if the two hypotheses are marginal dependent. Since $P(\sim T_2|\sim T_1) < 1$, we have

$$RC' = \log\left[P(T_1) + \frac{P(E|\sim T_1, \sim T_2)}{P(E|T_1, \sim T_2)}\frac{P(\sim T_2|\sim T_1)}{P(\sim T_2|T_1)}P(\sim T_1)\right]^{-1} > \log\left[P(T_1) + \frac{P(E|\sim T_1, \sim T_2)}{P(E|T_1, \sim T_2)}P(\sim T_1)\right]^{-1}$$

(7.2)

The right-hand-side of the above equation stands for the original RC if the two hypotheses are marginal independent (see equation (2.8)). Therefore, if God would not create multiverse and multiverse is unlikely to exist, the degree of confirmation of God hypothesis would be increased. In other words, the disconfirmation of multiverse indirectly increases the degree of confirmation of God hypothesis. In the following, I would like to argue that God has some reasons not to create multiverse ($P(\sim T_2|T_1) \approx 1$).[376]

Suppose that God wants to create human intelligence. He has two choices: 1. specially create all the fine-tuned constants and conditions, and 2. create a universe generator to generate many universes with different fundamental constants and conditions. Based on the God hypothesis, God is omnipotent, omniscient and perfectly good. Since both choices are logically possible, an omnipotent God is able to use either choice to create a life-allowing universe. For an omniscient God, He must know fine-tuning the universe can make life possible. However, can He guarantee that life would be evolved through a random nature of multiverse? The answer is yes. Although producing a life-allowing universe through multiverse scenario depends on probability, an omniscient God can estimate how large amount of universes should

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[376] Part of the following sections also appears in M. H. Chan, "Would God Create Our Universe through Multiverse?" *Theology and Science*, 13(2015): 394-407.

be generated for getting at least one life-allowing universe. Therefore, an omnipotent and omniscient God can create a universe generator such that an enough amount of universes would be generated for getting life. As a result, an omnipotent and omniscient God could choose either choice to create our universe.

In fact, some theistic philosophers support a theistic version of multiverse. For example, O'Connor argues that God has any number of distinct reasons for creating a variety of different possible worlds.[377] Collins thinks that since theists have traditionally believed that God is infinite and infinitely creative, the physical reality would be much larger than one universe. He thinks that "*God is infinite and infinitely creative, it only makes sense that creation would reflect these attributes of God, and hence that physical reality would be much larger than one universe, perhaps even infinitely larger*".[378] Therefore, it seems that creation through multiverse is more elegant and ingenious than creating a single universe.[379] In the following, I argue that a perfectly good God would choose the single universe scenario to create life-allowing universe rather than using the multiverse scenario. It is because a perfectly good God would choose the overall best choice, and the single universe scenario is definitely the best choice.

What are the criteria to assess the best choice? I suggest that a good choice should have the following three properties: 1. simple, 2. ontologically economical, and 3. fewest disadvantages. Therefore, the best choice should be the simplest, most economical, and have minimum disadvantages. In the following, I will provide some arguments to justify the suggested three criteria and discuss the two scenarios by using these criteria.

7.1.1 Simplicity

With reference to the "inference to the best explanation", simplicity is a criterion for a good theory. Moreover, we generally believe that a good God would create a beautiful or elegant universe. According to Hogarth, the defining feature of beauty or elegance is "simplicity with variety".[380] In view of this, "simple" is the most important feature to describe beauty or elegance. Therefore, simplicity is definitely one of the most important criteria to assess the best choice.

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[377] Timothy O'Connor, "Simplicity and Creation", *Faith and Philosophy*, July(1999): 405-412.
[378] Robin Collins, "Design and the Many-Worlds Hypothesis", *Philosophy of Religion: A Reader and Guide*, ed. W. L. Craig (Edinburgh: Edinburgh University Press, 2002), pp.130-148
[379] Robin Collins, "The Multiverse Hypothesis: a Theistic Perspective." In *Universe or Multiverse?* ed. B. Carr (Cambridge: Cambridge University Press, 2007), pp.459-480.
[380] W. Hogarth, *The Analysis of Beauty* (London: J. Reeves, 1753).

