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It's About Time: Dynamics of Inflationary Cosmology as the Source of the Asymmetry of Time

Emre Keskin

University of South Florida, ekeskin@mail.usf.edu

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It's About Time: Dynamics of Inflationary Cosmology
as the Source of the Asymmetry of Time

by

Emre Keskin

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Philosophy
College of Arts and Sciences
University of South Florida

Major Professor: Eric Winsberg, Ph.D.
Roger Ariew, Ph.D.
Douglas Jesseph, Ph.D.
Alex Levine, Ph.D.

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Dedication

I would like to dedicate this dissertation to my partner and my better half, Dr. Elizabeth Victor. Without Liz, this project would have been abandoned many times. Her support and confidence in me were the two most important driving forces during the last several years.

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Abstract

This project is about the asymmetry of time. The main source of discontent for physicists and philosophers alike is that even though in every physical theory we developed and/or discovered for explaining how the universe functions, the laws are time reversal invariant; there seems to be a very genuine asymmetry between the past and the future. The aim of this project is to examine several attempts to solve this friction between the laws of physics and the asymmetry and provide a new proposal that makes use of modern cosmology. In the recent history of physics and in contemporary philosophy of science there have been several attempts to explain the asymmetry of time and reconcile this asymmetry with time reversal invariant physical laws. David Albert developed one of the most recent attempts at solving the problem in *Time and Chance* (2000). Albert claims that there is a conclusive solution to the problem of asymmetry of time: namely, combining the laws of mechanics with several novel concepts that he introduces, the most important of which is what he calls “the past hypothesis”. Eric Winsberg developed another modern attempt to solve the problem of the asymmetry of time. Winsberg combines Hans Reichenbach’s branch systems proposal with a “framework” view of laws to solve the problem. Although this version of the branch systems proposal overcomes several problems associated with Reichenbach’s original construction of the proposal, certain aspects of it are still open to critique.

Following a brief introduction, my chapters include 1) a history of the problem of the asymmetry of time, in which I provide a historical overview of the issues particularly

discussed by Boltzmann and his interlocutors, 2) a detailed evaluation of David Albert's account of the asymmetry of time, where he argues that we can solve all the problems if we use a combination of laws of physics and the *past hypothesis*, 3) a detailed overview of Eric Winsberg's account that depends a specific way of looking at the laws of physics—the framework view, and 4) my account, which attempts to solve the problem of the asymmetry of time, making extensive use of the developments on modern cosmology, specifically regarding the inflationary mechanism.

I claim that if we take into account recent developments in modern cosmology and proposals for laws for initial conditions, then we cannot maintain the metaphysical status of the past hypothesis in Albert's project. Specifically, I argue that in order for a theory to make use of initial conditions of the universe, it has to include a set of laws from modern cosmology pertaining to that initial condition. I defend the position that inflation can supply the source of asymmetry when supported by the aggregate view of laws, which I introduce in the last chapter. The explanation of the asymmetry of time requires the use of dynamical equations from modern cosmology that would produce the boundary conditions. The boundary condition produced in this way would fill in for the source of the asymmetry of time. Consequently, I argue that the explanation of the asymmetry of time is encoded in the laws of modern cosmology.

Introduction

In this project, I will examine the problem of the asymmetry of time and propose a new explanation. Specifically, I will investigate contemporary attempts to explain the asymmetry of time, then propose a new solution to overcome certain difficulties. The main source of discontent for physicists and philosophers alike is that even though in every physical theory we developed and/or discovered for explaining how the universe (and everything in it) functions, the laws are time reversal invariant; there seems to be a very genuine asymmetry between the past and the future. The general aim is to give a satisfactory explanation of how it is possible for time symmetric laws to give rise to or explain time asymmetric physical phenomena.

In the recent history of physics and in contemporary philosophy of science there have been several attempts to explain the asymmetry of time and reconcile this asymmetry with time reversal invariant physical laws. We can trace the origin of such approaches to the development of the kinetic theory of gases in the early 19th century. One of the most influential (and to some degree successful) attempts at solving the asymmetry problem can be found in the works of Ludwig Boltzmann. Although there were two serious objections (reversibility and recurrence) to Boltzmann's argument for the asymmetry of time, his papers, in which he responds to the criticisms of his interlocutors (e.g., Zermelo, 1966), led to the development of statistical mechanics. Furthermore, his approach became the foundation of the most recent attempts at solving the problem: those developed by David Albert in *Time and Chance* (2000). Albert claims

that there is a conclusive solution to the problem of asymmetry of time: namely, combining the laws of mechanics with several novel concepts that he introduces, the most important of which is what he calls “the past hypothesis”.

In addition to the Boltzmannian framework, Hans Reichenbach developed another promising approach to tackling the problem of asymmetry of time in his posthumously published work *The Direction of Time* (1956). Reichenbach argued that we could explain the origins of asymmetry of time that we observe if we maintain that physical systems “branch off” from their environment under certain conditions. He suggested that the branching of a system corresponds to the moment of isolation from its environment. More importantly, we could use this moment to introduce the asymmetry into the time reversal invariant laws of physics. Reichenbach thought that this branching could explain why isolated systems behave asymmetrically, which in turn can be used to explain the general asymmetry of time we observe in the universe. A modern version of this argument by Eric Winsberg combines the branch systems proposal with a different approach to laws of nature, maintaining a “framework” view of laws. Although this version of the branch systems proposal overcomes several problems associated with Reichenbach’s original construction of the proposal, certain aspects of it are still open to critique. In any case, Winsberg’s account is an improvement over the theory Reichenbach originally introduced to explain the asymmetry of time.

Neither of these two mainstream attempts to solve the problem of time asymmetry are free from problems. The most serious objection against Reichenbach’s branch systems comes from Albert, who claims that the central notion of branching is highly problematic because of the difficulties associated with identifying isolated systems as

well as their moment of isolation. Albert's project came under scrutiny from different angles; John Earman and Eric Winsberg, among others, have raised serious challenges to Albert's approach. The common focus of the objections highlights problems regarding the central mechanism of how the past hypothesis solves all the problems of time asymmetry as Albert presents it.

Although the aforementioned Boltzmannian framework and the branch systems have their shortcomings, they also contain important insights toward forming a successful solution to the problem of the asymmetry of time. In addition to examining objections against these two projects, I will identify and isolate the problematic parts of these projects from the rest. In addition, I will raise my own objection, specifically against Albert's project. I will argue that if we take into account recent developments in modern cosmology and proposals for laws for initial conditions, then we cannot maintain the metaphysical status of the past hypothesis in Albert's project. Specifically, I will argue that in order for a theory to make use of initial conditions of the universe, it has to include a set of laws from modern cosmology pertaining to that initial condition. Following this, I aim to combine the better parts of these projects with my own account of laws of nature in conjunction with the laws from cosmology regarding the very early universe. I claim that this final synthesis will be more successful in explaining the asymmetry of time even though we still only use the time reversal invariant laws of physics, which should also include laws of modern cosmology. In order to achieve this I will do the following:

1) Conduct critical examination of two modern projects regarding the asymmetry of time.

2) Develop an account of laws of nature that can handle arguments from both accounts.

3) Construct a better account from the parts of the above two projects.

4) And, finally, incorporate laws from modern cosmology to the resulting combination of (2) and (3) to give a better explanation of the asymmetry of time.

The first chapter is a brief introduction in which I aim to clarify why there is a problem to start with in relation to the asymmetry of time. Furthermore, I will provide a short review of the technical issues of the physics of time reversal. We can consider the central problem as reconciling time reversal physical laws with the observed time asymmetry. In order to solve this problem, however, we have to possess a technical understanding of what it means for a law of physics to be time reversal invariant. This will provide the necessary background for critically examining the accounts I will discuss in the following chapters, which attempt to reconcile time reversal invariant laws with the asymmetry of time.

Following this short technical review, I will present a critical overview of Boltzmann's historical approach to the problem of the asymmetry of time. Although there are insurmountable objections against his project, objections which aim to explain why the overwhelming majority of local thermodynamic systems asymmetrically evolve in time, his theory forms the foundations of modern approaches dealing with the same problem. In order to show its foundational value, I will first present each alternative account in some detail. Following this, I will review the objections by Ernst Zermelo and

explain the strength of each objection, focusing on how damaging they are to the original historical account.

In Chapter Two, I will examine David Albert's global solution for the problem of the asymmetry of time. Although Albert thinks that the Boltzmannian framework has shed light on certain parts of the problem, he also points out that it is incomplete. The most important drawback of the Boltzmannian framework, Albert argues, is that its retrodictions fail to coincide with our records (and/or memories).¹ Resolving the issue of faulty retrodictions is one of the central motivations for Albert's project. He maintains that it is possible to give an account for the asymmetry of time that is not subject to the reversibility objection.

According to his proposal, this can be achieved by an elaborate combination of "right probability distribution," the deterministic laws of motion, and the past hypothesis. Albert has to make two commitments for this combination to function properly. He explicitly subscribes to the "best system" approach to laws. The feature he imports to his project from the best system approach is the requirement of the balance between simplicity, informativeness, and fit. In contrast, he implicitly maintains that the laws that belong to a set of laws satisfying the balance between simplicity, informativeness, and fit must have universal scope. If a statement is a law in virtue of being a member of such a balanced set, then it must be a *fundamental* law of physics that underwrites physical phenomena everywhere at all times. In this chapter, in addition to providing the details of these commitments, I will also highlight the problems arising from them.

¹ Throughout this project, I will use the term "record" as an umbrella term covering things like memories and any other concepts that can serve as records of past events.

In Chapter Three, I will examine approaches that attempt to solve the problems of the asymmetry of time by appealing to functioning of local isolated systems. An important example of such an attempt is Reichenbach's branch systems proposal (BSP). The proposal aims to solve the asymmetry problem by asserting that isolated physical systems cannot be considered as actual systems before isolation from the environment. While we can explain the monotonic increase of entropy toward the future with this proposal, we would not be making any faulty retrodictions regarding the increase of entropy toward the past, which is an insuperable problem for Boltzmannian framework.

Recently, Eric Winsberg reconstructed this proposal in order to provide an alternative to Albert's project. The original BSP proposal necessitates applying the statistical postulate at the beginnings of branching systems without a justification of this requirement. Winsberg's reconstruction of BSP includes the addition of the "framework" conception of laws that aims to justify why it is admissible to apply the statistical postulate at the initial moment of any system that becomes isolated from its environment. This approach takes laws as useful tools for understanding how the physical systems evolve in time. The advantage of the framework conception is that we can justify the application of the statistical postulate for systems that branch off from their environments. In contrast to the original proposal, Winsberg's reconstruction does not introduce the asymmetry in an ad hoc way or give a circular argument for it.

The aim of Chapter Four is to develop an alternative approach to tackle the problem of the asymmetry of time. The preceding investigations of the different attempts to solve this problem point to several important difficulties that we need to address for constructing a successful explanation of the asymmetry of time. In this chapter, I will

construct arguments for overcoming these difficulties. The first step is addressing one of the central disagreements between the alternative accounts we have examined so far: the nature and structure of the laws of nature. Each of the contemporary accounts has a specific way of understanding the laws of nature, and these ways are often contradictory. Moreover, there are certain difficulties associated with both Albert's fundamental view of laws and Winsberg's framework view of laws. I will construct a new way of understanding the nature and the structure of natural laws free from the problems associated with others.

In the second part of Chapter Four, I will construct an argument from cosmology that will point to an improved understanding of the initial conditions of the universe. Furthermore, I will defend the position that such an understanding would be more useful in explaining the behavior of local physical systems. The final section of this chapter will be dedicated to showing how the arguments in the first two sections can be combined to construct an overall better account to explain the asymmetry of time, one that avoids the pitfalls that others cannot escape.

Chapter One

History of the Problem of the Asymmetry of Time

1.1 Introduction: The Setup of the Problem

There is a difference between the past and the future. At least, we think there is a difference between the past and the future. They seem distinct from each other. We usually experience phenomena going from one direction of time to the other, and not vice versa. In other words, we observe irreversible physical events in the universe. Furthermore, we seem to have no influence on one of the directions of time, whereas we think that we have some ‘casual handles’ we can control on the other direction. We conclude that time is asymmetric and the direction of time is from the past to the future. However, a careful investigation would show that the *specific* direction of time we experience from the past to the future does not immediately follow from the universe possessing time asymmetry. This suggests that, although they seem interconnected, in fact there are two distinct research subjects regarding time, the subject of the asymmetry of time, and the subject of the direction of time. Although these two subjects are closely related, we should not assume the answers at which we might arrive for one would also prove to be viable answers to the problems for the other. That said, the focus of this

project is the asymmetry of time and constructing an account for overcoming the problems associated with it.²

The asymmetry of time is an interesting subject for the following reason. On the one hand, there are time asymmetric (irreversible) phenomena in the universe. On the other hand, we possess time symmetric physics to explain these asymmetric phenomena. Although there are some arguments against the time symmetry of physical laws, the consensus is that all of our modern physical theories, starting with Newtonian mechanics, are time reversal invariant.³ A neat feature of time reversal invariant laws of physics is that if you supply them with symmetric input, they provide symmetric output, and similarly by supplying asymmetric input, they provide asymmetric output. This feature suggests we observe time asymmetric physical phenomena, because there was at some point in time an asymmetric input introduced to the universe. We should ensure that this asymmetric input, the source of the time asymmetry we observe, is included in our accounts.

One other consideration we have to keep in mind for developing accounts to explain the asymmetry of time is the scale of the asymmetric phenomena. We observe time asymmetric phenomena from a microscopic scale to a cosmic scale. However, we should not expect explanation of the asymmetry at one scale to work for all of the remaining scales without proper justification. Similarly, explaining the asymmetry of time for local physical systems does not automatically translate to an explanation of the

² I aim to provide an account to explain the asymmetry of time. I make no explicit claims regarding the direction of time. Any ancillary answers to the problems associated with the direction of time that might stem from my discussions of the problem of the asymmetry are not central to my project.

³ I will discuss the details of this in the next section.

global asymmetry of time. Therefore, we should provide explicit reasons for why an account of time asymmetry, if successful, could explain all the relevant asymmetries.

1.2 Microstates, Macrostates, and Phase Spaces

Throughout this project, we are going to use two different ways of representing the state of a system at a given time—microstates and macrostates. The microstate of a system depends on its microscopic properties—specifically, the positions and momentum of the particles that make up the given system. Similarly, the macro properties of a system, such as temperature, volume, pressure, etc., identify the macrostates of thermodynamic systems. Numerous microstates can be compatible with a single macrostate, because it is possible for different micro properties to translate into one macro property. That is, more than one arrangement of particles that make up a gas might lead to the same temperature. The reason for this is straightforward. The temperature of a gas is a representation of the average kinetic energy of its particles, and various combinations of the momentum of the particles that make up the gas could yield the same average value for the kinetic energy. For example, suppose that we have a gas with only three particles, those of which could only have two momentum values—0 and 1. Further suppose that the temperature of the gas corresponds to the microstate with a total momentum of two. In such a case, three different microstates correspond to the same macrostate.

Furthermore, by using micro properties we can separately identify each particle of a given system. In a classical three-dimensional Euclidian space, we can give the exact status of a particle by using these microscopic properties. For example, for a single

particle in such a space we use three values for position and three values for momentum to identify it uniquely. In total, six values picks out a single particle at a given time; this makes it possible to represent the state of this particle at a given time as a single point in a six-dimensional space. If we want to represent an entire system composed of N particles, by using the same reasoning, we can construct a $6N$ -dimensional space, called the phase space, where the state of the system at a given time would be a single point. Using this space, we can define the trajectories of such points over time as the time evolution of the given system. Furthermore, because more than one microstate is compatible with a given macrostate, we can represent the macrostate of the system as a region of the phase space associated with it. Combining all of the above, we can represent the time evolution of a macrostate by the trajectory of the region of the phase space compatible with that particular macrostate of the system.

Additionally, we need a statistical postulate if we want to talk about the connection between a macrostate and a microstate compatible with that macrostate. We want to be able to have some specific knowledge of the microstate given the system's macrostate, because the dynamical laws of motion apply only to microstates and not to macrostates. Suppose that we have a thermodynamic system S , in macrostate M , which is compatible with many microstates, which constitute a region of the phase space. The actual microstate of the system S can be any one of those microstates.⁴ This of course is not saying much about the specifics of the system and its microstate. Fortunately, there is a probabilistic relation between macrostates and microstates. Given that S is in M , "the probability that $[S's]$ *microcondition* currently lies within any particular subregion of" the

⁴ There can be infinitely many such microstates.

region of the phase space of S compatible with M “is proportional to the familiarly calculated *volume* of that subregion” (Albert 2000, p. 66).

This probabilistic relation justifies our use of the trajectory of that subregion of the phase space as the time evolution of the system with respect to the dynamical laws of motion. If we had no knowledge of the microstate of the system, we could not use the equations of motion to determine the time evolution of the system. Consequently, in the absence of results to compare against the time evolution of the macrostate of the system, we would not be in a position to make claims regarding the compatibility of time reversal invariant laws and the irreversible phenomena.

Of course, there is not only one fundamental statistical postulate. The statistical postulate comes from a specific interpretation of statistical probabilities regarding thermodynamic systems. In other words, it is possible to have various statistical postulates depending on different interpretations of statistical probabilities. The question then arises—why chose a particular one over other possibilities? More specifically, what makes a statistical postulate more suitable from other ones such that we use it in determining the time-evolution of thermodynamic systems? The common answer to this question is that we use the most typical statistical probability. However, this answer is highly suspect because we can always ask what makes a particular probability interpretation more typical than some other interpretation. The answer to this question cannot be that one is more fundamental than the others are precisely because what we are asking is what makes that particular statistical postulate more fundamental. At this point, I assume that the particular statistical postulate is a well-formed one that leads to a result

compatible with the observations of how macrostates of a thermodynamic system evolve with the caveat that such compatibility does not guarantee fundamentality.

1.3 Time Reversal Invariance

The main issue I will examine is the problem of the asymmetry of time. I aim to investigate this problem from a specific point of view. I want to give a philosophical account of physical time.⁵ The variable at the focus of this project is “ t ”, the time variable as it enters into the equations of laws of physics. One of the details of this project is to give an account of the relationship between time symmetric laws and the asymmetric phenomena. Before we can start tackling the details, it is essential that we possess some technical understanding of what it means for a law of physics to be time reversal invariant. For a law to be time symmetric it must be unchanged under transformation T , time reversal transformation. In this project, I will assume the time reversal transformation operates as follows:

$$T: t \rightarrow t' = -t$$

First, let us look at what this transformation entails in the case of the equation of motion for Newtonian mechanics. If we use transformation T for variable t , the resultant variable t' would produce the same results as t from the equation of motion because the second order derivative with respect to t would be equal to the second order derivative with respect to t' . In other words, if an object is on a physically possible trajectory with t , then the trajectory of the object with t' must also be a physically possible trajectory. Consequently, the equation of motion of Newtonian mechanics is time reversal invariant.

⁵ This point of view excludes our feeling regarding the passage of time.