For the single universe scenario, although God has to create a set of anthropic fundamental constants and initial conditions, it has fewer entities and kinds of thing, but with a large amount of variety (we have different structures and matter in our universe). However, for the multiverse scenario, God has to create an appropriate universe generators (or create an appropriate super-law) such that an enough amount of universes are generated for life evolution. It is full of variety but much more complicated (as mentioned in Chapter 6). Therefore, under this assumption, a single universe with variety is more elegant than multiverse.

In view of this, O'Connor argues that we have to separate God's intrinsic from his relational properties.[381] That means God's simplicity does not entail that the world created by God is also simple. In fact, the argument of simplicity is not based on the doctrine of God's simplicity. Here, we argue that God would use the best choice, which should be also the simplest choice, to create our universe.

7.1.2 Ontological economy

From an engineering perspective, a good engineer would use an efficient way to create. Therefore, an economical choice would be an important criterion to assess a theory. An economical choice is closely related to a simple choice. The difference is that the simplest choice should contain the fewest things and kinds of things while the most economical choice should involve the fewest by-products and processes.

Intuitively, creating one universe by special creation is ontologically economical. Just one universe with fine-tuned laws and conditions can achieve God's purpose – creation of intelligent beings. However, for the multiverse scenario, one needs a large amount of "wasted universes" to achieve the same purpose. For those "wasted universes", which do not have correct life-allowing fundamental constants or conditions, are not functional. They are purposeless and totally dead. Some of them have no stars, no life and perhaps nothing evolved there. Since the natural laws of these universes are different from our natural laws, we are not able to observe them. The existence of these wasted universes does not give us any knowledge. One may argue that some useless and functionless stars and galaxies are also generated in the special creation scenario. Nevertheless, we can observe them and generate scientific knowledge from them. Also, most galaxies and stars are interacting with each other through gravity. They are not totally useless. Strictly speaking, most of the "wasted universes" are the useless by-product. For the special creation

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[381] Timothy O'Connor, "Simplicity and Creation", *Faith and Philosophy*, 16(1999):405-412.

scenario, there is no "useless by-product universe". Obviously, the special creation scenario is more ontologically economical.

In fact, Collins admits that creation through multiverse is an inefficient way for God to proceed.[382] However, he believes that God behaves like a great artist other than a great engineer. In general, for a great artist, he/she would express his/her creativity and ingenuity in creation rather than considering the least amount of material. Therefore, Collins believes that God may not use an economical way to create our universe. In other words, whether God would create our universe through multiverse depends on the intrinsic properties of God (artist vs engineer).

However, we need not accept this dichotomy. God can be both a great artist and a great engineer (or a better term: a great architect)[383]. In our universe, we can still see much diversity, such as black holes, dark energy, dark matter, galaxies, galaxy clusters, planets and satellites. God can express His creativity in the creation of a single universe (be a great artist). God can also use the least amount of material to achieve His purpose (be a great engineer). Although making a multiverse might express more creativity, this may not be His major purpose. Based on our discussion in the previous chapters, our universe contains an incredible amount of fine-tuning constants and conditions, which are set to evolve life. Therefore, creating life is definitely one of His major purposes. In fact, a great artist can express his/her creativity by drawing a small picture. However, God has to use a much more complicated way to create our universe through multiverse. He can only be a great artist, but not a great engineer. Therefore, being a great artist and a great engineer, God would not choose to create our universe through multiverse.

However, some may argue that for an omnipotent God, everything He did was simple and economical. Therefore, these concepts are meaningless when applied to God. It is true that it might imply nearly the same effort for an omnipotent God to make either a single universe or multiverse. However, not all the choices are wise choices. Consider a lottery game as an analogy. There are five green balls and one blue ball in a box. The one choosing the blue ball would get a prize. Suppose God plays this game. He knows how to get the blue ball by only one attempt because He is omnipotent and omniscient. He also notices that by playing many times (about 6 attempts), He can still get a blue ball to win. Which choice is the best one? Keeping all other factors constant, we would think that the former choice is the best because it is the simplest and most economical (a wise choice) while the latter one is stupid, provided that the only

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[382] Robin Collins, "The Multiverse Hypothesis: a Theistic Perspective." In *Universe or Multiverse?* ed. B. Carr (Cambridge: Cambridge University Press, 2007), pp.459-480.
[383] The term "architect" is suggested by Prof. Kung, Yap Yan in a private communication.

purpose of playing is to win. Although both choices are simple relative to God's omnipotence, God would choose the objectively simplest (cleverest) way to achieve the same goal (creation of humans).[384]

7.1.3 Minimum disadvantages

If God correctly fine-tuned a set of fine-tuned fundamental constants and initial conditions for life, then life evolution could be controlled easily for just one universe. However, for multiverse scenario, the outcome is probabilistic. A large amount of universes would be produced based on the quantum nature of the natural laws. This nature is indeterministic, and the outcome is not 100% guaranteed. Although God can guarantee a sufficiently large amount of universes produced such that probably at least one life-allowing universe would be produced, the "degree of control" is still less than the special creation scenario. Moreover, the type and the properties of the universe created are highly controllable by special creation scenario. He can design a best and the most beautiful universe as He likes. However, due to the indeterministic and purely random nature of the multiverse scenario, some universes created might be full of evils, suffering, problematic or ugly. There may be some good universes created, but simultaneously some bad universes would also be created, unless the multiverse scenario is not purely random. As mentioned in chapter 6, the "logical gap" of the parameter space of fundamental constants and conditions must be very small such that a life-allowing universe would be generated.[385] Therefore, it is quite likely to have these bad universes generated, which can be regarded as a disadvantage. Hence, only the special creation scenario could generate minimal disadvantages.

In fact, God can create some mechanisms to avoid the creation of bad universes. This would become a "fine-tuned multiverse scenario", and the "degree of control" would be the same for the special creation and fine-tuned multiverse scenarios. However, this type of multiverse (fine-tuned multiverse) is much more complicated. If God wants to give "freedom" to our natural world to generate universes, He would not additionally impose any constraints on it. Otherwise, it is "constrained free" (or fine-tuned) but not perfectly free. We need to give some extra arguments to prove that God would prefer a fine-tuned

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[384] M. H. Chan, "Would God create our universe through multiverse?" *Theology and Science*, 13(2015): 394-407.
[385] W. David Beck and Max Andrews, "God and the Multiverse: A Thomistic Modal Realism", *Philosophia Christi* 16(2014): 101-115.

multiverse rather than a fine-tuned single-universe.[386] In general, a fine-tuned multiverse would be much more complicated than a fine-tuned universe.[387]

In the above discussion, some may argue that the creation of many universes can generate diversity, which is also a good action (just like bio-diversity). For example, God would use evolution to create life rather than special creation. However, I argue that whether the diversity is good or not depends on different situations. Within a community, diversity is good because we can learn to respect and help one another. I call it the "interactive diversity". For example, different kinds of life on Earth would interact with each other. Therefore, the life on Earth generated by evolution is an example of interactive diversity. However, for the multiverse scenario, different universes cannot interact with each other. This "non-interactive diversity" is not necessarily good (may be bad). Although we are not sure whether diversity is good to God or not, we can conclude that "interactive diversity" may be good for a community, based on our experience. Therefore, God would probably create a single universe with diversity, but not many non-interactive universes. The non-interactive diversity in the multiverse scenario cannot generate any good things for each of the universe. As mentioned above, the useless universes can be thought as a disadvantage. On the other hand, the "amount of good" is not necessarily proportional to the "amount of diversity". A single universe might have enough diversity already. It is not necessary for God or our nature to have infinite diversity.

Based on the above three criteria, we can conclude that the special scenario is the best choice. Since a perfectly good God would choose the best choice, the probability of creation of multiverse by God is very low. Therefore, as mentioned above, if we have $P(\sim T_2|T_1) \approx 1$, the disconfirmation of multiverse can be used as an indirect evidence of God hypothesis. In fact, we have a thorough discussion on some of the negative evidence of the multiverse hypothesis (see section 6.5.2.2). These can be served as an indirect support of the God hypothesis.

7.2 Some other criticisms of the fine-tuning argument

Although in the previous chapter we have concluded that the existence of God is the best explanation of the fine-tuning phenomena, some philosophers have criticized this modern design argument. In this section, I will briefly outline these criticisms and respond to them.

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[386] M. H. Chan, "Would God Create Our Universe through Multiverse?" *Theology and Science*, 13(2015): 394-407.
[387] In fact, Robin Collins suggests that God would create a fine-tuned multiverse rather than a fine-tuned single universe.