Although the case for Newtonian mechanics contains important insights toward forming a general idea of time reversal invariance, we need to fulfill certain additional requirements to show that electromagnetism and quantum mechanics are time reversal invariant as well.⁶ In the case of electromagnetism we start similar to Newtonian mechanics, showing that both t and t' satisfy the equation of motion. However, showing t' also satisfies the equations of motion (i.e. reversing the velocity vectors) is not enough to arrive at exact time reversal in the presence of electromagnetic fields. In addition, we have to take into account the electromagnetic field itself and use the reverse of the magnetic field. In this case, in addition to showing that the reversed velocity vectors satisfy the equation of motion, we have to show that the reversed magnetic field satisfies Maxwell's equations as well. We arrive at the result that if a magnetic field satisfies Maxwell's equation, then so does its reverse. Thus, we can claim that the existence of solutions for the equation of motion with reversed velocities and the existence of solutions for Maxwell's equations with reversed magnetic field shows that electromagnetism is also time reversal invariant.

We can with some effort extend a similar reasoning to the equation of motion of quantum mechanics. The gut reaction is that if we can show that the equation of motion for quantum mechanics, the Schrodinger equation, is invariant under transformation T , then we can conclude that quantum mechanics is also time reversal invariant. However, as Albert points out, "the dynamical law that governs the evolutions of quantum-mechanical systems in time include only first derivatives" (Albert 2000, pp. 131-2). That

⁶ Although there are some questions about this, for this project I consider that we can safely assume that the laws of quantum mechanics are time reversal invariant. The interested reader can refer to the last chapter of Albert's *Time and Chance*.

is, if a state vector satisfies the Schrodinger equation with time variable t , then it is not the case that, with transformation $T: t \rightarrow t' = -t$, t' would also satisfy the Schrodinger equation. However, this does prove that quantum mechanics is an example of violation of time reversal invariance. In contrast, it suggests that, akin to the case of electromagnetism, there may be additional requirements that need to be satisfied before we can assert that quantum mechanics is time reversal invariant. Sachs indicates there are in fact three such requirements in the case of quantum mechanics (Sachs, pp. 31-49):

- 1) Kinematically admissible transformation must be consistent with the commutation relations.
- 2) If $|\Psi\rangle$ is an accessible state of the system then also $|\Psi'\rangle$ (where $|\Psi'\rangle = T|\Psi\rangle$).
- 3) The Hamiltonian function of the kinematic variables must be invariant under T .

Following these requirements, Sachs argues that we can prove that there are single particle and multi-particle (non-relativistic) quantum mechanical systems where we get time reversal invariance.⁷ At this point, it is safe to assume that for systems that we will use in this project we can always find a way to show that they do not violate time reversal invariance.⁸

Although we can conclude that the laws of physics are time reversal invariant (possibly with the exception of CPT invariance violations in K-meson decay), we do not

⁷ The details of these proofs are beyond the scope of this section; interested readers can find them in the chapter three of Sachs (1987).

⁸ It is important to emphasize this point because Albert claims certain physical theories, unlike what the conventional wisdom about these things says, violate time reversal invariance.

possess a universal way of showing this is the case.⁹ The way we prove that the current laws of physics are time reversal invariant might not be sufficient to conclude that no future law of physics would not violate translation T . Fortunately, a case by case analysis is adequate for my purposes in this project. Consequently, throughout my discussions I will assume that the laws of physics we encounter are time reversal invariant.

This time reversal invariance, however, does not imply that every motion has to have an inverse version. As Sachs emphasizes, “the statement of [time reversal] invariance is a statement about *equations* of motion, not about the actual motions of systems” (Sachs, p. 6, original emphasis). If one ignores this fact, it may be possible to arrive at incorrect conclusions, such as claiming there is a paradox because we get irreversible motion from reversible laws. However, there is no such paradox because to get motion from equations of motion we need further input. The equations of motion determine a specific motion when we include some initial or boundary conditions. However, time reversal invariance of the equations of motion has no bearing on what initial and boundary conditions we could use to describe possibly irreversible motion. Hence, there is nothing paradoxical about having irreversible phenomena with time reversal invariant laws of motion. The actual result at which I am aiming to arrive is a proper explanation of how all of these function together. I aim to give an account of the asymmetry of time that combines time reversal invariant laws, initial conditions, and irreversible phenomena.

⁹ Here, I side with Sachs regarding this point that the theories of interest to us are indeed time reversal invariant, including the classical mechanics and quantum mechanics.

1.4 The Historical Boltzmannian Framework

Boltzmann's attempt to derive the time asymmetric behavior of physical systems by only using time symmetric laws and time symmetric assumptions is to some degree one of the most successful historical attempts at resolving the time asymmetry problem. For this reason, it is a natural place to start this investigation.

Boltzmann's aim was to explain how time symmetric laws could govern and/or give rise to everyday time asymmetric, irreversible thermodynamic phenomena. Initially, the question he asked was this: could it be possible to derive the second law of thermodynamics from the reversible dynamical laws governing the motions of particles? He thought that he achieved this with his H-theorem and the *Stosszahlansatz* (assumption of molecular chaos). By 1872, Boltzmann's chief concern was to be able to give a satisfactory explanation of the behavior of non-equilibrium systems, specifically the properties regarding their approach to equilibrium. He wanted to reconcile the time-symmetric mechanics of the molecules that made up gases with their macroscopic irreversible behavior.

First and most importantly, he introduced the assumption of molecular chaos (*Stosszahlansatz*), an assumption regarding the number of collisions between the molecules that make up the gas. From the *Stosszahlansatz*, and by employing several other assumptions, the details of which are not significant for the current argument, Boltzmann derived his kinetic equation. He saw that a stationary solution to this equation describes the state defined as equilibrium. Boltzmann, with the aid of his H-theorem, showed that the only stationary solution to his kinetic equation maps onto equilibrium states. By employing these assumptions from time-symmetric mechanics, Boltzmann

concluded that he had constructed a proof for the irreversible monotonic approach of systems to equilibrium. Before moving on to objections to Boltzmann’s solution, let us look at it at some detail.¹⁰

H-theorem was intended as a mathematical representation of the tendency of molecules of a gas to monotonically approach to Maxwell-Boltzmann distribution, assuming that they start in a random distribution. Most crucially, the arguments that involve the H-theorem also bring into play the *Stosszahlansatz*. The assumption of molecular chaos (*Stosszahlansatz*) states, “[t]he number of molecules per unit volume is the same in the space to be traversed in any other part of the space” (Ehrenfest & Ehrenfest, p. 6).¹¹ Boltzmann defined the H function in his 1872 paper, which in the original paper appears as E¹² (entropy) although it clearly is distinct from entropy. Assume that the number of molecules in a gas can be represented as in (1), where q and p represents coordinates and momentum,

$$\delta n = (q_1 \dots p_r, t) \delta_{q_1} \dots \delta_{p_r} \quad (1)$$

After writing this, reduce it to the form of Maxwell-Boltzmann distribution function,

$$\delta n = n C e^{-\epsilon/kT} \delta_{q_1} \dots \delta_{p_r} \quad (2)$$

¹⁰ I will make use of several concepts without explaining them because they are not essential to the current discussion.

¹¹ Although many physicists, as well as philosophers, use *Stosszahlansatz* and the assumption of molecular chaos interchangeably, Ehrenfests thinks that there are differences between the two. Nevertheless, for our purposes, we do not need to investigate the issue in any more detail. There is, however, an important difference between the assumption of molecular chaos and assumptions about the number of collisions. Boltzmann uses these two assumptions differently.

¹² In the original paper Boltzmann states, “We shall give the proof of a theorem which forms the basis of our present investigation: that the quantity $E = \int_0^\infty f(x, t) \left\{ \log \left[\frac{f(x, t)}{\sqrt{x}} \right] - 1 \right\} dx$ can never increase” (Boltzmann, 1966).

Then if the μ -space is divided into blocks, for the i^{th} block of the μ -space we can write the number of molecules as,

$$n_i = f_i(t) \delta_{q_1} \dots \delta_{p_r} \quad (3)$$

We can now write the sum of molecules in those blocks, the H function as,

$$H = \sum_i f_i \log f_i \delta_{q_1} \dots \delta_{p_r} \quad (4)$$

Which we can then write as,

$$H = \sum_i n_i \log n_i + constant \quad (5)$$

At this point by using (5), we should think about the rate of change of the value of H with time. Hence, we should differentiate H with respect to time (to do this let us write (4) by replacing summation with its integral form),

$$\frac{dH}{dt} = \int \dots \int \left(\frac{df}{dt} \log f + \frac{df}{dt} \right) d_{q_1} \dots d_{p_r} \quad (6)$$

From this, Boltzmann showed that

$$\frac{dH}{dt} \leq 0 \quad (7)$$

Therefore, (7) states that if H is not in its minimum value it will decrease, and at equilibrium, it will have its minimum value and stay at that value.¹³This is Boltzmann's famous H-theorem, which led to reversibility and recurrence objections.

The main target of these objections was the relationship between the H-theorem and the time reversible dynamics of the particles that make up gases. Boltzmann argued that the stationary solution to the kinetic equation was a very specific solution. According to his arguments, the H-theorem was the driving engine behind the fact that such a

¹³ This way of looking at the H-theorem closely follows from Tolman (1934).

solution certainly maps onto equilibrium. However, as the following objections aim to highlight, the H-theorem was not at all compatible with time reversal invariant mechanics.

First, let us look at the recurrence objection that Zermelo raised against Boltzmann's conclusions. The recurrence theorem states that a finite system that obeys laws of conservation of energy will come arbitrarily close to its initial state in a finite amount of time. Zermelo applied this theorem to the kinetic theory of gases (Zermelo, 1966). Zermelo objects to Boltzmann's H-theorem (which claims that in such a system value of H monotonically decreases if it is not at its lowest value already), such that if a system displays entropy increase in a given time interval, it also needs to go through an entropy-decreasing state, and this will happen infinitely many times. In order to get a better grasp of Zermelo's objection let us look at the recurrence theorem in more detail.

In his paper, Poincare proves two things (Poincare, 1966). First, he proves that dynamic systems can be stable, meaning that they can return arbitrarily close to their original initial state. In addition, he shows there are infinitely many initial conditions that lead to stable dynamic systems. Second, he proves that the initial conditions that do not lead to stable systems are exceptions such that the probability of a system starting at an initial state that does not lead to dynamically stable system is arbitrarily close to zero. Consequently, almost all finite systems have to come arbitrarily close to their initial state in a finite amount of time. Following the first recurrence, the probability that the system is dynamically stable for all practical purposes is one. Hence, the system goes through another recurrence and comes arbitrarily close to its initial condition once again, and continues to go through the same cycle *ad infinitum*.

Although Zermelo concedes that Poincare had a different aim while proving the recurrence theorem (how the star systems function), he proved that the recurrence theorem could be applied to finite thermodynamic systems that do not violate the law of conservation of energy. This, Zermelo claims, is an indication that irreversibility cannot be explained by mechanics alone for the following reason. If we have a thermodynamic system with irreversible time evolution, then we know that the initial condition of that system was among the ones Poincare proved to be extremely improbable. However, all the thermodynamic systems we are interested in are finite and do not violate the conservation of energy. Hence, they are subject to the recurrence theorem. Thus, it is highly probable that most of the thermodynamic systems are not the ones with some exceptional initial condition. Zermelo interprets this such that what Boltzmann explains is only half of a recurrence cycle that systems go through. A thermodynamic system, barring that it has one of the exceptional initial conditions, has to go through an entropy-decreasing phase as much as it goes through an entropy-increasing phase. Therefore, the H-theorem, stating that the value of the variable H that stays the same after the system reached equilibrium, cannot explain the other half of the recurrence cycle the system has to go through. Consequently, the recurrence theorem shows that at best the Boltzmannian framework is an incomplete explanation of the relationship between the time reversal invariant dynamics of particles and the irreversible behavior.

Furthermore, Zermelo argues that there are two ways for a system to not fall under the scope of the recurrence theorem. One possible case is having an unbounded system. This is not applicable to local thermodynamical systems, especially those of gasses in closed isolated containers; after all, they all have finite volume. The other

possibility is to have particle systems that instantly achieve infinite speed. However, this could only happen if the systems were not obeying conservation of energy; in such a case, recurrence would not be our only problem. Therefore, Zermelo objects to Boltzmann's conclusions from the 1872 paper, that it is possible to get irreversibility only by using assumptions from reversible mechanics.

Boltzmann seems to dismiss Zermelo's objections. He claims that although the recurrence theorem is a valid mathematical proof, the required time intervals in order for the recurrence to happen have to be too long. Thus, there is no need to worry about them. In addition, he thinks that a statistical interpretation is enough to make his conclusions to be consistent with reversible mechanics. Zermelo, on the other hand, identifies the issue explicitly such that irreversibility can only come from initial conditions and not from reversible mechanics.

The second objection to Boltzmann's conclusion is the reversibility argument. In short, what the reversibility argument amounts to is that, from an arbitrary point in time given the time reversal invariant dynamical laws, the time evolution of the system should lead to the exact same states in both directions of time.

The central claim of reversibility objection is that the reverses of physical phenomena are perfectly in accord with the laws of physics. If a given phenomenon is not a violation of laws of physics, then the reverse of it cannot be a violation of laws of physics either. Let us take a system of particles at some arbitrary point in time. We can write out the state of the system at that instant if we know the location, velocity, and direction of each velocity vector. Suppose we let the system evolve toward the future. Furthermore, suppose that we examine the system after a while, for example in five

minutes. We can write out this later state by using the same method that we use to write out the arbitrary initial state, with the location, velocity, and the direction of motion for each particle. Now, suppose that at that second instant we reverse the direction of each velocity vector and let the system evolve for the same amount of time. After five minutes, the state of the system will exactly match up to the state we had at the arbitrary initial state. This shows that time reversed versions of particle systems, which are achieved by reversing the direction of velocity vectors, are no less physical than the original ones.

For example, if an event with monotonic entropy increase is physical, the entropy-decreasing version of that same event has to be physical as well. This entails that if we maintain some form of time asymmetry in nature because of the unidirectional monotonic increase in entropy, then our theories regarding the behavior of thermodynamic systems cannot satisfactorily explain the past states of such systems. Let us examine this part of the objection using a simple system, a glass of water with an ice cube in it. Suppose that we have a glass of water with a partially melted ice cube in a room under normal conditions. Let us call this initial state *partial*. Let the system evolve for five minutes. After five minutes, we would observe that the ice cube has melted. Let us call this second state *melted*. The equations of motion lead to the prediction that the region of the phase space of the state *partial*, with an overwhelmingly high probability, is on the trajectory that will evolve to the phase space that is associated with the state *melted*. The later *melted* state is a higher-entropy macrostate compared to *partial*. Now, suppose that we reverse the direction of the velocity vector of each particle that makes up the system at state *melted*. If we let this state evolve for five minutes, we will get back to *partial*. This

process of an ice cube appearing in a glass of water is no less natural than the ice cube melting, because of the time reversal invariance of laws of physics.

However, this points to the situation that if we look at the evolution of the state *partial* five minutes into the past, we should conclude that this past state would also had to be a higher-entropy macrostate compared to *partial*. In other words, using time reversal invariant laws of motion will lead to the retrodiction that if we currently have a partially melted ice cube in a glass of water, five minutes before that we should have observed just water at uniform temperature. In contrast, we know from our experiences and records of the past that five minutes ago there should have been an intact ice cube in the glass. Consequently, the state *partial* is a local entropy minimum. The most probable situation when the system is at *partial* is that there are overwhelmingly large numbers of trajectories toward the past and toward the future approaching to equilibrium.

These two objections show that the H-theorem is not compatible with the mechanics. In the course of replying to these objections, Boltzmann's reconstruction of the H-theorem led to the inclusion of probabilities in the kinetic theory, which gradually became statistical mechanics.¹⁴

¹⁴ This is important because it is the point at which we started to use probabilities in physics in order to explain thermodynamic phenomena.

Chapter Two

A Global Proposal: The Past Hypothesis

2.1 Introduction

The aim of this chapter is to give a detailed examination of David Albert's proposal for solving the problem of the asymmetry of time. Albert strives to arrive at a result that will answer the question of asymmetry on a global scale. He constructs his account to explain the asymmetric time-evolution not just of local thermodynamic systems, but also for *all* physical systems in the part of the universe to which we have access. His main objective is to come up with a set of laws underlying the global asymmetry of time; it is an additional feature of his project, because of the way he sets it up, that it can also hypothetically explain the time asymmetric evolution of local thermodynamic systems without supplementing it with additional assumptions.

In the following sections, I will go over the details of Albert's project in order to see whether it might be able to deliver on its promise of providing a global solution to the problem of the asymmetry of time for all physical phenomena. Following this examination, I will discuss several objections to his project. There are two types of objections to this way of solving the problem of the asymmetry of time. The first type—most forcefully championed by John Earman—attacks the physical elements of the project and claims that the physics is not working. This first class of objections claims that the main assumptions of the Boltzmannian framework, especially as they are adopted

and supplemented by modern global approaches such as Albert's, are "ill-motivated and ill-defined, and its implementation consists mainly in furious hand waving and wishful thinking" (Earman 2006, p. 400). At the center of Earman's objection is an attack on the plausibility of having a well-defined "past hypothesis," which is the most essential component of Albert's project. This type of objection maintains that Albert's project cannot even get off the ground—because it fails from the point of view of physics—let alone solve the problem of the asymmetry of time.

The second type of objection, given that there might be a plausible way of usefully defining the initial condition of the universe with the past hypothesis, discusses whether it is really the case that we can use such an initial condition to our advantage while trying to identify the source of the asymmetry of time. This type of objection argues that even if we assume that the physics is working—as opposed to Earman—it is not clear that the underlying metaphysics of laws could plausibly work without any problems. In other words, the second class of objections claims that the metaphysics of Albert's project is not working.

Lastly, I will briefly put forward my own objection, which I will develop in later chapters, which largely belongs to the second type. I claim that the problem of the past hypothesis is its status as a fundamental law of nature, rather than being ill defined for the purposes of explaining the asymmetry of time that we observe. In chapter 4, I will argue that it is not possible to sustain the metaphysical status of the past hypothesis in Albert's project as a fundamental law of physics. Furthermore, I will also argue that if we cannot classify the past hypothesis as a fundamental law of physics, then it cannot stand in the required relation to the laws of statistical mechanics in order to give a mechanism of the

asymmetry of time. For these reasons, I will focus on the details of the past hypothesis in the present examination of Albert's project.

2.2 Initial Setup

Albert's aim is not to develop a mechanics from the ground up to solve the problem of the asymmetry of time. Rather, he starts with an already established mechanical theory and supplements it to identify the source of the asymmetry of time correctly. At the end what Albert wants to do, in addition to explaining the global asymmetry of time, is explain the time asymmetry that "underwrite[s] the actual content of our thermodynamic experience" (Albert 2000, p. 159). The underlying physical theory he employs includes statistical mechanics chiefly developed by Boltzmann and certain aspects of Newtonian mechanics, specifically the equation of motion. In the end, he arrives at a system that could explain the time asymmetric behavior of local thermodynamic systems and all physical systems, which we can refer to as "universal Newtonian statistical mechanics."