7.2.1 No objective prior probability

Sober suggests that it is relatively easy to compare two posterior probabilities P(E|T1) and P(E|T2) of theories T1 and T2. However, it is difficult to determine the actual values of the prior probabilities P(T1) and P(T2). Since we don't have the objective prior probabilities (the probabilities are undefined), it is impossible for us to determine which one, P(T1|E) or P(T2|E), is greater.[388] In other words, we don't have enough background knowledge or data to determine the prior probabilities. There may be some more information we don't know that determine the prior probabilities. Also, we have only one universe which is not enough to determine the probability. Therefore, there is no reason to accept the fine-tuning argument's claims about probability. Moreover, since we do not have the prior probabilities P(T1) and P(T2), we can simply assume that they are equal based on the Principle of Indifference.[389] Therefore, if P(T1)=P(T2), the posterior probabilities P(E|T1) and P(E|T2) determine which theory should be the best. This principle is known as the Likelihood Principle.[390] If it is true, we can get P(non-generated multiverse|FT) > P(God|FT) because we have P(FT|non-generated multiverse) > P(FT|God).

In fact, Sober is adopting the "frequency-based objective interpretation" of probability. This interpretation is based on the experimental probability, which means we can only determine the probability by experimental data. For example, the probability of getting a "1" by throwing a fair dice is about 1/6 should be based on experiments (throwing a dice one thousand times), but not from prior knowledge. Monton comments on this by stating that it is not necessary to stick to this interpretation. It is still reasonable for us to use the "subjectivist interpretation".[391] On the subjectivist interpretation of probability, one's probability for a proposition represents one's personal degree of belief that that proposition is true.[392] Therefore, our personal degree of belief can still compare the prior probabilities among different hypotheses. However, this kind of interpretation would have difficulties if different people's subjectivist probabilities differ a lot.

Generally speaking, it is not necessary to determine the actual value of the prior probability by experimental data. In my argument, I follow Swinburne's approach to compare the prior probabilities objectively based on simplicity and our knowledge. For example, we compare the number of things involved in different hypotheses, which can be determined objectively. Based on several objective

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[388] E. Sober, "The Design Argument," *The Blackwell Guide to the Philosophy of Religion*, ed. W. E. Mann (Oxford: Blackwell Publishing, 2005), p.120.

[389] Benjamin Jantzen, *An introduction to Design Arguments* (Cambridge: Cambridge University Press, 2014), p.177.

[390] Elliot Sober, "The Design Argument", *God and Design,* ed. Neil Manson (New York: Routledge, 2003), p.29.

[391] B. Monton, "God, Fine-tuning, and the Problem of Old Evidence," *British Journal of Philosophy of Science* 57(2006): 405-424.

[392] Ibid.

criteria, we can obtain P(God) > P(multiverse), though we do not have the exact value of the prior probabilities. For a scientific theory, we also do not have the exact value of its prior probability. Nevertheless, we can still compare different theories and choose the best one to account for the required observations. Modern science would break down if we just consider the Likelihood Principle. For example, in science history, a geocentric model with numerous deferents and epicycles can give a similar prediction power compared with a heliocentric model. However, scientists accept heliocentric model because it is a simpler and more elegant model to explain the motion of planets (especially for the retrograde motion of planets). If we just compare their likelihood functions, they would generate nearly the same results. However, the prior probability of a heliocentric model is much higher than the complicated geocentric model. This example illustrates the importance of the consideration of prior probability.

7.2.2 Possible alternatives criticism

In the previous chapter, we have considered mainly 4 hypotheses: chance-alone hypothesis, observational selection effect hypothesis, multiverse hypothesis and God hypothesis. In general, there may be many more alternative hypotheses that can address the fine-tuning phenomena. Suppose there are n hypotheses, $T_1, T_2, \ldots, T_n$. Therefore we have

$$P(FT) = \sum_{i=1}^{n} P(FT|T_i)P(T_i). \tag{7.3}$$

A hypothesis T_1 is confirmed if and only if $P(FT|T_1) > P(FT)$. Therefore, the confirmation of the hypothesis T_1 would satisfy

$$P(FT|T_1)[1 - P(T_1)] > \sum_{i=2}^{n} P(FT|T_i)P(T_i). \tag{7.4}$$

The above inequality means that we should consider all plausible alternative hypotheses before claiming a hypothesis is confirmed.[393]

Theoretically the above argument is true. However, it proves too much. It is always possible that some unknown hypotheses exist. What we can do is to compare all the existing hypotheses. Just like in cosmology, it is possible to have numerous unknown possible models. Nevertheless, we confirm that the Hot Big Bang model is the standard model in cosmology nowadays. Therefore, before any new

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[393] K. Staley, "Probability in Fine-Tuning Design Arguments," http://philsci-archive.pitt.edu/archive/00003354/01/fine_tuning _probability_4.pdf

hypothesis has been formulated, our conclusion is still valid. In other words, unknown hypotheses should not take part in any consideration. Otherwise, science is not possible because no scientific theory can be confirmed as it is in principle possible for us to construct infinitely many scientific models to account for an observation.

Moreover, based on current knowledge, we can estimate the prior probability of getting other unknown alternatives. For example, it is known that there are four fundamental forces in the nature. Is there any fifth fundamental force? The probability of getting a fifth fundamental force is not large because we still don't find any new particles that are related to the fifth fundamental force. Therefore, it is possible for us to estimate a probability that comprises all the unknown alternative theories. In view of the fine-tuning phenomena, we can show that the probability of getting a good alternative is not high. As mentioned before, we have discussed the most probable hypotheses based on the two main kinds of explanation in our experience (scientific explanation and personal explanation). For personal explanation, there are only limited choices of person who can transcend a universe and control a universe. The probability of having an alternative hypothesis for personal explanation is very low. For scientific explanation, we have discussed different types of explanations, such as single-universe scenario and multiverse scenario. We have also discussed the possibility of any law-like and random process that can explain the fine-tuning phenomena. Besides law-like and random processes, we do not have any other process to explain our natural world. Therefore, it seems that the considerations of the scientific explanations are nearly exhaustive. In other words, the probability of having an alternative scientific explanation is very low. In fact, the burden of proof should be on the critics' side. Otherwise, as mentioned above, this kind of criticism can always be applied to all existing scientific theories, not only in the fine-tuning argument.

7.2.3 Weak or strong confirmation?

In the above argument, we conclude that P(God|FT) > P(NG multiverse|FT) and P(God|FT) > P(generated multiverse|FT). However, this conclusion is just a "Weak Confirmation. The "Weak Principle of Confirmation" states that if an observation O is more likely under hypothesis H_1 than under hypothesis $H_2,\ldots,H_n$, then O counts as evidence in favour of accepting H_1 over $H_2,\ldots,H_n$.[394] It is equivalent to $P(H_1|O) > \max\{P(H_2|O), P(H_3|O), \ldots P(H_n|O)\}$. However, this just provides some force in the confirmation. What we need should be a "Strong Confirmation". The "Strong Principle of Confirmation" states that if an observation O is more likely under hypothesis H_1 than under hypothesis $H_2, \ldots, H_n$, then

[394] K. E. Himma, "Prior Probabilities and Confirmation Theory: A Problem with the Fine-Tuning Argument," *International Journal for Philosophy of Religion* 51(2002): 175-194.

we are epistemically warranted in accepting H_1 over $H_2,\ldots, H_n$.[395] A "Strong Confirmation" is obtained if and only if $P(God|FT) > P(\sim God|FT)$ or $P(God|FT) > \frac{1}{2}$. Can we draw a conclusion of the strong confirmation?

Suppose there are only 4 possible hypotheses (God hypothesis, chance-alone hypothesis, generated multiverse hypothesis and non-generated (NG) multiverse hypothesis) to explain the fine-tuning phenomena. Although we have P(God|FT) > P(generated multiverse|FT), P(God|FT) > P(NG multiverse|FT) and P(God|FT) > P(chance|FT), it does not entail $P(God|FT) > P(generated\ multiverse \cup NG\ multiverse \cup chance|FT)$. If all the hypotheses are mutually exclusive, we have $P(generated\ multiverse \cup NG\ multiverse \cup chance|FT) = P(generated\ multiverse|FT) + P(NG\ multiverse|FT) + P(Chance|FT) = P(\sim God|FT)$. Although the three individual probabilities may be very small, the sum can be still greater than P(God|FT). The strong confirmation can be obtained if and only if we have $P(God|FT) > P(\sim God|FT) = P(generated\ multiverse \cup NG\ multiverse \cup chance|FT)$.