But, why use Newtonian mechanics? We know the theories of modern physics far surpass Newtonian mechanics in explaining how the world works; we know that the world is not Newtonian. We can better explain the nature of physical reality with relativity theory and quantum mechanics. Albert, of course, is not contesting any of this. Nonetheless, he develops the main theme of his proposal by assuming that the world is Newtonian. Subsequently, he gives an outline of a similar argument by appealing to quantum mechanics after he establishes as the core of his project that we need additional fundamental laws of physics to explain the time asymmetric behavior of physical

systems. In other words, he asserts that the crucial elements of his proposal are independent of the specifics of the dynamics of the world. That is, the conclusions he draws are independent of the shortcomings of Newtonian mechanics in explaining how the world works; they are also independent of the improvements that quantum mechanics provide. More specifically, the “past hypothesis,” as will be examined in detail in upcoming sections, would successfully lead to desired results about the asymmetry of time without depending on any distinct theoretical elements of Newtonian mechanics and quantum mechanics. For this reason and for the sake of clarity, Albert constructs the main structure of this proposal by using Newtonian mechanics. Hereafter, I will follow the same convention.¹⁵

It is not surprising to find the Boltzmannian framework at the center of this universal Newtonian statistical mechanics. Compared to alternative approaches, such as the branch systems that I will discuss in Chapter 3, Albert finds the Boltzmannian framework to be the most successful attempt at explaining the time asymmetric physical behavior of local systems. It is important to point out here that although Boltzmann’s statistical mechanics are different from Gibbs’s, the differences between the two approaches do not translate into a difference in a solution to the problem of the asymmetry of time, especially for the way Albert uses statistical mechanics. For this reason, throughout the current project I will assume that whenever there is a reference to statistical mechanics it is referring to the Boltzmannian framework. Consequently, whenever I mention universal Newtonian statistical mechanics, I am talking about the Boltzmannian framework at the core of such a system.

¹⁵ The interested reader can refer to the last chapter of (Albert 2000) for an examination of the overall project that employs quantum mechanics.

There were, however, objections raised against Boltzmann's conclusions, which I examined in the previous chapter. These objections and the problems they identify suggest that if we were to build a new framework on top of Boltzmann's, we should have to modify the original framework. Alternatively, one could argue against the validity of these objections. However, this is not a viable approach. The problems associated with the Boltzmannian framework, especially those regarding the problem of the asymmetry of time, seem insurmountable without altering Boltzmann's original theory. On the other hand, there are essential insights and methods in the Boltzmannian framework, so it is not reasonable to abandon it in its entirety. Although Albert thinks that the Boltzmannian framework has shed light on certain parts of the problem of the asymmetry of time and that it constitutes an important part of his overall approach, because of the aforementioned objections it is ultimately not a successful solution to the problem. For example, one consequence of the reversibility objection is that the Boltzmannian framework fails to coincide with our records (and/or memories).¹⁶ This is one of the most important drawbacks of the Boltzmannian framework: it makes faulty retrodictions. Below I will examine the details of how the Boltzmannian framework in its original form yields faulty retrodictions regarding the past states of physical systems before moving on to Albert's account.

2.3 The Reversibility Objection Revisited

The Boltzmannian framework is the starting point for Albert's project. Hence, resolving the issue of faulty retrodictions is one of his core motivations. He thinks that it

¹⁶ Hereafter, I will use records of the past to include our memories as well as any other records, such as results from measurements.

is possible to give an account of the asymmetry of time that will simultaneously constitute a global solution *and* not be subject to the reversibility type of objections. That is, Albert is concerned with providing a solution to the problem of the asymmetry of time that is applicable to all physical systems and not just for some specific ones. According to his proposal, we can arrive at such a global solution by an elaborate combination of “right probability distribution,” the deterministic laws of motion, and *the past hypothesis*.

Although the Boltzmannian framework managed to produce correct predictions, it failed to conform to our experiences of the past as well as to our records of it. This is precisely the consequence that the reversibility objection aims to highlight. The reversibility objection showed that—given an arbitrary state of a physical system—both the future and the past states have higher entropies. In contrast, we want to have lower entropy values for the past states of a physical system in relation to its present entropy. There is a way to achieve this desired result within the original Boltzmannian framework: we can postulate that the system was in a certain macrostate in the past and that that macrostate is in accordance with our records.

In order to see how postulating a certain macrostate for the ‘past history’ of a system could be a plausible answer to the reversibility objection, let us look at an example. I want to emphasize that Albert’s main objective is not merely to give a solution to the reversibility objection. At the end of his exposition, we are supposed to realize that if we construct a correct global explanation of the asymmetry of time, “the proper remedy,” then we would not have to tackle the reversibility problem to begin with.

The central claim of the reversibility objection is that the reverses of physical phenomena are perfectly in accord with the laws of physics. If a given phenomenon is not

a violation of laws of physics, then the reverse of it cannot be a violation of laws of physics either. For example, if an event with monotonic entropy increase is physical, the entropy-decreasing version of that same event has to be physical as well. This, however, entails that if we maintain some form of time asymmetry in nature because of the unidirectional monotonic increase in entropy, then our theories regarding the behavior of thermodynamic systems cannot satisfactorily explain the past states of such systems.

Suppose we examine a section of the time evolution of a physical system. Assume that we choose an arbitrary initial condition at an arbitrary initial time, and let the system evolve according to dynamical laws of motion. In order to make the example more accessible, let us also assume that this physical system is an ice cube and a glass of water in an energetically quasi-isolated room. Furthermore, suppose that the ice cube is partially melted and located in the glass of water. This is our initial state—let us call it *partial*. Let the system evolve for five minutes. After five minutes, we would observe that the ice cube has melted, given that five minutes was sufficient for the particular amount of ice we had at the beginning to melt. Let us call this second state *melted*. The microphysics at this point tell us that the region of the phase space that is compatible with *partial* should follow, with an overwhelmingly high probability, a trajectory that passes through the region of the phase space that is compatible with *melted*.

Boltzmann defined the entropy of a system in relation to the volume of the phase space of that given system. In addition, he argued that the equilibrium state is the macrostate that corresponds to the largest volume of the phase space. In our example, the trajectory of the system in the phase space starts out from *partial* and moves toward *melted*. Further examination shows that the volume of phase space that corresponds to the

macrostate *melted* is larger than the volume of the phase space that corresponds to the macrostate *partial*.

Furthermore, the possibility of a state not evolving toward equilibrium is arbitrarily close to zero, because the “abnormal” microstates, the microstates that are on trajectories for entropy decrease, make up a very small (and, according to Albert, scattered) volume in the phase space. In addition, this probability distribution over that subregion is a uniform one, because the microstates that violate monotonic entropy increase are relatively small in number. Hence, such microstates do not constitute any significant part of the subregion of the phase space, which in turn leads to the significantly very low probabilities (again arbitrarily close to zero) that they will be the microstates corresponding to the macrostate of the system. Thus, the later *melted* state is a higher-entropy macrostate compared to *partial*. Consequently, this shows that it is overwhelmingly possible that when the system’s initial condition is *partial*, such a system would be a trajectory toward the maximum entropy macrostate, and *melted* is a state on that trajectory.

At this point, we have a tentative proposal that makes correct predictions regarding the time asymmetric behavior of the physical systems. Every component of the proposal employed up this point—the dynamical laws of motion and the statistical postulate—necessitates that almost all of the macrostates, and the corresponding regions of the phase space that are not already at equilibrium, must sit on trajectories that will eventually evolve into equilibrium states. Consequently, these two components give rise to asymmetric behavior when we examine the evolution of physical systems in one particular direction of time, although none of them seems to entail any time asymmetry.

However, a reverse derivation of the evolution of such systems—again by using the above two principles—shows that this setup makes incorrect retrodictions. To use our ice cube example, suppose that we reverse the direction of the velocity vector of each particle that makes up the system at the macrostate *melted*. Further suppose that we let this state evolve for five minutes with the reversed velocity vectors. After five minutes, we would observe that the system evolves back to the macrostate *partial*. The process of an ice cube appearing in a glass of water is no less natural than the process of an ice cube melting because of the time reversal invariance of the laws of physics. This means that there must be something problematic with the two components we used to achieve the initial result of the evolution of the energetically quasi-isolated system from *partial* to *melted*.

We can safely assume that the problem is not at the level of the equation of motion; otherwise, faulty retrodictions would not even be our immediate concern, because we would need to reconstruct physics before we could discuss the direction of time. This indicates that we should first consider the statistical postulate as the source of our problems. As we will see, the statistical postulate is in fact not compatible with time reversal invariant laws.

This, however, points to the situation that if we look at the evolution of the state *partial* five minutes into the past, we should conclude that this past state would also have to be a higher-entropy macrostate compared to *partial*. In other words, using the time reversal invariant laws of motion will lead to the retrodiction that if we currently have a partially melted ice cube in a glass of water, five minutes before that we should have observed only water at uniform temperature. In contrast, we know from our experiences

and records of the past that five minutes ago there should have been an intact ice cube in the glass. Consequently, the state *partial* turns out to be a local entropy minimum.

The most probable situation when the system is at *partial* is that there are overwhelmingly large numbers of trajectories approaching equilibrium toward the past as well as toward the future. We could even claim that the probability of a partial ice cube appearing in the glass of water as a fluctuation is much higher in contrast to having a complete ice cube that slowly melted. This result points to the fact that the statistical postulate is not compatible with the time reversal invariant laws of physics. Now that we have a hold on what the problem is, we can move on to discuss Albert's solution to it.

2.4 Albert's "Proper Remedy"

Albert thinks that it is possible to give an account of time asymmetry that is not subject to the reversibility objection. Recall that what we are looking for is a combination of "right probability distribution," the deterministic laws of motion, and what Albert calls the "past hypothesis." Although his central motivation is not to provide an answer to the reversibility objection alone, once we have the complete solution to the problem of the asymmetry of time, we will not have local entropy minimums. This in turn protects Albert's "proper remedy" from reversibility-type objections.

Previously, we saw that the combination of time symmetric laws and the statistical postulate managed to produce correct predictions, but failed to conform to our commonsense thermodynamic experience and records about what happens in the past direction of time. Thus, the first step in constructing a global account for the asymmetry of time should include a way to overcome the problem of faulty retrodictions.

Albert argues that there is a relatively straightforward way to eliminate faulty retrodictions. The crucial aspect of such an approach is postulating that the system was in a certain macrostate in accordance with the records of the past. Briefly, what Albert claims is that any particular time other than the first moment of the universe would fail to correct at least some retrodictions. To fix all the retrodictions about the past states of the systems, we should postulate a certain point in time for which there are no further past states. This certain point in time is nothing other than the first instant of the universe. This is a rudimentary picture of the need for introducing a specific initial condition of the universe, which requires further explanation.

There are two ways of looking at the situation in order to justify the need for introducing a specific state for the initial condition of the universe. First, we will examine what happens on the macro level. Then we will look at what happens on the micro level. Eventually, both cases lead to the same conclusion, which is that in order to fix faulty retrodictions we have to postulate that there was a very specific first instant of the universe, which is the source of the asymmetric behavior of physical systems. Following these examples, we will be at a point where we can examine what this postulate about the first instant can achieve in relation to the problem of the asymmetry of time and what its metaphysical status has to be in order for it to be a viable solution to the problem at hand.

First, I will start with the macrolevel example. On the macro level, we want to gain an understanding of the requirement that to have correct retrodictions regarding even the simplest physical systems we need to appeal to the initial state of the universe. Furthermore, we have to keep in mind that Albert aims to arrive at a specific postulate about the first instant that is different from just a list of momentum and position values of

all the particles at the initial state of the universe. He wants to show that the statement of the initial state of the universe is also a fundamental law of physics. One of the motivations behind this aim is Albert's commitment to the best system analysis of laws for understanding the nature and structure of the fundamental laws of physics. Albert maintains that a statement is a fundamental law if that statement is one of the axioms of "the best system." The best system analysis of fundamental laws requires a detailed look that falls outside the scope of this example, but which I will cover in the next section. For the macrolevel case, we will again use the system of a glass of water and an ice cube to show that we need a postulate for the very first instant of the universe.

In the previous example, we had a glass of water sitting in an energetically quasi-isolated room with a partial ice cube in it. When we observed the system evolve according to the laws of dynamics for a sufficient amount of time, we saw that the partial ice cube had melted. Moreover, suppose that we also made a prediction by using the laws of dynamics at the time when the ice cube was partial. Our prediction was that five minutes later there would be no ice cube and only slightly colder water at uniform temperature. After five minutes, the state of the system was in accord with our prediction; hence, we concluded that the prediction was accurate.

In contrast, when we used the same method to retrodict the past states of the system, we ended up with faulty retrodictions. That is, if we retrodict the state of the system five minutes into the past by using the laws of dynamics we predict that the system would be in a state where again there was no ice cube and slightly colder water at uniform temperature. However, such a retrodiction contradicts our records¹⁷ of the past.

¹⁷ Throughout this project when I refer to records of the past, it includes written records, memories, and any other method of having some kind of "record" of the past.

Here is the first step towards solving the problem of faulty retrodiction. We should replace the faulty retrodiction that there was slightly colder water at uniform temperature with the postulate that there was an intact ice cube in the water. More specifically, what we must do is postulate that the system was in a particular initial condition five minutes ago. Consequently, this first step corrects the faulty retrodiction regarding the state of the system that was five minutes in the past.

However, if we examine the state of the system at an earlier time, for example ten minutes ago, the postulate we had for the state of the system at five minutes combined with the laws of motion will lead to a faulty retrodiction for the state of the system at ten minutes ago. In order to fix this new faulty retrodiction we could introduce a similar postulate for the state of the system for ten minutes ago, just as we did for the state of the system for five minutes ago. This will fix the faulty retrodiction for ten minutes in the past. However, if we make another retrodiction for a state that comes before the state at ten minutes in the past, we will end up with a new faulty retrodiction. We could push our postulate about the past states of the system further and further into the past; but the more we postulate about a past state, the more the current proposal will lead to more faulty retrodictions about states that occur earlier than that state. At first this way of attempting to solve the faulty retrodictions problem does not seem to produce a viable result, because every time we correct one retrodiction, some other retrodiction will fail to accord with the records of the past states of the physical system in question. The only plausible way to solve the problem of the past in this situation is to postulate about a past state such that there are no states prior to it that would again lead to faulty retrodictions. If we ever arrive at such a state, then we could postulate about this state. Therefore, we do not run

the risk of having faulty retrodictions for any other past state simply because there would not be any.

Of course, the above picture is what happens at the macro level. We need to provide an explanation of the corresponding micro level. The most instructive and productive method for looking at what happens to such systems is to examine the time evolution of their trajectories in phase space. A trajectory in the phase space is the time evolution of a given system, if we have the proper $6N$ dimensional space for the given system. What we need to do is to look at the trajectory that corresponds to the macrosystem with which we were working. The reversibility objection, then, in the vernacular of phase space, is the claim that for every single trajectory of a system from A to B to C (A, B, and C all being points in the phase space), there will be a trajectory of the system from C to B to A. Furthermore, this tells us that if we take the macrocondition corresponding to point B in the phase space, it is equally likely that the trajectory is from A to C as it is from C to A.

However, Albert aims to show that the reverses of the trajectories are not as likely as the trajectories toward the future direction. That is the crux of giving a solution to the problem of the asymmetry of time; that is, events that happen in one direction do not happen in the other. In addition, given point B on the phase space (which, in our example, corresponds to the partial ice cube macrostate in water), Albert wants to ensure that the trajectory that leads to point B lines up with the trajectory that corresponds to our records. Albert calls regions of the phase space that correspond to the macrostate of the systems “M-regions.” First, when we have such an M-region in the phase space that corresponds to a specific macrostate of the system, for example the M-region of the glass of water and

ice cube system at time B, there are parts in that M-region that lead to states with higher entropy toward the past. He identifies these regions as abnormal regions of the phase space “that lead to *violations* of the laws of thermodynamics” (Albert 2000, p. 67).

However, Albert is quick to remind us that those *abnormal* regions of the M-region of the system are neither uniformly distributed nor do they have individually large volumes.

The upshot of having such “scattered” and small regions in the M-region is that whenever we randomly consider a part of the M-region it is highly likely that such a random region would not be one leading to the violation of laws of thermodynamics. In other words, whenever we have an M-region, although there are regions in that M-region that will lead to entropy increase toward the past, the possibility of such a region corresponding to the macrosystem is overwhelmingly low (arbitrarily close to zero). Second, he shows that because of the scattered distribution of *abnormal* microstates, whenever we apply the uniform probability distribution to the M-region of a given system, we will get almost the exact result as if we were to apply the uniform probability distribution “over the macrocondition as a whole” (ibid.).

We now have the necessary tools to understand how to give a “proper remedy” for the reversibility objection from the micro level. The first step is to identify the region of the phase space, the M-region as Albert calls it, corresponding to macrocondition B. Following this first step, we look for possible trajectories that lead to entropy increase toward the past and possible trajectories that lead to entropy increase toward the future. At this point, we should know two things about the system. First, the abnormal trajectories are scattered and *individually* cover extremely small volumes of the phase space corresponding to the macrostate B. Second, if we apply the uniform probability

distribution to the M-region, although there are such abnormal regions in the M-region, we will end up with an accurate picture of what will happen toward the future. Of course, the reversibility objection does not argue against any of these. What happens on the micro level, according to the reversibility objection, is that given the M-region of the system that corresponds to macrocondition B, it is still possible that the trajectory passing from B might have passed from an *abnormal* region of the phase space. In order to overcome the reversibility objection at the micro level we need to postulate that five minutes ago the trajectory of the system was in a region of the phase space that did not violate the laws of thermodynamics. This is analogous to the first step we made in overcoming the reversibility objection at the macro level. Again—similar to what we observed at the macro level—given this postulate regarding the properties of the subregion that the trajectory of the system had passed through five minutes ago, it is highly likely that the trajectory of the system might pass through an abnormal subregion ten minutes ago, a region that leads to violations of the laws of thermodynamics. In order to fix this issue we have to postulate that ten minutes ago the trajectory was not passing through an abnormal subregion of the M-region for the given system, and so on. This closely follows the strategy that we employed for the macro level. Accordingly, to overcome the reversibility objection we have to postulate about the first instant of the universe. Such a postulate should fix the trajectories in the phase space such that they do not pass through abnormal regions. When we apply the uniform probability distribution at the first instant of the universe, it will be same as applying it to the entire M-region that corresponds to the initial macrocondition of the universe. Consequently, we have shown

that it is possible to overcome the reversibility objection both from the macro level and the micro level if we postulate about the first instant of the universe.

This is exactly what Albert proposes. He indicates that we can fix the problem of entropy increases toward the past if there are no more past states for the moment at which we posit the state of the system according to the records. He claims, “by now it will be perfectly clear that all such posits are bound to fail unless they concern *nothing less than the entirety of the universe at nothing later than its beginning*” (Albert 2000, p. 85, my emphasis).