Based on the confirmation principle, we can determine whether our conclusion is a strong confirmation or not. Assume all the hypotheses are mutually exclusive and let T1 = generated multiverse, T2 = non-generated multiverse and T3 = chance. We have $P(God|FT) = S(God, FT)/P(FT)$ and $P(\sim God|FT) = P(T1|FT) + P(T2|FT) + P(T3|FT) = [S(T1, FT) + S(T2, FT) + S(T3, FT)]/P(FT)$. Since S(T3,FT) is nearly zero, we can safely neglect this term. By using Eq. (6.4), $S(God, FT) > S(multiverse, FT) = S(T1, FT) + S(T2, FT)$, we get $P(God|FT) > P(\sim God|FT)$, which means a strong confirmation is obtained.

In the above analysis, we also assume that there is no other unknown naturalistic hypothesis which can explain the fine-tuning phenomena. As mentioned in the above section, this assumption can be justified because the probability of having an alternative unknown scientific explanation is very low. Therefore, our analysis provides a strong confirmation of the fine-tuning phenomena.

7.2.4 Irrelevance of the fine-tuning evidence

Himma suggests that if we have two theories T1 and T2 such that P(FT|T1) = P(FT|T2), i.e. both theories can equally explain the fine-tuning problem, we need to compare their prior probabilities P(T1) and P(T2). Therefore, the argument of fine-tuning now depends on the success of the other arguments

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[395] Ibid.

purporting to show that one of the theories is more likely to be true. The argument simply renders irrelevant the appearance of fine-tuning.[396] As a result, we are epistemically warranted in accepting one hypothesis T1 over another T2 only when the prior probability of T1 is higher than T2. If it is true, what is the role of the fine-tuning evidence? The prior probability has already determined the result. Himma also thinks that we lack an objectively reliable way to settle the disagreement between theists and atheists regarding the prior probabilities of the two hypotheses. Since we don't know the prior probabilities, the "Strong Principle of Confirmation" is not valid.[397]

I don't agree with both arguments. Firstly, the prior probability is not really independent of the fine-tuning phenomena. One can always create any hypothesis H to explain the fine-tuning phenomena. However, when you want to increase its explanatory power, what you need to do might be putting more variables or assumptions so that the hypothesis H can fit as much observational data as it can. Therefore, in order to raise the posterior probability P(FT|H), the drawback is to lower the prior probability P(H) because of the additional assumptions. For example, for the metaphysical multiverse hypothesis, you need to assume that each universe must have different sets of fundamental constants and initial conditions, which is a pure assumption. This would decrease the prior probability of the hypothesis. Therefore, the fine-tuning phenomena indirectly contribute to the prior probability. As mentioned in the previous chapter, Gil and Alfonseca perform a computer simulation and discover that if we want to provide a satisfactory explanation of the fine-tuning phenomena by using multiverse theory, the physical laws required are complicated and show certain time dependence.[398] In other words, if we want to fit the observational data, we have to modify our hypothesis (usually add more assumptions or entities) and lower the prior probability.

For the second argument, I agree that there is no consensus on whether God exists based on the arguments other than the fine-tuning evidence. It means that we can't generally claim $P(God) > P(\sim God)$. However, in our context, P(God) is the prior probability of a particular God hypothesis that is used to explain the fine-tuning phenomena. As mentioned above, it is intrinsically related to the fine-tuning evidence. What I have done in the above section is to show that P(God) > P(multiverse), but not P(God) > $P(\sim God)$. In fact, we determine the posterior probabilities objectively, but not subjectively. Our conclusion is still correct no matter you are an atheist or a theist.

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[396] Ibid.

[397] Ibid.

[398] Francisco Gil and Manuel Alfonseca, "Fine Tuning Explained? Multiverses and Cellular Automata", *Journal of General Philosophy of Science* 44(2013): 153-172.

7.3 Conclusion

In the first part of this chapter, we have discussed the effect if the God hypothesis is compatible with the multiverse hypothesis. We have shown that if God would not create multiverse, and the existence of multiverse is unlikely based on observational evidence, the degree of confirmation of the God hypothesis would increase. It means that the disconfirmation of the multiverse from observations can be used as an indirect evidence to support the God hypothesis. Also we have encountered some criticisms on our fine-tuning argument. Most of these criticisms appeal to skeptical views, which are not strong arguments to oppose our conclusion. We have already discussed and given responses to these criticisms. Instead, we show that the God hypothesis can give a strong confirmation to explain the fine-tuning phenomena. Therefore, based on the fine-tuning evidence, the theistic worldview is rationally preferable to the naturalistic worldview.

Chapter 8 Conclusion

In this thesis, I have first outlined all the fine-tuning evidence, including the existence of anthropic elements based on the fine-tuned fundamental constants (primary fine-tuning), the fine-tuned chemical and physical properties of some anthropic elements, the fine-tuned environment and initial conditions for life and the fine-tuned evolution process. These evidences suggest that the probability of the existence of intelligent human beings by chance is extremely small. Therefore, it requires an explanation of our existence. We have encountered several possible hypotheses, chance-alone hypothesis, observational selection effect hypothesis, theistic hypothesis, metaphysical multiverse hypothesis and the generated multiverse hypothesis. Among these hypotheses, we have to choose one which is the best explanation of the fine-tuning problem. The criterion of the best explanation, according to the confirmation theory, is to compare the posterior probability and the prior probability. The best hypothesis is the one if the product of the posterior probability and prior probability of the hypothesis is the largest.

For the chance-alone hypothesis, although the prior probability P(chance) is not zero, the posterior probability P(FT|chance) is too low such that P(FT|chance)P(chance) ≈ 0. Therefore we get P(Chance|FT) ≈ 0. For the super-law hypothesis, we argue that this kind of explanation can only push the problem to a more fundamental level because we have to seek an explanation to explain the fine-tuned super-law. In fact, the closest attempt of this explanation, the string theory, is not yet a standard theory. Therefore, it is not a good explanation of the fine-tuning phenomena.

For the other explanations, such as the anthropic principle and the observational selection effect, we have already shown that the anthropic principle just shows the consistency between observations and theories, but not an explanation. Moreover, we argue that there is no difference in viewpoints from a "bystander" and an "observer". Therefore, we do not have any observational selection effect when we are observing those fine-tuned constants and conditions.

For the non-generated multiverse hypothesis, we assume that there are infinitely many possible constants and initial conditions without logical gap, it is very likely to have one universe such that it is life-permitting. Therefore we have P(FT|NG multiverse) ≈ 1. However, we need a lot of assumptions, such as each universe has different fundamental constants and initial conditions, and it does not have any theoretical basis of its existence, the prior probability is very low, i.e. P(FT|NG multiverse)P(NG multiverse) is very low. For the generated multiverse, it is mainly extrapolated from unconfirmed theories, string theory and eternal inflation theory. This decreases the prior probability of the generated multiverse hypothesis before assessing the fine-tuning phenomena. Also, the number of possible sets of fundamental constants is finite and subject to the constraints in string theory. It is quite likely that the

generated fundamental constants do not fall into the anthropic region. Therefore, generally speaking, we conclude P(FT|generated multiverse)P(generated multiverse) is low. For the theistic hypothesis, based on the assumed properties of God – omnipotent, omniscience and perfectly good, it is very likely that God creates intelligent human beings. Therefore we have P(FT|God) ≈ 0.5. By considering some other evidence such as the Kalam cosmological argument, there is a possibility that God exists. By comparing the assumptions needed for theistic hypothesis, metaphysical multiverse hypothesis and generated multiverse hypothesis, the prior probability of theistic hypothesis is higher than the others (much fewer assumptions). Therefore, by using P(FT|God) ≈ 0.5, the product P(FT|God)P(God) is the largest compared with the other hypotheses. We conclude that the fine-tuning evidence supports the existence of God more than the other naturalistic hypotheses.

Besides, we also discuss the compatibility of the God hypothesis with multiverse hypothesis. We show that a perfectly good God is unlikely to create humans through multiverse scenario. Since the current evidence disfavours the existence of multiverse, the incompatibility of the hypotheses indirectly supports the teleological argument.

In addition, we have also discussed many criticisms of the arguments presented above. All these criticisms cannot disprove the above conclusion based on current knowledge about our natural world. Nevertheless, if one day there are some new observations which may affect the arguments presented, our conclusion can still be challenged.

To conclude, after a comprehensive study of the fine-tuning arguments, the fine-tuning phenomena strongly support the theistic worldview.

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