In short, when we solve the retrodiction problem for five minutes in the past, and then examine the state further into the past, the statistical postulate and the laws of physics will make a faulty retrodiction regarding the state of the system at ten minutes ago. In order to fix that faulty retrodiction we pushed the postulate about the past state further and further into the past. No matter how much further we postulated about a past state, the proposal produced faulty retrodictions regarding the states prior to the last state about which we had a posit. Every time we correct one faulty retrodiction, another retrodiction fails to accord with the records of the past states of the physical system in question. Consequently, the only plausible (according to Albert) way of solving the problem of the faulty retrodictions of the past states of the physical systems is to postulate about a past state before which there are no other states. Following that the only rational step is to postulate a specific state (details of which we will look at later in this chapter) of the first instant of the universe, which prevents us from making any more faulty retrodictions about any physical system whatsoever. However, this is not the end of Albert’s proper remedy. Although this proposal of introducing a specific initial

condition for the universe overcomes the problem of faulty retrodictions, it is not enough to explain the asymmetric behavior of physical systems or to make any specific claims about how to give an account of the global asymmetry of time.

At this point, we need additional constraints for both the statistical postulate and the nature of the initial condition of the universe to arrive at a viable solution to the problem of the asymmetry of time. Albert's strategy for doing that requires a modification of the statistical postulate in order to use the initial state of the universe to derive the entirety of the asymmetric time evolution of *all* the physical systems in it.

His version of the statistical postulate necessitates that we put some additional constraints on the probability distribution of a past state that led to the current actual macrostate. The reasoning behind this requirement is the interconnectedness of the initial state with the current macrostate and microstate of the system. However, this connection has to be more than a trivial one. If we look at the history of the phase space, we see that the probability distribution over some past state (not necessarily the initial one) eventually led to the current microstate of the system. Moreover, we need to ensure that the current state of the universe is not amongst the ones that violate the laws of thermodynamics. In addition, the same current state should not be a state that directly followed from some microstate that, at some point in the past, violated the same laws. These additional constraints insure that there is a trajectory originating from the initial state of the universe that passes through the region of the phase space associated with the current macrostate. Moreover, this trajectory must display monotonic entropy increase. It is possible to satisfy all of these requirements by using "a uniform probability distribution, on the standard measure, over the region of the present macrocondition, *but*

further restricted to those microconditions that are compatible with the macrocondition that held at the beginning of the universe” (Winsberg 2004b, p. 713, emphasis mine).

Therefore, we need to assume that the restricted statistical postulate need be applied only once and only at the first instant of the universe.¹⁸

That is, however, not the end of the project. Albert’s proper remedy has to ensure the unidirectional monotonic increase of the universe. What we discussed in the previous paragraphs can give a viable explanation of the direction of the entropy increase. The monotonic increase, however, requires placing a further constraint on the initial state of the universe. It is a relatively trivial exercise to show that the entropy of the current state of the universe (or the part of the universe that we can talk about, or the observable universe) is far from its maximum value.¹⁹ Therefore, in the past the entropy of the universe must have been further away from the maximum value in contrast to the entropy of the present state. This means that if the entropy of the universe is currently at a relatively low value, then at the beginning of the universe the entropy had to be much lower in order not to inhibit entropy increase since then *and* still be far away from its possible maximum value. We cannot just hope for the sake of our proposal that the initial condition was indeed a low entropy state. The current proposal needs it to be the case that the entropy of the early universe was indeed very low in order to explain properly the global asymmetry of time as well as the thermodynamic behavior of the local physical system. Therefore, Albert posits that the universe indeed did start with a very low entropy macrocondition, which had a sufficiently low value that it still had room for more

¹⁸ This instant need not be exactly when the Big Bang happened; it would be sufficient, for Albert’s account, to apply it at some later instant where the laws of physics do work, such as 10^{-40} seconds after the actual Big Bang.

¹⁹ Please see Sean Carroll’s *From Eternity to Here: The Quest for the Ultimate Theory of Time* (2010).

increase, even though entropy is steadily increasing since the Big Bang. The statement that the universe started at a very specific macrostate that had a very low entropy is what Albert calls the past hypothesis.

Albert claims that this particular combination of the law of motion, the uniform probability distribution over a specific subregion of the phase space of the universe (with above constraints), and the empirical fact that the entropy of the initial condition of the universe was appropriately low will give us the correct predictions and retrodictions about the time evolution of thermodynamic systems. One of the most essential components of this proper remedy is the statement that the initial condition of the universe had very low entropy. This empirical fact ensures that the entropy monotonically increases in one direction of time. It, however, must also underwrite the laws of statistical mechanics in a way that enables us to use them to explain why the time directedness of local thermodynamic phenomena coincides with the global direction of time. To achieve this Albert proposes one additional property for the initial condition: that it has to be a fundamental law of physics. He argues that the “correct system” of understanding the metaphysics of the fundamental laws of physics depends on Humean Supervenience, which in turn classifies the initial condition as a fundamental law of physics. However, the details of Humean Supervenience and the “correct system” of laws are implicit in Albert’s account. In the following two subsections, I will examine the details of the past hypothesis as well as how we can classify it as a fundamental law of physics given the “correct system” of understanding the metaphysics of the fundamental laws of physics. But before looking at the metaphysical issues regarding the laws of physics, let us look at the physical shortcomings of Albert’s project.

2.5 Physics of the Past Hypothesis

As I mentioned at the beginning of this chapter, there are two general objections to Albert's proper remedy—one from physics and the other from metaphysics. Initially, let us look at the problems of the proper remedy from the point of physics.

Albert's entire project depends on the *fact* that the laws of physics are time reversal invariant and the time-evolution of thermodynamic systems are asymmetric. The project depends on this apparent incompatibility because what Albert wants to achieve is to show that there is a proper explanation of the situation in physics. Therefore, we have to have a grasp on this *fact* that laws are time reversal invariant as well as how Albert solves all the problems of Boltzmann.

First, Earman (2002) argues that the depiction of time reversal invariance in Albert's project is at best misleading and at worst plain wrong. Let us see what the problem is. The time reversal invariance, in very general terms, means that given that we have a set of ordered states of a system that are not violation of laws of physics, then the reverse ordered state would not be violation of the laws of physics as well. This understanding of time reversal invariance depends on what one takes to be the state of a system. According to Earman, Albert's concept of the state of a system at a given instant leads him to misidentify the time reversal invariance of certain physical theories—especially that of electrodynamics. It is possible to identify the states of a system by looking at the 'complete description' of the states. Albert takes this complete description to be such that "all of the physical facts about the world can be read off the full set of state descriptions" (Earman 2002, p. 246). The problem, however, is that such a complete description leaves out "dynamical completeness;" otherwise we would leave out important information regarding the state of the system "that is relevant to determining,

via the laws of motion, the future and past histories of the system” (ibid.). For this reason, Earman thinks that Albert’s way of identifying the states of a system at a given instant is faulty and would lead to misunderstandings such as declaring electromagnetics to be not time reversal invariant, which Earman indicates is a faulty identification.

Assume for the sake of argument that the above issue has no effect on how the past hypothesis operates in connection with the time reversal invariant laws to explain the asymmetric time evolution of thermodynamic systems. Even if this is the case—such that Albert’s way of defining time reversal is not faulty—Winsberg argues that the past hypothesis fails to identify any time asymmetry for thermodynamic systems unless there are additional implicit assumptions doing most of the work. Winsberg argues that the way Albert solves the asymmetry by introducing the past hypothesis and presuming that we apply the statistical postulate once at the beginning of the universe is suspect.

The first possible way of understanding how all this explains the asymmetric time-evolution of local thermodynamic systems is to claim that given the past hypothesis—that the universe started at a sufficiently low entropy—and that the statistical postulate applied at this first instance will lead to monotonically increasing entropy of the entire universe. However, as Winsberg identifies, a slight decrease of the entropy of a local thermodynamic system “could easily be offset by a more than average increase in some other part of the universe” (Winsberg 2004a, p. 500). In other words, it is perfectly plausible to have a local thermodynamic system with decreasing entropy without lowering the average entropy of the universe. What this signifies is that with an empirical fact about the initial state of the universe and a statistical postulate used in conjunction with that empirical fact—the past hypothesis—we do not get any guarantees regarding

the direction of the entropy for local thermodynamic systems. The past hypothesis and the statistical postulate do not introduce the constraints necessary for local systems to have the same direction of entropy increase with that of the universe; we need more.

We want a constraint to be able say that the direction for the entropy increase of the local system is the same as the entropy increase of the universe. In other words, we need to find a way to ensure that “[s]ince it is overwhelmingly likely that the universe is in a region that will lead in the future to steadily higher entropy, it must be overwhelmingly likely that the microstate of the [local system] is in some subregion of the fibrillation that will lead in the future to [local system’s] steadily higher entropy” (Winsberg 2004a, pp. 500-1). Albert presumes that we get such a guarantee by appealing to the past hypothesis and the statistical postulate applied once at the beginning of the universe. Yet, Winsberg argues that in order to say this we need an additional principle that will take us from the universe being in a very specific region that evolves toward maximum entropy to a given local system being in a very specific region that evolves toward maximum entropy at the same direction that of the universe. He argues that this is missing from Albert’s proper remedy. Nevertheless, presuming there is a principle that would help us to introduce a constraint to make sure that the direction of the entropy increase for local thermodynamic systems is the same as the direction of the entropy increase for the universe does not solve the problem. Nevertheless, Winsberg indicates that such a principle is not in fact doing any restricting for the following reason: “[r]estricting the set to those microconditions that are compatible with the past hypothesis does nothing because the [local system’s] previous interaction with the rest of the universe effectively randomizes the microconfiguration of the [local system]” (Winsberg

2004a, p. 502). This suggests that we need yet more constraining to do even if we have some additional principle. Yet, Winsberg argues that additional footwork associated with this extra principle would make Albert's proper remedy look a lot like the branch systems proposal, which he adamantly opposes.

In discussing these two problems, I assumed that it is somehow possible to define the content of the past hypothesis properly. After all, the past hypothesis claims nothing more than that the universe started at a very low entropy. However, Earman argues against this claim. He makes it very clear that the problem is not that the first instant of the universe was a low entropy state. He argues that the entropy value of that state cannot be a well-defined one. Furthermore, even if we can somehow properly define the value of the entropy for the initial state, he argues that this would not be enough to explain the asymmetric time-evolution of local systems (Earman 2006, p. 400). To be precise, what Earman arguing saying is that if we want to build the asymmetry on some asymmetry of entropy, Albert's proper remedy would fail if "the said entropy is Boltzmann entropy" (ibid.). Earman asks us to suppose that Boltzmannian entropy for the initial state of the universe is well defined. Following this he indicates that this low value cannot in any way guarantee a *monotonic* increase in entropy because entropy increase is dependent on "the dynamics of the particular cosmological model" (Earman 2006, p. 419).

The other problem he identifies is connected to the structure formation in the universe. It is generally assumed that the structure formation is closely tied to the minute irregularities of the initial state of the universe. These irregularities and fluctuations of the initial state are amplified by certain processes and end up as the large-scale structure we observe in the universe. If there were no irregularities and fluctuations, the cosmological

processes would not amplify them to evolve into the large-scale because there would not be anything to use as “the seeds” of the structure. That is, although the initial state of the universe was uniform—it had low entropy—it could have even lower entropy, which would have been better for Albert’s proper remedy. However, in that case there would not be enough fluctuations and irregularities to be amplified by cosmological processes and therefore “the structure formation would not have taken place, and there would be no subsystems in which statistical thermodynamics of the familiar form would apply” (Earman 2006, p. 419). All of these arguments indicate that the physics in relation to the past hypothesis of Albert’s proper remedy seems highly suspect if not outright false. In the following sections, I will examine the status of the past hypothesis regardless of the suspicion that the physics of Albert’s proper remedy is faulty.

2.6 The Status of the Past Hypothesis

The status of the past hypothesis as a fundamental law of physics plays an essential role in Albert’s proper remedy. The past hypothesis itself is a statement about the initial conditions of the universe (or the parts of the universe to which we have empirical access). Specifically, it is a statement of an empirical fact. This empirical fact is that the universe started at a very low entropy macrocondition.

The statement regarding the initial condition of the universe cannot be just a statement of empirical fact in order for it to explain the asymmetry of time. The past hypothesis has to be more than just a statement of the low value of the entropy of the initial macrocondition of the universe. In fact, the past hypothesis *has* to be a fundamental law of physics to do what is required of it by Albert’s proper remedy. There is no other alternative metaphysical status for the past hypothesis. It cannot be anything

less than a fundamental law if we use it to provide a global explanation for the asymmetry of time. In contrast, if the past hypothesis were just an empirical fact, although it would still be successful in solving the problem of retrodictions, it would fail to explain the global asymmetry of time as well as the direction of asymmetry for local energetically quasi-isolated thermodynamic systems. Moreover, it would fail to bestow lawhood on the statements of special sciences, specifically the statements of statistical mechanics, which is another essential requirement of Albert's proper remedy. That is, it would fail to explain why the systems that are of interest to us behave the way they do. In order to fulfill all of these requirements imposed by Albert's proper remedy, the past hypothesis *has* to be a fundamental law of physics.

In order to support his claim that the past hypothesis is a fundamental law of physics Albert uses two interconnected arguments. First, he appeals to David Lewis's best systems analysis of laws. Second, he argues that we use the past hypothesis in exactly the same way as we use any other fundamental (theoretical) law of physics: for making predictions.

In Chapter 4, I will specifically argue against the metaphysical status of the past hypothesis as a fundamental law of physics. Later, I will argue that the past hypothesis can fulfill its role in Albert's proper remedy only if it is at odds with the main feature of best systems analysis, which is balancing the simplicity of a theory with its informativeness. I construct a counterargument to show that for the past hypothesis to fulfill the requirements of Albert's proper remedy it has to be part of a larger set of laws that includes cosmological laws of the very early universe. Prior to this, however, I will elucidate the concept of lawhood that Albert employs.

2.7 Metaphysical Issues Regarding the Fundamental Laws of Physics

Albert explicitly states that to account for the global asymmetry of time we need three *laws* of physics and one empirical fact. The empirical fact is a statement about the “directly surveyable condition of the world” at any given moment (Albert 2000, p. 96). I will focus specifically on some of these *laws*, as they are the more controversial elements of Albert’s proper remedy. The first law Albert employs is the Newtonian law of motion; it should be made clear that the status of Newtonian laws is not our immediate concern. The other two laws are the “past hypothesis” (PH) and the “statistical postulate” (PROB). Recall that we cannot explain the apparent asymmetric behavior of physical systems by appealing only to the Newtonian law of motion because of certain problems, such as the reversibility objection.

The main purpose of this section is to elucidate the metaphysical status of the PH and highlight Albert’s reasons for the requirement that it has to be a fundamental law of physics. In the previous sections, I briefly mentioned that there are two reasons why the PH has to be a law. Here, I will analyze these reasons in detail. For these purposes, I will once again appeal, though this time briefly, to the reversibility objection. The central claim of the reversibility objection is that the time-reversed versions of physical phenomena are necessarily in accord with the laws of physics mainly because of the time-reversal invariance. The most apparent consequence of time-reversal invariance is that if a given phenomenon is not a violation of the laws of physics, then the time-reversed version of it cannot be a violation of the laws of physics. For example, if an event with monotonic entropy increase is physical, then the entropy-decreasing version of that same event has to be physical as well. This, however, entails that if we maintain some form of time asymmetry in nature because of the unidirectional monotonic increase in entropy,

then our theories of the behavior of thermodynamic systems fail to explain the past states of such systems.

As we examined in detail, Albert claimed that the two additional *laws* (PH and PROB) are *necessary* to overcome objections such as reversibility. The issue I want to highlight here is not whether these two additional laws are indeed necessary for overcoming reversibility type arguments; rather, I want to focus on how we can justify that they are indeed laws of physics. In other words, what is our basis for claiming that PH and PROB are fundamental laws of physics in the same principled sense that we take the Newtonian law of motion or any of the laws of modern physics from general relativity to quantum mechanics to be a law of physics? What is our justification in classifying the past hypothesis as a fundamental law of physics?

Even a superficial reading of the situation would reveal that what we have is not a simple classification problem. Albert introduces the PH as a fundamental law of physics, because he makes use of its status in the rest of his project; i.e.: he uses the PH to bestow lawfulness on the statements of special sciences. More importantly, it is not just that Albert uses the status of the PH as a fundamental law of physics to his advantage; it is *essential* to classify the PH that way. Otherwise, his proper remedy would not be a remedy for the problem of the asymmetry of time. In order to show that the PH is successful (in conjunction with the rest of time reversal invariant mechanics and PROB) in explaining the time evolution of physical systems, it *has* to be a fundamental law of physics that can “rule over” the laws of special sciences. Let’s make all of this clearer. There are two main reasons why the proper remedy works only when the PH is a fundamental law of physics.

First, there is the requirement of giving lawhood status to the statements of special sciences. But, why do we need this to explain the asymmetry of time? The answer is in part related to Albert's implicit commitment to the imperialist (or fundamentalist) view about the fundamental laws of physics.

Certain features of the imperialist view about laws can help us to understand the above requirement. One is that all laws have universal scope. If a given statement is a law of physics, then it has universal scope regardless of whether it is a fundamental law or a law of some special science. It must be applicable everywhere at all times. In the case of the proper remedy, statistical mechanics plays an essential role. It explains the asymmetric evolution of systems in time with the help of the PH. The PH, as we saw, constrains the possible past states of a system to a certain set. All the microstates of a system that are members of such a set must be on certain trajectories. These trajectories must have a zero (or arbitrarily close to zero) probability of ever passing through a microstate that is *abnormal*, which in this context refers to states violating the laws of thermodynamics. Thus, the PH ensures that when we observe a local thermodynamic system we know something very specific about its past. The PH, of course, achieves this by ruling out *abnormal* states by applying the uniform probability distribution and conditionalizing on the initial state of the universe given that the current state of the system is compatible with the initial condition.

It is clear from the above explanation that the laws of thermodynamics, and so the laws of statistical mechanics, are crucial for Albert's proper remedy. In addition to being crucial to an explanation of the asymmetry of time, the statements of statistical mechanics are within the scope of the imperialist view. Accordingly, they must have universal

scope. Nevertheless, it is possible to make the same predictions and derive the same conclusions regarding thermodynamical systems without having to assume universal scope. In fact, we will look at the details of such an approach in the following chapter. However, the imperialist view must exclude such a possibility. An imperialist (about laws of physics) can achieve this with a mechanism of assigning universal scope to statements of special sciences. This in turn requires that we use a fundamental law of physics, which already has universal scope, to assign the same scope to the statements of special sciences. The principle reason behind this strategy is that one cannot use a statement to assign lawhood in the imperialist sense to another statement without the statement first being a universal law. The PH, although it can overcome the reversibility objection without necessarily being a law, cannot assign universal scope to the statements of statistical mechanics. Consequently, the only possibility open to Albert is to classify the PH as a fundamental law of physics.

Second, Albert's proper remedy has only one boundary condition to explain the asymmetric behavior of *all* physical systems. If we want to overcome the reversibility objection and at the same time maintain universal scope for the laws of physics, then again an imperialist needs the PH to be more than just a boundary condition. It has to stand as a boundary condition for all physical systems, regardless of whether they are energetically quasi-isolated. Of course, there is nothing in principle prohibiting us from using one boundary condition for all systems. If we are going to use the PH in that way, however, we must ensure that it can actually be a boundary condition for all of the systems. The most straightforward way of doing that is to assume that the PH has universal scope. An imperialist can easily justify assigning universal scope to the PH if

she maintains that it is a fundamental law of physics. For these two reasons, it is not a matter of choice for Albert whether to classify the PH as a fundamental law of physics; it is an indispensable requirement. The next step is to examine what makes a statement a fundamental law of physics in the above sense. This will help us to get a better grasp of what the requirement of having the PH as a law entails for an imperialist account of the asymmetry of time.

2.8 Theoretical Laws of Physics: A Humean Approach to Laws

It is important to have a proper understanding of what Albert takes to be a fundamental law of physics for two reasons. First, it will help clear up any lingering issues regarding the plausibility of the proper remedy. Second, it will constitute a proper target I will argue against in Chapter 4, which is the plausibility of the status of the past hypothesis as a fundamental law of physics.

Albert maintains that the way we know the metaphysical status of the past hypothesis is exactly the way we know the metaphysical status of any other theoretical law of physics. That is, the way we know that the universe started in an extremely low entropy state comes from *inductive reasoning* about what we know of the universe in the present (Albert 2000, p. 94). We presume that the very early universe's macrocondition was one of low entropy not because we have made measurements, but because it leads to *useful predictions* regarding how the world works. This argument in part resembles Goodman's argument in which he asserts, "rather than a sentence being used for prediction because it is a law, it is called a law because it is used for prediction"

(Goodman, p. 21). Thus, when we combine the above two premises it should be clear that Albert introduces the past hypothesis as a theoretical law of physics.

Furthermore, Albert's argument also in part resembles Feynman's arguments regarding the laws of physics in *The Character of Physical Law*, especially the insight for the necessity of a statement regarding the initial condition of the universe to overcome reversibility-type objections. However, the two arguments start to diverge when it comes to the metaphysical status of the initial condition. It is possible to consider the hypothesis about the initial condition of the universe, that it was a low entropy macrocondition, as lawlike and even as a fundamental law of physics. However, Feynman is quick to remind us that we are dealing with two different types of laws when we include the initial condition of the universe in our system of physical laws. He maintains that the laws about the initial condition of the universe "come outside the province of what we ordinarily call physical law" (Feynman, p. 116). Following this, he draws an important distinction between the laws about the evolution of the universe as a physical system, which I take to be identical to laws that Albert classifies as theoretical, and the laws that "state the condition the world was in in the past" (ibid.).

In the case of the past hypothesis, Albert does not appeal to such a distinction. One apparent reason for this is that both types of laws help us make predictions. For Albert, the predictive power of statements is sufficient for classifying statements as law, given that they are also part of the best system analysis of laws. However, it is misleading to ground the distinction between two types of laws on the predictive power of statements. It is not the case that a statement being useful for prediction makes it a fundamental law of physics. As Goodman succinctly explains, we see that "only

statements that happen actually to have been used for prediction would be *lawlike*” (Goodman, p. 22, my emphasis). This suggested predictive power of statements should be one of the contributing factors to identifying a law, but it is alone not enough to classify candidate principles as theoretical laws of physics. Thus, asserting that the past hypothesis is a law just because it is useful for making prediction falls short of being a justifiable position. At this point, Albert implicitly appeals to the best system analysis of laws to strengthen his claim for the status of the past hypothesis as a fundamental law of physics. He would argue that any statement that is part of the best system analysis for our world would also be useful in making predictions.

To justify the classification of the past hypothesis as a fundamental law of physics, in addition to its predictive power, Albert appeals to David Lewis’s best system analysis of laws. To understand how an initial condition of a system can be a fundamental law of physics we have to examine BSA in more detail.

Concerning the metaphysics of the fundamental laws of nature, Albert maintains that the correct approach is the best systems analysis of laws (BSA). We can infer from his arguments that the past hypothesis is a fundamental law precisely because it conforms to the BSA constraints of lawhood. For this reason, it is essential to examine the BSA in order to see whether Albert could actually maintain that the past hypothesis is a fundamental law of physics by appealing to it.

An account of laws that can be marked with the term “best systems analysis” first appears in Frank Ramsey’s writings (Ramsey 1931). However, Lewis developed the most commonly used contemporary version of the BSA throughout several of his works (Lewis 1986, 1994). Here, I will only examine Lewis’s version.

The BSA that Lewis constructed depends on a view about the status of the matters of fact generally referred to as Humean Supervenience. Lewis maintains that there is nothing more fundamental in the world than “local matters of particular facts” and “all else supervenes on that” (Lewis 1986, p. ix). Given this foundational requirement, it is almost impossible to maintain that laws of nature are among those features of the world such that they do not supervene on the “vast mosaic of the local matters of particular fact.” That is, they are somehow emergent or fundamental features about this world *independent* of what it is in the world. Accordingly, Lewis argues against the suggestion that there are laws of nature over and above what is already in the world. In other words, Lewis argues against the view that laws of nature exist in some sort of Platonic heaven regardless of whether this world exists or not. Similarly, he dismisses the possibility that there could be a different world with the same fundamental laws as ours. According to his account, if the world were different, the laws would have to be different as well. In contrast, if we maintain that laws supervene on the local matters of fact, we see that these laws cannot have the causal powers that an anti-Humean requires in order to explain a governing model of fundamental laws. In addition, Lewis strongly maintains that Humean laws could achieve everything that anti-Humean laws (i.e., a governing laws) could, even though they are the kind of things that supervene on matters of fact and lack any kind of governing or causal powers.

Lewis takes his cue from Ramsey in order to construct a BSA of laws that appeals to Humean Supervenience. Ramsey claimed we should look into the axioms of deductive systems to identify the laws of nature. Lewis takes this suggestion as a starting point for a more intricate account of the laws of nature. The essential point in this suggestion is that

laws are statements of deductive systems. In contrast, universalist accounts of the laws of nature, for example, argue that the laws have universal scope and are not just axioms of some deductive system; in other words, they have some sort of “governing” power. In a universalist account of the laws of nature, such as Armstrong’s (1985), laws have certain properties, one example of which is their power to underwrite necessities. Such powers are missing from Lewis’s account of laws precisely because laws are just axioms of a particular deductive system that is contingent. By contrast, in the universalist accounts the laws are fundamental in the way that they do not depend on the matters of fact. However, not having such causal or governing powers is not a shortcoming of Lewis’s account of laws. It is in fact one of the constraints of constructing a Humean account of laws that they do not possess such causal powers.

As Lewis puts it, the core concept of the BSA of laws is that “truth supervenes on being” (Lewis 1994, p. 74). That is, at the fundamental level we find only “spatiotemporal relations.” By contrast, governing law models must appeal to certain other features at the fundamental level to ensure that the laws indeed have causal powers, such as Armstrong’s universals, or the laws of (final) physics. Lewis is certainly unambiguous regarding his account of supervenience, that all the relations in the world other than spatiotemporal ones are subsequent to spatiotemporal relations. The laws of physics must be in the part of the world that supervenes on fundamental facts. In other words, at the fundamental level there are no other relations except spatiotemporal ones, which he identifies as “distance relation, both spacelike and timelike, and perhaps also occupancy relations between point-sized things and spacetime points” (ibid.); everything else supervenes on these fundamental relations and points.

On the other hand, it is important to note that Lewis was defending the “philosophical possibility” of Humean Supervenience. He is quite clear that if we arrive at a different and/or better physics it is perfectly possible that “a better supervenience may emerge” (Lewis 1994, p. 474). This indicates that the methods of Humean Supervenience are not in principle immutable, but they are flexible enough to adapt to the ultimate facts of the world, whatever they might be. If a better physics indicates that what is at the fundamental level is not spacetime points but something different (for example strings instead of point particles), then it is possible to modify the BSA to accommodate those new fundamental facts. We would construct a new best system such that at the fundamental level there would be different relations to fulfill the role of the spacetime points in the current account.

Suppose that we discovered a new feature of the world such that everything else supervenes on it. In other words, imagine there is a feature of the world that could fulfill the role that spacetime points fulfill in the current account, such as strings of M-Theory. In order to update the BSA properly in such a case, we have to know the precise role of spacetime points in the old best system. More generally, we have to know what makes a feature of the world a Humean property. Barry Loewer states that a property is Humean “if its instantiation requires no more than a spatiotemporal point and its instantiation at that point has no *metaphysical* implications concerning the instantiation of fundamental properties elsewhere and elsewhere” (Loewer 1996, p. 102). Metaphysical independence from other fundamental properties is what makes a property Humean and a fundamental feature for supervenience. This suggests that if a new physics points to the existence of such metaphysically independent properties in the world, then we can and should modify

Humean Supervenience to make use of the newfound fundamental property, whatever it may be.

Loewer constructs an example that particularly highlights both the flexibility of Humean Supervenience as well as Lewis's claim that a better physics might lead to a better supervenience. Loewer reminds us that in quantum mechanics, when we have particles in an entangled state, what we see is a failure of supervenience on local matters of fact. It is probable to use entanglement as a counterexample to the plausibility of Humean Supervenience because intrinsic local properties of particles in an entangled state cannot give us the "full quantum state" of these two particles. In contrast, Loewer uses this example to show that it is possible to modify Humean Supervenience in the light of a better physics in a manner that Lewis envisioned. He appeals to the Bohmian interpretation of quantum mechanics to show that Humean Supervenience can accommodate entangled particles and their local intrinsic properties that do not determine the full quantum state of the two particles as a system. He suggests that, in addition to spacetime points as fundamental intrinsic properties that everything else supervenes on, we should look at the representation of an n -particle system in Bohmian mechanics. In such a case, Loewer continues, we will have a $3n$ configuration space in which the amplitudes of quantum states would be the values of certain points in the configuration space. Moreover, he suggests that we should consider those "field values ... as intrinsic properties of points" that are metaphysically independent of the instantiation of other intrinsic fundamental properties of the world (Loewer 1996, p. 104).

Although it is highly contestable that Bohmian mechanics is the correct way to interpret quantum mechanics,²⁰ one of the points here is to demonstrate the flexibility of Humean Supervenience. The other point is not to defend Bohmian mechanics, but rather to illustrate that quantum non-locality is not a threat to Humean Supervenience. The most crucial lesson we should learn from Loewer's attempt is that as long as one can find an intrinsic property that fulfills the role of spacetime points in the original account, it is inconsequential that such a property is radically different from spacetime points. The point is to show that we should "count a property as Humean in a world iff it is an intrinsic quality of points in *the fundamental space of that world*" (Loewer 1996, p. 104; my italics).

However, an important question remains. What if such a modification of Humean Supervenience is only possible in Bohmian mechanics (or interpretations that are fundamentally similar to it) and impossible in any other alternative interpretations of quantum mechanics? If this is the case, do we really learn anything of value from Loewer's example? I think it is possible to arrive at similar results using other interpretations. Thus, I think that the answer is yes, we do learn a valuable lesson from Loewer's example. In order to demonstrate this, I will examine another interpretation in which quantum non-locality is not a threat to Humean Supervenience. For this purpose, a discussion of non-locality in the Ghirardi–Rimini–Weber (GRW) theory will be instructive.

²⁰ The canonical objection is that there is no relativistic (Lorentz invariant) version of Bohmian mechanics. However, Ward Struyve and S. Colin (2010) argue for a Lorentz invariant version of Bohmian mechanics. This suggests that opponents of Bohmian mechanics have to come up with other reasons why it cannot be a viable interpretation of quantum mechanics.

What we need to show is that there are intrinsic fundamental properties in GRW that are metaphysically independent of instantiation of other fundamental properties. Subsequently, we can conclude if GWR is the correct interpretation, then it is not a threat to supervenience even if there is still non-locality. The aim is to show that in GRW we can still keep Humean Supervenience provided that we make the appropriate modifications to handle non-locality.

The motivation for GRW, and similarly the motivation for all the interpretations of quantum mechanics with the collapse of the wave function, is to identify the collapses precisely. That is, the main objective of GRW is to ensure that every measurement has a definite outcome. To understand this requirement, let's look at some rudimentary details of quantum mechanics. Quantum mechanics tells us that particles evolve according to Schrödinger's equation of motion. However, Albert points out that "every elementary particle in the world ... as a matter of physical law, ceases (for an instant) to evolve in accordance with the dynamical equations of motion" (Albert 1994, p. 94). When this happens particles, nevertheless, continue to evolve. This means there should be some other way of explaining what happens when they stop conforming to the dynamical equation of motion. At such an instant, the elementary particle "undergoes a collapse which leaves it in an eigenstate of position" (ibid.). What happens is that "[the] 'apparatus' interacts from time to time with the 'system', 'measuring' 'observables'. During measurement the linear Schrödinger evolution is suspended and an ill-defined 'wavefunction' collapse takes over" (Bell, p. 173). Bell put the words system, measuring, and observation in quotes because it is not possible to find a proper definition of these terms in the formalization of quantum mechanics. Moreover, for Bell and for realists

regarding physics, it is not a good way to construct physical theories that would ultimately depend on the existence of human observers; i.e., what would it mean for a theory to require “measurement” if there is nobody around to make measurements? The goal of GRW theory is to give a proper definition of this wave function collapse and divorce it from concepts like measurement.

GRW entails that instead of having a measurement dependent on collapse, the wave function of particles can go into spontaneous collapse. An essential difference between GRW theory and other interpretations of quantum mechanics is that to achieve this spontaneous collapse of the wave function they actually modified the linear Schrödinger equation. As Bell put it, to introduce this random element of collapse, GRW asserts that “while a wavefunction ... normally evolves according to the Schrödinger equation from time to time it makes a jump. Yes, jump!” (Bell, p. 102). Therefore, GRW does not appeal to measurements, observers, or anything like these; there is only the Schrödinger equation of motion with a probabilistic element that leads to random wave function collapses. In this theory, then, at the most fundamental level, instead of particles of Bohmian mechanics, we find the wave function. In comparison to the $3n$ dimensional configuration space of Bohmian mechanics, the GRW wave function also “lives” in a $3n$ dimensional space. Again, in comparison to Bohmian mechanics, where the amplitudes of quantum states that are the values of certain points in the configurations space are the intrinsic properties of points, in GRW the random collapses of the wavefunction that “are localized in ordinary space ... centered on a particular spacetime point” (Bell, p 205) are metaphysically independent from existence of beings capable of things like “measurements.” Thus, they are metaphysically independent from the instantiation of

other fundamental properties of the world. We are now entitled to conclude that, in a manner similar to what Loewer does for Bohmian mechanics, non-locality in GRW is not a threat to Humean Supervenience, because we can properly modify it by using localized wavefunctions of GRW in lieu of spacetime points in the original view.

However, we are not yet done with non-locality. In addition to the aforementioned interpretations of quantum mechanics, all of which are patently non-local, we have a different type of interpretation stemming from Hugh Everett III's relative-state account of quantum mechanics. In contrast to previously examined interpretations of quantum mechanics, relative state-type interpretations, including David Wallace's many worlds,²¹ which depends on decoherence, and David Albert/Barry Loewer's²² many minds interpretation (which I will collectively refer to as the many worlds interpretation of quantum mechanics),²³ are patently local. In the case of the many worlds interpretation we have two alternative ways of approaching the issue of non-locality and its connection to Humean Supervenience.

The first and the most obvious conclusion where quantum mechanics does not demonstrate any non-locality, is that there is no longer a problem of non-locality to reconcile with Humean Supervenience. Thus, there is no need to modify Humean Supervenience to begin with; the original formulation of it will work perfectly well in the many worlds interpretation of quantum mechanics. If locality holds, then we can recover

²¹ The interested reader can refer to David Wallece (2012).

²² The interested reader can refer to Abert & Loewer (1988).

²³ Although the differences between the decoherence view and the many minds interpretation are essential for the solutions of important problems in the foundations of quantum mechanics, those differences are not material to the discussion of locality, especially for the purposes of discussing Humean Supervenience.

the physical properties of a system from local facts of the world alone; hence, the original Humean Supervenience holds without any modifications.

The second way to think about it is that the removal of non-locality in the many worlds interpretation actually comes with a cost. Although different from the non-locality of other interpretations, where the non-locality is in the same world, when we introduce many causally isolated worlds we introduce an intraworld non-locality to our physics. However, in the many worlds interpretation, the local matters of fact would be the only matters of fact related to the status of a system in a given world. So, once again, the original Humean Supervenience would hold without any modifications. This shows that if one subscribes to Humean Supervenience, it is demonstrable that the metaphysics of laws is independent of which interpretation of quantum mechanics one maintains.

We achieved two results by establishing that Humean Supervenience is interpretation independent. First, if we properly modify Humean Supervenience, quantum non-locality is not a threat to it under any interpretation currently available. Second, and more importantly, the lesson we learned from Loewer's example is not just limited to Bohmian mechanics. It is overwhelmingly the case that, at least in our world, Humean Supervenience is independent of the subtleties of quantum mechanics. Consequently, the essential claim of Humean Supervenience is not that everything has to supervene on spacetime points; rather the essential feature of the account is that everything else supervenes on fundamental properties whose instantiations are metaphysically independent of other fundamental properties. Furthermore, it is not necessary that these properties are spacetime points, or similar to spacetime points, or that they are points in the configuration space as long as they fulfill the requisite role in a supervenience

approach. In any case, all these considerations show that we should not easily reject the plausibility of Humean Supervenience as an account of the fundamental set up of this world and conclude that Albert is wrong simply because he appeals to BSA.²⁴

2.9 Objections to the Proper Remedy

Now that we have established there is some merit to the plausibility of the metaphysics of laws that Albert employs, we should look at the objections to his proper remedy. Although I will construct my objection to the status of the past hypothesis in the next chapter, here I will give a brief summary of objections from the literature. I will then give an overview of my objection to Albert's proper remedy before moving on to the next chapter.

A first objection to Albert's account focuses on the scope of his project. If we want to account for the universe as a whole system, then we cannot consider Albert's proper remedy as a plausible explanation. It is, however, not completely clear how it could account for the behavior of individual thermodynamic systems, especially when they are energetically isolated. Suppose that there is an energetically quasi-isolated system, for example a glass of water, on an entropy-decreasing trajectory. Such an entropy decrease would have almost no effect whatsoever on the overall entropy increase of the universe. Therefore, it is not clear how the proper remedy, which can account for the entropy increase of the universe, could also account for the entropy increase of

²⁴ It is important to mention that the reason I am referring to this world is that according to Lewis, Humean Supervenience is not necessarily the case for every possible world. That is, there might be a world with emergent qualities such that they do not supervene on the local facts of matter or on spacetime points. Lewis argues that this world, however, is not like that and Humean Supervenience holds.

individual systems without additional constraints. Hence, it is at best an incomplete proposal.

Furthermore, Eric Winsberg argues that in addition to being incomplete under certain conditions, Albert's proper remedy cannot escape from making faulty retrodictions. If Albert's proper remedy actually aims to account for the entropy-increasing behavior of energetically isolated systems, it needs to provide some probability distribution at the instant of isolation. However, the only probability distribution used in this proposal is applied at the beginning of the universe. If we want to explain the entropy increase of an energetically isolated system by using Albert's proper remedy, there must be a probability distribution for the moment of isolation, which it assumes to have without any justification. Moreover, if we can have a probability distribution for free at the initial moment of an energetically isolated system, then nothing prohibits us from saying we can have it any other time; otherwise we would need to justify why the initial moment is preferred to any other state of the system. This is, however, not the only problem with having a probability distribution at the initial moment. In addition, in Albert's proposal, having such a probability distribution without justifying its source leads to the fact that "the initial macrostate of the universe doesn't screen off *any* of the possible microstates" (Winsberg, 2004b, p. 714). This, in turn, leads to faulty retrodictions, because without the "screening off" of the microstates, the probability distribution over the macrocondition of the energetically isolated system at the initial moment is no different from the right probability distribution discussed in section 2.1 while introducing Albert's proper remedy.

I will construct a two-part objection to Albert's proper remedy, the focus of which is the metaphysical approach to the status of the fundamental laws of physics. In the first part, I will assume that best system analysis is a viable position but the past hypothesis cannot be a part of BSA for our world because it violates the requirement of balance between simplicity and informativeness and even possibly the fit to the real world. I will further divide this part of the objection into two. First, I will claim that although the past hypothesis is simple, the increase in informativeness is not solely because of including it in Albert's proper remedy. I will show that we cannot consider the past hypothesis independently of a large package of constraints and laws about the early universe and the laws of modern cosmology. The past hypothesis has to be a member of this larger set in order to achieve what it is supposed to do in Albert's proper remedy. I will argue that for this reason, if we want to include the past hypothesis in our account, we also have to add an entire set of laws of modern cosmology to our best system. This extra baggage diminishes the claims of simplicity.

Second, I argue that even if we concede that the past hypothesis is simple, we include it in our best system of laws because of its simple statement, rather than its ability to explain the time evolution of physical systems in conjunction with time-reversal invariant dynamical laws. I will argue that there were states of the universe earlier than the past hypothesis that cannot be stated as simply. In either case, I maintain that including the past hypothesis in a system that makes use of the best system analysis cannot be justified because it does not lead to a good balance between simplicity and informativeness and it can only be a law if it is a part of the laws of modern cosmology.

In the second part of my objection to Albert's proper remedy, I examine the situation assuming that the best system analysis is not a viable position regarding the metaphysical status of laws. In this section, I will combine the advantages of the best systems analysis with the advantages of a local approach to laws, which I will discuss in Chapter 3. Following that, I will argue that a hybrid way of looking at the metaphysical status of laws, a hybrid between imperialist and local approaches, can solve the problem of the asymmetry of time while avoiding the pitfalls of either account.

Chapter Three

Local Solutions: The Brach Systems Proposal, Patchwork Laws, and Frameworks

3.1 Introduction

In the previous chapter, I examined a global approach that attempts to solve the problem of the asymmetry of time. Two distinct aspects could be the reason for classifying an approach as global. The first aspect is the scope of the solution. For instance, Albert's proper remedy aimed to give an account of the asymmetry of time for *all* physical systems, instead of explaining the time evolution of a specific set of physical systems (such as local thermodynamic phenomena). The second aspect is the scope of the fundamental laws of physics used in the solution. Regardless of whether an approach concerns all physical systems, we can still qualify a solution to be global if it claims that the fundamental laws of physics are capable of assigning lawfulness to statements of special sciences. As we encountered, Albert's proper remedy incorporates both aspects of a global solution.

In contrast, the subject of the present chapter is examining the attempts to give local solutions to the problem of the asymmetry of time. Similar to global approaches, the local approaches have two distinct aspects when it comes to what makes an approach local; one is in regards to the limits of domains for the laws, whereas the other is concerned about the status of laws in a given local domain. One essential difference between the two approaches is that local ones inevitably have to be about a limited set of phenomena. Thus, the contrast between different local proposals depends on the scope

they assign to the fundamental laws they employ. Given these considerations, when I refer to local solutions, I am referring to accounts that aim to solve the problem of the asymmetry of time for mostly local phenomena and/or appeal to laws whose scope is not global.

First, let us consider the plausibility of the reasoning behind constructing local accounts of physical phenomena. Initially, we should ask why go local. It is not immediately evident that local explanations are what we seek in science. After all, in the history of science the overarching goal of almost all of the scientific work was to produce explanations with the largest possible explanatory domain that depends on smallest number of initial assumptions. What advantage there is, then, in giving only a *partial* explanation? The answer to these questions has two parts. The first part is about the temerity of the human mind. When we construct physical theories and come up with the laws of physics with global scope, no one actually thinks that we could actually test these theories at the global level. Initially, we observe local physical phenomena. From the results of these observations, we infer that whatever laws regulate, or govern, or explain the local physical phenomena, they must also regulate, or govern, or explain physical phenomena everywhere in the universe at all times. The opponents of global approach reasonably question the justification of the extrapolation from local results to global ones. For example, in *The Dappled World*, Nancy Cartwright asserts that the only justification of the extrapolation that global approach requires is nothing but “the fundamentalist faith” (1999). The opponents of global approach claim that there is a principled step missing in the extrapolation from local observations to global claims that is at the center of the imperialist view. Although the familiar issues of inductive justification from

observed phenomena to unobserved phenomena are a part of the problem, it is not limited to that. As Cartwright repeatedly emphasizes, the fundamental laws of physics with global scope are not even correct at the local level. The essential point of her claim is that these allegedly global laws only work in very specific and relatively small domains. Whenever one tries to apply them to complex situations with larger domains, there are always additional constraints that one has to take into account in the application of the global law. According to Cartwright, this is evidence that the problem with global laws is not only that they are infected by induction, but rather that they are not the correct laws if taken globally.

The second part of the answer is the realization that the source of certain ‘fundamental’ problems of physics is in fact the result of the commitment to a global approach. Especially, Winsberg argues that once we let go of such global claims, we will see that many fundamental problems of physics that global accounts try to solve disappear. For example, regarding the fundamental problems of statistical mechanics, he argues that if we maintain a particular local account regarding the scope of the applicability of the fundamental laws of physics, we would see that some of these fundamental problems that we thought to be insurmountable are not even problems to begin with. I will thoroughly discuss the details of this argument in the following sections in the context of framework view of laws.

These two observations are sufficient reasons for suspecting the plausibility of a global metaphysics of laws. This suggests that at least a discussion of the shortcomings of global imperialist view is granted. Furthermore, as we will see, for some they are enough

evidence to justify the need to construct alternative accounts. In this chapter, we will examine several of these alternative local approaches.

Despite the potential shortcomings of the global imperialist view, not everybody on the other side thinks that we should go all the way local. It is possible to construct accounts to explain the behavior of local physical systems without actually committing to a range of scope of laws, whether global or local. An example of such an approach is Reichenbach's branch systems proposal. In contrast, it is possible to account for the local physical phenomena while strictly limiting the laws of physics to a local scope. That is, we could operate under the commitment that the laws of physics do not have universal scope. It is possible to divide this commitment into several accounts. One of these accounts is Cartwright's patchwork approach to laws. Although Cartwright is not specifically concerned with the problem of the asymmetry of time, applying her system of laws to a local explanation of phenomena, such as the branch system proposal, results with a more plausible account, as we will encounter in following sections.

Later, I will focus on Winsberg's framework formulation of laws. In addition to limiting the scope of laws, he argues that we should reformulate the metaphysical status of laws of physics. According to Cartwright's account, the metaphysical status of laws in each patchwork is similar to the status of laws in a global approach. Specifically, once we are in a patch, nothing prohibits us from presuming that the laws govern in the sense that a globalist employs the concept within the given patch. In contrast, Winsberg argues that when we let go of the commitment that laws have global scope, we should also let go of the governing picture as well as any commitment to the scope of laws even within a particular patch.

In the rest of this chapter, I will give a detailed examination of the aforementioned local approaches. I will start with the historical attempt at accounting for the asymmetry of time with a local approach. Subsequently, I will give the details of Cartwright's patchwork account and Winsberg's framework account followed by objections to each one.

3.2 A Historical Approach

Reichenbach has attempted to solve the asymmetry of time problem by introducing the branch systems proposal (BSP), which depends on what he calls "the sectional nature of time direction" (1956, p. 125). A detailed look at Reichenbach's BSP and the underlying sectionality of time will provide us further insight regarding the problems that did not have satisfactory solutions within the Boltzmannian framework, specifically the reversibility objection.²⁵ On the other hand, BSP has to deal with its own novel problems stemming from assumptions exclusive to the branching structure of physical systems. Some of these problems are specific to how Reichenbach constructed his proposal, while some of them are indicative of generic problems for any local approach to the fundamental laws of physics. For example, one problem specific to Reichenbach's BSP is the uncertainty regarding the vagueness of the identification of the moment of the isolation from the environment. In contrast, the most important

²⁵ In several papers, published after the reversibility objections and the recurrence objection of Zermelo, Boltzmann claims that his stochastic version of the second law in connection with the assumption regarding the number of molecular collisions and the assumption of molecular chaos overcome any issues raised by those objections. He does not present, however, an explicit argument showing how he solves these problems. As the majority of the discussion in Chapter 2 showed Albert's worry was to improve on Boltzmann because the problems did not go away as he thought they did. Furthermore, as Tim Maudlin argues, the assumption of the number of collisions and the assumption of molecular chaos smuggles in the asymmetry of time to Boltzmannian framework, which shows that Boltzmann did not actually derive the asymmetry of time from entirely time asymmetric assumptions and laws.

overarching worry facing a proponent of a local approach to laws is to explain physical phenomena at least with the same success level, if not more, as fundamental laws with universal scope seem to achieve. I will discuss the details of these later in this chapter.

In Reichenbach's formulation of BSP, there is no explicit discussion of the metaphysical status of laws. By contrast, modern local approaches specifically try to give a justification for why laws should be limited in their scope. Before moving to the details of these modern approaches, let us look at what Reichenbach had in mind for the solution of the problem of the asymmetry of time. This will give us some insight about how a local approach to solve the problem of the asymmetry of time looks like before we delve into the more complex issue, which is to solve the problem locally while simultaneously giving a metaphysical account arguing for non-universal scope of the laws of physics. One of the main aims of BSP, similar to Boltzmann's later attempts, is to provide an alternative solution to the reversibility problem. Reichenbach argues that if we consider certain local physical systems did not exist prior to their isolation from the environment we would not make faulty retrodictions regarding such systems. He postulates that an isolated system has no past states before it branches off from its environment.

For the purposes of his theory, Reichenbach considers 'the environment' as a relatively large physical system with its own trajectory in the phase space. Following this initial assumption, he gives a relatively loose definition of a branch system. According to Reichenbach, we should examine certain physical processes that create "temperature difference in their environment which lead to compensation processes going from order to disorder" (1956, p. 118). Furthermore, when we examine such systems we should see that "[t]he creation of ordered initial states ... is not achieved ... in isolated systems

which undergo an entropy decrease, but in *subsystem of comprehensive* systems the total entropy of which goes up while the subsystem is put in a state of relatively low entropy” (ibid., my emphasis). Then, we define the “subsystem of comprehensive systems” satisfying above constraint as “branch systems”. This shows that not every isolated system is a branch system. According to Reichenbach, such branch systems get isolated from the environment and stay isolated for a certain amount of time before they rejoin with the larger system. For the period of time where they were isolated from the environment, such systems undergo an evolution according to the laws of physics. This evolution of any branch systems is one that takes them from a low entropy macrostate to a high entropy macrostate. Reichenbach adds that we have to restrict these entropy values to the isolated system itself, because we are concerned with the entropy of the branching system and “not [the entropy of] the universe or the main system” (ibid.). However, Reichenbach does not provide any clues whether he has an explicit commitment to laws with universal scope.

Given the above constrains, what we have is a proposal claiming that, and given that we have branch systems that obey the aforementioned constraint of moving from low entropy to high entropy, it is plausible to define the direction of time as the direction in which the entropy of branch systems increases. There is, however, a serious shortcoming of this proposal as a solution to the problem of the asymmetry of time. As Reichenbach identifies it, this proposal would only work if the environment where all the branch systems live also sits on a trajectory with entropy increase.

Recall that the essence of the Poincaré’s recurrence theorem is that if a given system with the appropriate properties required by the theorem (not necessarily the

environment or an isolated system of it), that system in question has to display entropy decrease as much as it displays entropy increase. Now, for Reichenbach this means that, akin to what initially happened to Boltzmann, his proposal only explains the direction of time for when there is a global entropy increase. Moreover, his proposal is patently wrong when the environment is on a trajectory with entropy decrease.

The reason why Reichenbach's proposal is wrong in such a case is the following. Suppose that the environment where we are testing his proposal is on a trajectory with entropy decrease. Further suppose that while the entropy of the overall system is decreasing an isolated system that somehow comes into existence gets branched off from it (imagine I put an ice cube in a Dewar vacuum flask). Now, given Reichenbach's proposal we expect this particular branch system must reconnect with the environment at some time distinct from its time of isolation. At this point, it would be question begging to say that the particular branch system will reconnect with the environment in the future, because that is exactly what we are trying to show and we are not entitled to assume it. In this example, if we let the subsystem evolve, we will observe that it will evolve from a high entropy state to a lower entropy state. Thus, at the time where the subsystem reconnects with the environment it will have relatively very low entropy in contrast to its initial state where it branched off from the environment. If we use the initial crude formulation of Reichenbach's proposal to identify the direction of time by looking at the direction of entropy increase of branch systems, we have to conclude that again the future direction of time is where the branch systems have relatively high entropies. This conclusion as Reichenbach identifies it, however, will not be in accord with our

observations and our thermodynamic experience. What we have so far is, then, only an incomplete local account of the asymmetry of time.

At this point Reichenbach appeals to Boltzmann's conclusion for how to interpret the direction of time in a universe, where there are different epochs, some with overall entropy increase and some with overall entropy decrease. Boltzmann's conclusion was to assign a specific direction of time in each such epoch and forgo of the idea that there must be an overarching direction of time for the entire universe. Reichenbach refers to this as the sectional nature of time. Assuming the absence of an overarching direction of time in conjunction with maintaining that the nature of time is sectional and not just random enables us to realize that Reichenbach's solution was in some sense complete. For the sake of argument, suppose that we maintain that the laws of physics have universal scope. In such a scenario, the tentative branch systems proposal can only solve the problem of the asymmetry of time for local systems, where local is defined as one epoch where the increase of entropy is unidirectional; let us call them "local entropy epochs". Given this constraint, a solution of the problem of the asymmetry of time limited to the local entropy epochs would not be a satisfactory global solution. In contrast, if we were not imperialist about the laws of physics, then giving an account of the asymmetry of time for a part of the universe would be mostly satisfactory.²⁶ This is one level of locality of Reichenbach's branch systems proposal. However, there is still no explicit commitment to the scope of laws within any given local entropy epoch. This is the first part of the argument supporting the claim that one could construct a local

²⁶ The degree of success depends on the details of the particular local solution. We will shortly examine the details of Reichenbach's local solution. After such examination, we can accurately pass judgment regarding the success of his proposal.

account of the asymmetry of time without rejecting or maintaining that the laws of physics have universal scope. In order to examine the other level of locality in Reichenbach's proposal let us now look at the details of the claim that appealing to branch system could be an explanation of the direction of time for the local entropy epochs.

So far, our discussion of Reichenbach's account operated at a high level and we assumed that his proposal of appealing to branch systems was successful. The rest of this section is dedicated to see if this is indeed the case. Reichenbach starts with some initial setup. First, he reminds us that given the postulate that there are different local entropy epochs where it is possible to find two epochs with reverse directions for the direction of entropy increase. In such a case, he asserts, one can appeal to three different languages to describe the direction of time of "the main system".²⁷ Suppose that by using the first language we can identify the direction for the entropy increase as the positive time. Further suppose that the second language is the language of a different local entropy epoch in which the relative evolution of the direction of entropy is from high to low. Given that, the second language will have an opposite direction of time in contrast to the first one. Moreover, Reichenbach urges us to consider a third language "which does not refer to a time direction" (1956, p. 135). The usefulness of this third language, according to Reichenbach, is the fact that we identify branch systems by referring to their terminal points with specific entropy values. This, he claims, does not admit or presuppose an underlying direction of time, which ensures that he is not smuggling in the asymmetry that he is trying to explain.

²⁷ Here what Reichenbach means by main system corresponds to one local entropy epoch.

Following this constraint on what type of language to use, Reichenbach is ready to put forward the branch systems proposal. The proposal has five assumptions that we will examine. These five assumptions in conjunction with the neutral language of time and branching systems are supposedly capable of explaining the asymmetry of time. However, as we will shortly see, similar to Boltzmann, Reichenbach also smuggles in asymmetry that he is trying to explain. Let us start with the assumptions that are important to our discussion. The first assumption is that the current entropy value of the universe is far from its theoretical maximum and the universe is not at equilibrium. There is not too much to discuss about this assumption. We know from theoretical considerations that the entropy of the universe still has room to increase, which means that the current state of the universe is not of ultimate disorder. This assumption enables us to talk about some asymmetry of time because there is necessarily transition from one entropy value to another given that the system is not at equilibrium.

The second assumption is the assumption regarding the existence of branch systems. It just tells us that there are branch systems “which are isolated from the main system for a certain period, but which are connected with the main system at their two ends” (1956, p. 136). As is evident, Reichenbach is purposefully not using a language with directionality in describing the terminal ends of branch systems, because he rightly thinks that using a directional language would be putting in the asymmetry by hand. The third assumption states that the branch systems make use of the probability lattices. This is probably the most crucial assumption of the entire system and the reason why the branch systems proposal fails to explain asymmetry of time without using any asymmetry. I will show how this assumption destroys the entire proposal in the next

section. The fourth assumption qualifies these terminal points again by appealing to a neutral language. It says that for almost all of the branch systems given that they have terminal points “one end is a low-point, the other a high-point” (ibid.).

Finally, the last assumption is the principle of parallelism of entropy increase. This principle tells us, “in the vast majority of branch systems, the directions toward higher entropy are parallel to one another and that of the main system” (ibid.). Recall Boltzmann’s claim that it is possible to derive a conclusion akin to the last assumption, the parallelism of entropy increase, from similar previous assumptions (excluding assumption three, the probability lattices). Unfortunately, this conclusion was false, because from the time reversal invariance of laws of mechanics and other assumptions, such as the one that says the present entropy of the universe is not at its maximal value, it is equally possible to derive the exact opposite of the parallelism principle. It is evident that Reichenbach is aware of this issue. He claims that the branch systems proposal works independently of the last assumption. Moreover, he includes the last assumption as an empirical observation rather than a derived result from the first four assumptions. In conclusion, he claims to solve the problem of the asymmetry of time with the branch system proposal that depends on the above assumptions.

In summary, the assumption that the sub-system did not exist before branch-off point enables us to overcome the problem of past states of the sub-system with higher entropies than the moment of isolation. All we have to do is to say that because there was no system before the branching, there cannot be a well-defined entropy of the sub-system before the branching. Hence, the objection that the past states of the system must have higher entropies is not applicable to the sub-system that becomes isolated from its

environment. Moreover, we can counter the claim that the past states of the sub-system are not in accordance with our records by the same method, which just asserts that those past states are ill-defined or non-existent.

In this proposal, while we can explain the monotonic increase of entropy toward the future, we would not be making any faulty retrodictions regarding the increase of entropy toward the past, because there are no past states of the system and therefore no need to consider the entropy of the past states. Thus, Reichenbach claimed to solve the problem of the asymmetry of time with only time symmetric assumptions and simultaneously overcome the reversibility objection. A more thorough examination of these assumptions, however, shows us that Reichenbach smuggles in the asymmetry that he is trying to explain. In the next section, I will start by demonstrating how the asymmetry is implicitly included in the assumptions of the branch systems proposal. Subsequently, I will examine the objections from the literature.

3.3 Problems with Branch Systems Proposal: The Rogue Asymmetry

The first question we should ask is, is it indeed the case that the first four assumptions of branch system proposal are free from any implicit asymmetry. The answer is, unfortunately, in the negative. The culprit is the third assumption, the one regarding the probability lattices. Interestingly, the point where the asymmetry seeps in is similar in both Boltzmann's and Reichenbach's accounts. In the case of Boltzmann, the problem was his assumption that the H-theorem, which depended on the assumption of molecular chaos that he used to quantify the motions of molecules in a given gas, was free from any time asymmetry. Yet, as we saw in the first chapter, it was exactly this

assumption regarding the probabilities of the motions of molecules that had asymmetric elements in it.

In comparison, Reichenbach employs what he calls the probability lattices to quantify the motions of molecules that make up the physical systems in which we are interested. These probability lattices are collections of probabilities regarding the trajectories of every molecule that make up a given system. In the first instance where he constructs such a lattice for diffusion process of gas molecules, Reichenbach indicates, “when we write down these sequences [of paths of molecules] for all molecules participating in the diffusion process, we obtain a probability lattice ... [where] each horizontal row [of the lattice] represents the history of a molecule” (1956, p. 98). The third assumption of the branch systems proposal states that the probability lattice of branch systems is the same lattice just applied to all branch system and not just limited to diffusion of gases. This harmless looking assumption, however, is not time reversal invariant. In fact, in order for branch systems to explain the asymmetric behavior of physical systems probability lattices *have* to be asymmetric. In order to explain the observed motions properly, the probabilities that Reichenbach constructs from these lattices must not hold in both directions of time. That is, somehow these probability lattices must prohibit the reverses of the histories of molecules. Otherwise, we would once again end up with the reversibility objection. That is, it would be possible to show from the given probability lattices that the motions of particles toward the past would be overwhelmingly toward higher entropies, as they will use the same probabilities for the future direction. In order to avoid such retrodictions, these probability lattices prohibit motions of particles toward the past that would yield high entropy.

Furthermore, if the probabilities hold in both directions of time, then the first four assumptions cannot explain why the direction of entropy increase of the main system overlaps with the direction of entropy increase of majority of branch systems. The reason would be once again that in such a case we would face the reversibility objection. There is nothing in the first, the second, and the fourth assumptions that can explain the asymmetry. Moreover, the fifth assumption, as Reichenbach himself points out, is not essential to the success of branch systems proposal and it is an empirical fact not directly derived from the other assumptions.

The only assumption that could explain the asymmetry is the third one, which must give a history of probabilities regarding the time evolution of particles that produces correct results in the positive time and does not produce the reverses in the negative direction. However, the third assumption could achieve this result only if we assume that the probabilities are asymmetric to begin with. Consequently, the assumption that was supposed to explain the asymmetry of time must already have that asymmetry built into it in order to explain the time evolution of branch systems.

3.4 Objections from Albert

In this section, I will focus on David Albert's objections against the branch systems proposal. The first objection targets what Albert thinks to be the most crucial element of the BSP: the moment of branching. Albert argues that it is not plausible to assume that we can pinpoint the exact moment that a system becomes energetically isolated from its environment. If we cannot identify the moment of branching, then we cannot apply the statistical postulate. In the absence of well-defined initial conditions,

BSP cannot account for the asymmetric behavior of physical systems. At first glance, this sounds like a serious objection because it undermines the most important aspect of the entire proposal.

On the other hand, Reichenbach in the initial stages of his proposal explicitly highlights that no isolation would ever be perfect. He operates under the assumption that we have sufficient knowledge regarding these isolated systems even if we do not have access to every detail such as the exact moment of branching from the environment. Given this realization of the limitations, if he was aware of the above objection, he could overcome it by claiming that applying the statistical postulate around the time of branching would be sufficient to identify the direction of time. Furthermore, we could even increase the precision of our calculations by applying the statistical postulate closer to the moment of branch by some arbitrary limit. Although this would not pinpoint the exact moment of branching, the interval we acquire from applying the limiting function that includes the moment of branching could be sufficiently small. Given that our worry is to identify the direction of time from symmetric assumptions, at such a limit the approximation would be good enough for our purposes, such that we can safely assume that applying the statistical postulate over that interval would result in same predictions as if we knew the exact point of branching.

Albert's second objection focuses on the difficulties with providing the limits of isolated systems. He asks, "how is it that the medium-sized system we decided to focus on was the glass of water with the ice in it and not (say) the room in which that glass is currently located, which also contains the table on which the glass is currently sitting and the freezer from the which the ice was previously removed?" (Albert 2000, p. 89). A

system becomes a branch system in the case that it becomes energetically quasi-isolated from the environment. Moreover, if a portion of a branch system later gets energetically quasi-isolated from the initial branch system, that portion itself becomes another branch system. Reichenbach could easily answer this objection again by claiming that the difficulties in exactly identifying branch systems do not translate in to a difficulty of identifying the direction of time. However, Albert could point to the fact that BSP has no commitments to a certain metaphysical status of the fundamental laws of physics to give the following argument against it. It is possible to assume that the laws that BSP uses have global scope, because BSP neither prohibits a global approach to laws nor endorses a local view. Now, if one maintains that laws of physics, including the ones that Reichenbach uses to explain the direction of time, have global scope, then the above replies to Albert's objections do not carry any force. Albert could argue, for example, that failure to identify the limits and the exact moment of branching possibly could lead to different results regarding the direction of time. In other words, difficulties in exactly identifying the essential properties of branch system could translate to difficulties in identifying the direction of time.

It is important to emphasize that given global commitments, the failure of BSP is not because there are some issues regarding the identification of, say, the limits of an isolated system. Rather, one of the reasons for the failure of BSP is its lack of commitment to a particular metaphysics of fundamental laws of physics. Given this reason, I do not agree with Albert that his objections can undermine the plausibility of BSP. By contrast, I still maintain that BSP is not plausible because, in addition to the aforementioned lack of commitment regarding the status of laws, one of the central

assumptions of the BSP is afflicted by the very asymmetry it is trying to explain, as I demonstrated in the previous section.

3.5 Modern Local Accounts

Reichenbach's reasons to construct a local account to explain the direction of time were specific to the problem he was trying to solve, namely the faulty retrodictions about the past state of physical systems. He thought that it could be possible to refer to the terminal points of a branching system without using concepts loaded with the asymmetry of time. He was not, on the other hand, concerned either with the metaphysics of the laws of physics, or with the questionable inference from local to global. Although it was beneficial to examine it as an introduction to local solutions of the problem of asymmetry of time, in its original form we cannot get any further insight from it regarding the advantages and disadvantages of local approaches, especially ones that have explicit commitments to locality of laws.

By contrast, one of the most notable local approaches, championed by Nancy Cartwright, is not specifically about the problem of the asymmetry of time. Yet, it has specific commitments regarding the locality of the fundamental laws of physics. Here, I will combine Reichenbach's branch systems proposal with Cartwright's "patchwork" view of laws in order to see whether BSP could be a viable option when it requires commitment to a local account of the metaphysical status of laws. However, as I will argue, such an explanation is not local all the way down. As we will see, within a

patchwork the laws would be applicable to the entirety of the patch, therefore failing to constitute an ultimate local solution of the problem of the asymmetry of time.²⁸

In contrast, Eric Winsberg's framework view is local all the way down. The framework view maintains that even in a limited domain it might be possible for a law of physics not to apply to the entirety of that local domain. In addition to the limited scope of laws, in this view the metaphysical status of laws is different compared to their status in the imperialist approach. Given the extra dimension of locality, the framework view solves some of the problems of the BSP and any account whose foundations include the patchwork view of laws. Furthermore, and more importantly, it shows that some of the problems we thought to be fundamental as well as insurmountable turn out to be artificial problems brought about by the commitment to flawed accounts of laws.

After examining both of these accounts, I will discuss whether a local approach is superior to a global one and if so I will identify the best one to use in constructing a solution to the problem of the asymmetry of time.

3.5.1 Patchwork Laws and Asymmetry of Time

Cartwright's short answer to the question "why go local?" is that the global laws simply fail to account for everything at all times. She discusses the reasons why she claims the global approaches are false in *How the Laws of Physics Lie* and *The Dappled World*. Despite the fact that in both books she argues against the global approaches, there is one essential difference between the two. In the former, her main target was the realism

²⁸ I should note one caveat at this point. I do not see a viable way to remove the implicit asymmetry from the assumptions of BSP. On the other hand, for the purposes of examining a local account of asymmetry of time that simultaneously assigns local status to the fundamental laws of physics, I will assume that the central assumptions of BSP are free from complications.

of globalist approaches. Before *The Dappled World*, standing against the plausibility of some sort of scientific realism was thought to be her ultimate goal, even by Cartwright herself. While demonstrating that the laws were patently false (or at best relatively substandard approximations), she also aimed to show that most of the problems associated with the fundamental laws of physics stems from realist commitments. In contrast, as she clearly states in *The Dappled World*, her actual target was never scientific realism. Rather, her aim was to reveal the problems of the imperialist tendencies of global approaches regarding the metaphysical status of the fundamental laws of physics as well as the “fundamentalist faith” that permits one to extrapolate from the local results to global claims.

Cartwright does not aim to show that all the laws of physics are wrong. She argues that if one maintains a global scope for the laws of physics, then one has to conclude that such laws are patently false. Yet, what she means by false is not that they fail to capture anything whatsoever about the structure of the natural world. Their falsehood is not a result of their failure to explain physical phenomena. Indeed, there were false laws of physics that failed to account for certain physical phenomena correctly. In contrast to this trivial falsehood, she is concerned about a different form of falsehood. According to Cartwright, the fundamental laws of physics with imperialist tendencies—the ones with the universal scope—are false not because they generate incorrect results, but because they do not explain all the possible physical phenomena *in their domain*. Their falsehood, therefore, is a result of their failure to be a truly global law of physics.

In general, imperialists claim that the fundamental laws of physics properly work everywhere at all times. Moreover, these laws apply to all physical phenomena. Even if the currently available laws of physics are not truly global, imperialists' claim is that the ultimate fundamental laws of physics have to be global. By contrast, Cartwright identifies, "[p]hysics in its various branches works in pockets, primarily inside walls ... inside which the conditions can be arranged just so, to fit the well-confirmed and well-established models of the theory" (1999, p. 2). Although a particular law of physics might seem to work properly in all of the instances to which it was employed so far, it would still fail to be a truly universal law. Cartwright demonstrates that the laws of physics work without additional constraints only in extremely specific instances. Consider the following example from Cartwright's discussion. Suppose that a physicist wants to predict the trajectory of a dollar bill falling from a certain height. In this case, the physicist would appeal to laws regarding the motions of objects in a gravitational field. Cartwright asks what happens if the free fall of the dollar bill happens not in an isolated room where there is no air friction, no flow of air in different directions, and nothing else that might potentially interfere with the free fall of the bill, but out in the street. She wants to uncover how a law operates outside of 'the walls.' The question is whether the law would still produce correct results under non-isolated conditions. What happens to the explanation of the fall of the dollar bill when there is friction and counter airflow and some other interference? The physicist would possibly reply that in cases with interference she has to supplement the law of free fall with, for example, laws about fluid mechanics to account for the motion of the dollar bill. Given such a reply, Cartwright concludes that the law of free fall does not in fact have a global scope and works properly

only ‘inside the walls.’ She emphasizes, “the laws of our contemporary science are, to the extent they are true at all, are at best true *ceteris paribus*” (1999, p. 6). That is, the laws are true once we neatly define the limits within which they work.

The patchwork view of laws argues against the global scope of the fundamental laws of physics, this much is clear. Yet it is not immediately evident how we define the scope of laws “inside the walls.” What should we expect from the fundamental laws in a limited local domain given that we maintain a patchwork view of laws? The response is that in a local domain, we maintain that the fundamental laws of physics with the same imperialist tendencies about their scope. Even though we limit the scope of the laws within the borders of the domain, we operate as if they are fundamental laws within their domain. According to Cartwright’s account, in each patch there is a particular set of fundamental laws with global reach within that domain. Within each patch, every fundamental law would be applicable everywhere at all times. That is, the laws of physics would be correct within their neatly delimited domains. Consequently, in the overall picture the aggregate of all the fundamental laws of all the patches are going to have a universal scope. Such a system of laws will have imperialist tendencies similar to the fundamentalist view with all the laws having universal scope. In other words, we end up with patches of imperialist laws, each similar to global laws within their own domain. Initially, this aspect of Cartwright’s patchwork view of laws seems to alleviate the issue of falsehood of laws to some degree. The patchwork laws are not false in the sense that Cartwright takes the global laws to be false, because the patchwork laws apply to a particular set of physical events. Thus, we would have the correct laws by giving up the constraint that the laws of physics apply everywhere at all times.

However, the patchwork view achieves this result without actually addressing the fundamental problem of the imperialist view. The fundamental problem of the imperialist view is that the laws of physics do not actually apply for the entirety of the domain to which they are supposed to apply regardless of whether their domain is universal or not. The issue is to identify the reasons why a law might fail to apply to its domain. Cartwright's solution to this problem is to limit the domains of the laws. At first, this might seem to be a viable solution. As I discussed above, the laws that apply to the free fall of the ball would work if their domain were limited so that there were no interfering factors. However, this does not tell us *why* limiting the domain would solve the problems of the imperialist view of laws. Is there a principled way of limiting the domain of a law that claims to apply globally? If the answer is to limit the domain of the law such that the law applies to entirety of the limited domain, this answer does not identify what makes a law of physics correct when we limit its scope.

Cartwright argues that what makes a limited law correct in such a case is that we observe that it works. She is explicit about her empiricist commitments. She claims that when we use a law of physics in a limited scope and get the correct answers, we are entitled to conclude that whatever law we used to explain the *observed* behavior of the system should be the correct law within that limited scope. This suggests a connection between the limits of empiricism and the limits of the scope of laws in science. The scope of Cartwright's brand of empiricism would always limit the scope of the law under investigation. This leads to circularity in identifying the domain of applicability of the laws. This view places the scope of a law into a domain where we observe it to work properly. It then claims that the law is correct with the domain prescribed in the first step.

Consequently, although the patchwork view alleviates one important problem of imperialist global accounts (the fact that they are not global), it does not immediately present itself as the ultimate metaphysics for the fundamental laws of physics.

Nevertheless, there is one advantage of the patchwork view over imperialist global approaches; it does not need to establish a fundamental connection between the fundamental laws and statements of special sciences. In the previous chapter, I discussed Albert's reasoning to classify the past hypothesis as fundamental law of physics with universal scope. In Albert's proper remedy the past hypothesis is more than the initial condition of the universe; additionally, the past hypothesis gives the statements of statistical mechanics their metaphysical status as laws of physics with universal scope. As Loewer indicates, "[the past hypothesis] and PROB can bestow lawfulness on them only if they themselves are [fundamental] laws ..." (2007, pp. 304-305). Winsberg succinctly identifies Loewer's reasoning behind this requirement. He tells us, "since the thermodynamic laws are not fundamental laws—they are laws of a special science—not only their truth, but also *lawfulness*, must follow from fundamental physics" (forthcoming, my emphasis). That is, because the truth of the laws of thermodynamics also comes from the past hypothesis, it must be a fundamental law of physics. As Winsberg argues, however, this connection is highly implausible and depends on the imperialist tendencies of the globalist account of laws or, as Cartwright puts it, depends on the "fundamentalist faith," which has no proper justification.

In contrast, the patchwork view of laws does not have to resort to such a connection between the statements of the special sciences and the fundamental laws of physics for the following two reasons. These reasons directly follow from the fact that the

patchwork account does not necessarily have to satisfy the lawfulness and truth claims regarding the laws of special sciences from a different source other than the empirical results of the laws of special science within their particular domain. First, there is no need to have a connection between the fundamental laws of physics and the statements of special sciences to show that the special sciences' statements are law-like, because the patchwork view does not appeal to any hierarchy of laws in which fundamental laws assign lawfulness to the statements of special science. Second, the truth of the laws of special sciences does not necessarily depend on anything that is outside of the patch they do work.

On the other hand, I am not arguing either for or against the plausibility of the patchwork view in general. I argue that when solving the issues arising from the imperialist tendencies, Cartwright's account at most limits them to certain domains. In order to clarify this claim, I will now give a more thorough examination of what happens at a local level given the patchwork view of laws. In this example, I will demonstrate how the problems of the BSP persist even if I assume the underlying metaphysics of laws is the patchwork view. The problem persists not because of the internal issues of the BSP (specifically the asymmetry inherent in its assumptions), but because the patchwork view in fact does not solve the central problem of the imperialist approach to the laws. The most problematic issue of the BSP is the implicit asymmetry built into its assumptions. The problem of the implicit asymmetry in the probability lattices, however, does not depend on any particular underlying metaphysics of laws. The asymmetry is in the assumptions by virtue of Reichenbach's method of handling the probability lattices associated with the physical systems. Thus, maintaining any particular metaphysics of

fundamental laws has no effect on the construction of the assumption regarding the probability lattices. This problem is, then, inconsequential in the discussion of the kind of underlying metaphysics of laws that could produce better results in conjunction with the BSP. Consequently, hereafter I presume that the assumptions of the BSP are not problematic. I will focus on testing if adding the patchwork view of laws helps to overcome the problems that Albert raised against the BSP.

Albert had two issues with the original BSP: fuzzy boundaries of the isolated systems and unidentifiable moment of isolation. He thought that these issues were enough to dismiss the proposal as a viable alternative to his solution. Here, I examine whether the patchwork laws could help to overcome these problems. Let us start with the first one. Albert thinks that this is the most crucial of his objections. He asks how one could talk about the properties of the branch systems as well as try to predict and retrodict the time-evolution of these systems according to the equations of motion, and if it is impossible, accurately identify the boundaries of the systems in question. Of course, in posing this question Albert presumes that the correct metaphysics of the laws of physics is the global approach with the imperialist tendencies. Given his commitments to the imperialist approach, the inability to identify the limits of a physical system is indeed a crucial problem. The fundamental laws with universal scope have no tolerances; they need precise inputs to function properly. That is, if the equation of motion we use to model the branch systems is a universal law, then we are concerned about a unique solution of a differential equation given a specific initial condition. It is even if it is plausible to have a range of initial conditions from which the differential equations could produce a range of outputs. However, there is no such range for the boundaries of branch

systems in Reichenbach's formulation of the account. It is not the case that we have a coarse-grained knowledge of the initial moment of isolation such that we can use a range as the initial condition. It is the case that the moment of isolation is simply fuzzy. The difference is the following. In the case of a range for the initial condition, with coarse-grained information, it might be possible to take a limit that gets closer to the actual moment of isolation. By contrast, when the moment of isolation is fuzzy there is no possibility of employing such a limiting case as the inputs of the differential equations. Furthermore, in the BSP it is perfectly permissible to have, as Reichenbach himself points out, fuzzy boundaries of systems. For an imperialist this translates into not having a specific initial condition or a specific range of possible initial conditions to feed into a specific differential equation. Therefore, a proposal that does not provide necessary elements required for the application of a universal law covering the phenomena that the proposal aims to clarify cannot constitute a viable explanation.

Albert's second objection parallels the first to some degree. In general, the imperialist approach asserts that if a proposal cannot uniquely identify, such as in the case of the BSP, the initial instant of a physical system, such a proposal cannot provide necessary elements required for the applications of a universal law.

Suppose that the underlying metaphysical of laws for the BSP proposal is the patchwork view. Can this assumption help us overcome the above objections? Unfortunately, the answer is in the negative. In this view, while there are no fundamental laws in the imperialist sense which can bestow lawfulness to other lower level laws, as I argued above, Cartwright does not eliminate all of the problematic aspects of global approach. Although the patchwork view limits laws to certain patches and does not

require any law to have a universal scope, when we look at specific laws, such as the laws of thermodynamics, we see that within their patch these laws operate as if they have universal scope.

The upshot of eliminating fundamental laws in the imperialist sense is that we no longer need to use the past hypothesis to justify that laws of thermodynamics are indeed laws of physics. In this case, we no longer have to justify that the initial condition of the universe is necessarily a law of physics to use the laws of thermodynamics. The laws of thermodynamics that work within a specific patch in which we are interested, on the other hand, have to preserve their universality inside the patch. They cannot be laws such that they work for some cases and not for others. They have to underwrite all the appropriate phenomena within their patch. These “patch-laws,” then, lose one essential property of global laws entirely—power to bestow lawfulness, while retaining the other partially—having a universal scope. They do not retain the latter entirely because they are no longer applicable everywhere. Yet, they retain the latter partially, because within their domain they are applicable at all times to all appropriate physical phenomena. This partial locality of the patch-laws, however, does not help to overcome the problems of the BSP.

The aforementioned problems arise not because some fundamental laws have power to assign lawfulness, but because the BSP is incompatible with the universal laws, which have to be applicable everywhere at all times. Even if we use the patch-laws, fuzzy boundaries with indeterminate points of branching could not provide necessary specific initial conditions for the equations to produce results that are in accordance with our thermodynamic experience. That is, the problems of the BSP arise not because of the

property of the laws Cartwright eliminates, but because of the property that she chose to keep. For this reason, it makes no difference to the BSP whether we maintain the imperialist view of laws or the patchwork view; we cannot overcome Albert's objections. We have to look for another form of local approach to laws.

3.5.2 The Framework Laws and Branch Systems

In the previous section, I argued that Cartwright's local approach to laws is not local enough to solve the problems of the BSP. In other words, the element of the laws of physics that Cartwright localized had no effect on the source of the problems of the BSP. The patchwork view failed to identify the source of the issues correctly. More precisely, it is not the fact that patchwork laws are not local enough that causes its failure to solve the issues, but rather that patchwork laws do not address the problems arising from a commitment to imperialist approach to the metaphysics of laws. Cartwright's approach misidentifies the source of the problem. The issue is not about limiting the scope. Rather, the issue is about the essential connection between physical phenomena and the laws that are concerned with those phenomena. In effect, patchwork laws are not addressing the problem.

By contrast, Eric Winsberg identifies that the problems of the BSP are not related to the limiting the scope of laws, but they are related to—as in the globalist Boltzmannian framework—the commitment to the fundamentalist faith regarding the laws of nature. Furthermore, the issue is not about the scope of the fundamentalist faith. As I argued in the previous section, whether this faith is localized or global makes no difference to the problem at hand. The issue prohibiting the BSP from being a viable alternative is not the

scope of the laws or scope of the fundamentalist faith; rather, it is what we take laws to be at a more fundamental level. That is, the problem is the fundamentalist faith itself. So far, we encountered two distinct views about the laws of physics: either they govern the physical phenomena with necessity or they are tools we devise to understand and predict the physical phenomena. Winsberg asserts that we should maintain the latter rather than the former. This latter view will eliminate the aspect of the imperialist view of laws—the fundamentalist faith—that generates the problems associated with the asymmetry of time. He also argues that maintaining the view that the laws of physics are tools to model physical phenomena would lead to the realization that some of the problems associated specifically with statistical mechanics were not even fundamental problems to begin with.

Recall that one of the motivations in constructing the BSP was to find a way to fix the problems regarding the past states of the physical systems. It aimed to solve the problem of faulty retrodictions by claiming that there are actually no past states of such systems before they branch off from their environment. The original BSP necessitated applying the statistical postulate at the beginnings of branching systems without a proper justification of this requirement. The only justification of this requirement was a vague reference to temporal priority. There is—as Albert points out—no principled reason why we cannot apply the statistical postulate to the branched system at some moment in the middle of isolation, or at the time of reabsorption into the environment. This leads to either failing to explain the asymmetry of branch systems or an improper use of the very asymmetry in the explanation of itself within the context of the branch systems.

In order to overcome these issues, Winsberg's reconstruction of the BSP depends on the particular metaphysics of laws that he calls the "framework" view of laws. The framework view claims that the laws of physics do not need to be universal; there is no necessity that they hold everywhere at all times. Yet, this does not mean that they are localized as in the patchwork view. It is permissible that a law may have a very large scope in framework view—as long as the law is useful to model a physical phenomenon, there is no need to introduce artificial patch-like boundaries for the scope of laws. The framework view permits laws that have extremely large scope—for all practical purposes global scope—and laws that are very limited in scope. There is nothing metaphysically or physically essential about the scope of a law. That is, Winsberg identifies that introducing artificial limits to the scope of laws is not going to solve the problems infecting the physical theories discussed so far.

According to the patchwork view, laws operating within a patch are similar to the imperialist laws in one important respect—they are applicable everywhere at all times in a given domain. The patchwork view switches from the global fundamental faith to a limited and localized fundamental faith. Yet, the problems of the accounts trying to solve the issues related to the asymmetry of time stem from the fundamental faith and not from the scope of laws.

In contrast to the partially local patchwork view, Winsberg tells us that the laws of science "provide a framework for building models, schematizing experiments, and representing phenomena" (Winsberg 2004b, p. 716). The framework view aims not to sidestep the issues by introducing ineffective boundaries for the domains of laws, but to attack to the fundamentalist/imperialist faith regarding how the laws work. In order to do

that, Winsberg argues that we should not take the metaphysical status of laws so fundamentally. There is no indication from any of the arguments provided by both Albert and Cartwright regarding the fundamentalist/imperialist faith that giving it up will not result in ‘the decline and fall’ of scientific enterprise. Moreover, such a faith in the fundamental character of the laws seems to be the most probable source of the problems associated with explaining the direction of time. We need an account that can implement such an approach—an approach without the unsupported fundamentalist/imperialist faith.

In contrast, the framework view jettisons the fundamentalist/imperialist faith in laws. It takes laws as useful tools to understand how the physical systems evolve in time and does not impose artificial boundaries for the scope of laws. Let us now see how this could help to improve the viability of the branch systems proposal.

In the context of branch systems, the framework view could properly justify the application of the statistical postulate at the initial moment of isolation from the environment. A further advantage of this particular account is that we can justify the application of the statistical postulate for systems that branch off from their environments and simultaneously overcome Albert’s objections. In this view, it is not required or even essential to pinpoint the initial moment of branching. Similarly, it is not required or essential to identifying the limits of an isolated system. The worry is not to provide initial conditions to some differential equations, but rather to “build models to represent phenomena.” Second, the framework view has all the advantages of the patchwork approach resulting from the limited scope of the laws, without any of the drawbacks because in the framework view there is no recourse to the fundamental faith even in the limited sense employed by Cartwright.

The advantages of the framework view are not just limited to giving a correct explanation of the asymmetry of time. We seem to gain much more in the pursuit of solving foundational problems of statistical mechanics if we maintain this view. In addition to successfully tackling the problem of the asymmetry of time, the framework view of laws shows us that some of the problems that we deemed to be important and almost impossible to resolve without great effort and ingenuity disappear under this way of understanding scientific laws. As Winsberg argues, it is possible to trace the source of all our problems to what we expect from scientific laws. If we expect laws to “give us necessary, universally applicable, complete, and exact descriptions of the way the world will necessarily be, given any physically possible set of initial conditions” (Winsberg 2004b, p. 716), then what we get are all these insurmountable foundational problems. He states that we must switch to a different conception of laws, which leads to the conclusion that the foundational problems were not problems to begin with.

Unlike what the patchwork view prescribes, the laws according to the framework view do not have to hold at all times, even when they are limited to specific domains. However, the framework view does not aim to limit the scope of laws to some domains. There are no preset patches according to the framework view. This indicates that it is permissible for one law to have global scope and some other law to have a more limited scope. The essential feature of the framework view is that there is no fundamentalist faith operating behind the scenes to explain how laws underwrite the physical phenomena. There is no such faith because we do not assume that laws ‘rule over’ the physical phenomena. All we need from the laws of physics is that they be useful in constructing models and predicting physical phenomena. In short, both the imperialist view and the

framework view of laws are useful to explain physical phenomena that are of interest to us. It is just not clear from the point of view of a proponent of the framework view, why imperialists need more than that; it is not clear why we need to have the audacity to claim that from what we know we can extrapolate to everywhere at all time. Furthermore, it is not clear from what we observe laws have some fundamental governing power. Even though both views help us understand the physical phenomena, the imperialist needs to position this understanding on top of a metaphysically thick foundation leads to all of its shortcomings.

In contrast, once we subscribe to the framework view that the laws are nothing more than tools by which to understand the world around us, we find a solution to the problem of asymmetry of time in the context of branch systems. This solution, however, asks us to modify our commitments to the metaphysics of laws. It is plausible for a proponent of the imperialist view to ask for a solution to the problem of the asymmetry of time that is amenable with her metaphysical commitments. In that case, the task for the proponent of the framework view is to show the implausibility of a solution to the problem of the asymmetry of time in which the underlying metaphysics of laws is the imperialist view.

As a final note, whether we use the imperialist approach, the patchwork view, or the framework view, we cannot overcome the problem of implicit asymmetry in Reichenbach's original formulation of the BSP. The reason why the BSP fails is not a lack of commitment to an underlying metaphysics of laws (whether it is imperialist, patchwork, or framework), but because it already uses the asymmetry that it supposed to explain. Furthermore, the problem is so intertwined in the structure of the account, it is

impossible to get it off the ground without that implicit assumption. That is, without assuming the asymmetry in the motions of molecules that make up the physical systems, the proposal cannot explain why majority of branch systems have entropy increase in the same direction as the main system. All of this suggests that problem is not going away that easily and that we need to construct a new account, which is the subject of the next and final chapter.

Chapter Four

Dynamics of Inflation as the Source of Asymmetry

4.1 Introduction

The aim of this chapter is to develop a new approach to tackle the problem of the asymmetry of time. The general picture arising from the previous chapters is that there are two important aspects of the problem. First, an account to explain the asymmetry of time, whether identifying its source or identifying how asymmetry is compatible laws of physics, has to deal with metaphysical issues regarding the laws of physics. Second, once an account commits to particular metaphysics for laws of physics, it has to ensure that the solution is also compatible with modern physics. That is, we have to make sure that particular claims of such an account for the asymmetry of time do not conflict with what the physical laws permit.

The preceding investigations of the different attempts to solve this problem point to several important difficulties that fall into either one of these categories—namely, some proposals have problems with their metaphysics, some have problems because they include results that contradict modern physics, and some have both issues. In order to construct a successful proposal we need to address both metaphysical issues on the level of laws of physics and the compatibility with physics itself.

In the rest of this chapter, I will construct a proposal to address both of these difficulties. The first step is addressing metaphysical disagreements between the

alternative accounts we have examined so far in regards to commitment to a specific nature and structure of laws of physics. Each contemporary account is dependent on a particular metaphysics of the laws of physics—whether imperialist, patchwork, or framework—and these distinct metaphysical approaches generally have conflicting commitments. Moreover, as I discuss in Chapter Three, there are certain difficulties associated with both Albert’s fundamental view of laws and Winsberg’s framework view of laws when these views are coupled with physics to explain the asymmetry of time. One of the aims of this chapter is, then, to construct a new approach to the nature and the structure of the laws of physics, which has advantages over the previous views—specifically the ones I introduced in the last chapter.

In the second part of this chapter, I will give a counter argument to Albert’s proper remedy that takes its cue from modern cosmology. In light of this counter argument, I will construct an approach to the asymmetry of time by appealing to modern cosmology that will direct us to a proper understanding of the initial conditions of the universe and how we can use such an understanding of those initial conditions to explain the behavior of local physical systems. At the end of this chapter, we will have an overall better account to explain the asymmetry of time—by combining the metaphysical and physical sections—one that avoids the pitfalls others cannot escape.

4.2 A New Way of Understanding the Structure of Natural Laws

At the end of Chapter 3, I briefly mentioned that the view of laws of physics to which one subscribes contributes to how one determines what is a fundamental problem in physics and what is not. In this section, I will examine the two prominent views of

laws that we hitherto implicitly and explicitly encountered in more detail. I aim to show that both views have some drawbacks. After identifying these disadvantages, I aim to construct a new way of understanding the structure of laws of nature. I will use this in conjunction with my arguments from cosmology to give an improved account of the asymmetry of time.

Although Albert does not explicitly argue regarding the scope of laws of physics, we can infer from his arguments that he assumes that they have universal scope. Let us call this way of understanding the scope of laws of physics the “strong fundamentalism” view. There is an important reason why his view can be dubbed as strong fundamentalism and not just fundamentalism. According to this view, the laws of physics have to be *individually* and collectively applicable everywhere at all times. The ‘strong’ part comes from the requirement of individually having universal scope. This requirement is one of the reasons that the past hypothesis has to be classified as a law of physics in Albert’s ‘proper remedy.’ If the past hypothesis is not a fundamental law of nature in the strong sense, it will fail to underwrite the asymmetry of time. Eventually, this requirement forces Albert to maintain a strong fundamentalist view regarding the laws of physics. This is one end of the spectrum. On the opposite end lies the framework view of laws.²⁹ The framework view argues that there is no need to assume that all laws of physics, individually or collectively, have to be universal in scope. The laws themselves do not *govern* the physical phenomena. They are just tools used for understanding and predicting them. The laws, therefore, do not have to have universal scope, yet they might have broad scopes such that for the purposes of modeling, the

²⁹ This is assuming that we maintain there are laws of physics.

narrowness of the scope of laws would not lead to any problems in modeling. In fact, the commitment that all laws must have universal scope is the underlying cause of certain foundational issues in physics. Once we see that there is no such scope requirement for laws, we should also realize that certain problems are in fact not problems at all.

I will argue that although the fundamentalism of Albert's view is excessive, we do need some sort of universal scope. In addition, even though the framework view helps us get rid of certain problems, it does not guarantee a global scope. Hence, I will develop a view that incorporates a proper scope to cover all physical events under some physical law and is at the same time useful in overcoming problems arising from employing the initial condition of the universe as a fundamental law of physics.

4.2.1 An Improved Proposal for the Scope of Laws

The arguments so far show that if one wants to account for the initial worry—how to reconcile the asymmetry of time with time reversal invariant laws of physics—one has to make sure that their account has a proper metaphysics of laws as well as being compatible with modern physics. Let's start with the proper metaphysics of laws. What does it mean for an account to have a proper metaphysics of laws? Different accounts yield different advantages and disadvantages. Is the proper metaphysics the one that combines all of the advantages and disposes the disadvantages? It seems highly improbable that we can construct a metaphysics of laws by merely listing disconnected statements of different accounts because these disconnected advantages are most likely to fail to integrate with each other to comprise an intelligible account of laws. Even worse, such a cluster of statements might even be contradictory. Consider the following

example. One of the most crucial advantages of Albert's system is that it finds a way to stop the faulty retrodictions from ever arising as an issue. His system achieves that by assuming the past hypothesis to be a fundamental law of physics, which is justified by claiming that the past hypothesis is a statement in the best system. However, as I previously highlighted, Albert's best system implicitly assumes an imperialist approach that seems to be the source of many disadvantages. Once we remove such an imperialist approach to laws to make the metaphysics to be compatible with, say, a less imperialist view about laws—imagine, for example, a system that is universal but not imperialist—we lose one the advantages of Albert's system. In other words, advantages and disadvantages of alternative accounts of the asymmetry of time do not come as neatly and independently packaged lists. The elements of these accounts are tightly connected in such a way that removing one feature of them cannot leave the rest unaffected. This suggests that the most prudent way to proceed is to construct a new metaphysics—if not from the ground up, it has to be at the least more than just a list of advantages from different sources.

4.2.2 The Aggregate View of Laws

A more successful metaphysics of laws requires two things: 1) a very broad—if not universal—scope, and 2) a connection between the statement of special sciences and fundamental laws. The justification for the first requirement is relatively straightforward—we want the laws to talk about the world without appealing to any physical phenomena that falls outside their scope. This is different than requiring a distinction between accidental generalizations and genuine regularities. An event might

be an accidental generalization without being outside of the scope of laws. That is, this requirement is not trying to be anything substantial—every phenomenon in the universe somehow falls under some law. This does not even require us to be realist about laws. Even if laws do not have actual casual powers, they could be used in explanation of physical phenomena. The only criteria is that no event falls outside of the scope of laws—regardless of whether the laws govern the physical world, or just useful fictions to explain the world, or even just a list of statements of a deductive system. Even though it might be implicit, a global scope is a shared feature of different approaches that I previously examined. Let me briefly reiterate how different accounts talk about a global scope.

First, Albert’s proposal that appeals to the best system analysis has a global approach because no physical event lies outside the scope of the statements of the best system. Furthermore, the best system—whatever that might turn out to be—is based on the Humean Mosaic, and the Humean Mosaic is the aggregate of all “spatiotemporal relations” and nothing else. Therefore, the scope of the best system analysis is global because it covers everything that comprises the Humean Mosaic, which in turn is comprised of all of the spatiotemporal relations; nothing falls outside of the scope of the laws arrived at from the (final) best systems analysis.

Second, even though Cartwright aims to limit the scope of laws, her account is not a limitation on the global reach of all the patches taken together. That is, although any given law is not going to be a universal law—such that they would work only in their specific patch—Cartwright does not provide any argument to the effect that these patches do not have a global scope when taken as a collection. According to Cartwright, it is

possible for a physical event to not fall in the scope of a particular patch of laws. Yet, this does not lead to the generalized claim that it is possible for a physical event to not fall under the scope of any patch of laws. In other words, even though the individual patches have limited scope, the scope of all of the patches taken together is global.

Finally, Winsberg's framework account could be interpreted as having an extremely broad scope, if not a strictly universal. Recall that in Winsberg's account laws only lose their fundamentalist characteristics and not their general scope. There is a straightforward explanation for having a global scope. Consider an account of the asymmetry of time that does not appeal to global laws. Such an account, although it might cover a great number of physical phenomena, always runs the risk of being affected by events not cover under the scope of laws, which might interfere with the direction of time. Such explanations would always be suspect because they do not take every possibility into consideration. That is, one could always construct a skeptical argument emphasizing the possibility that the explanation might be essentially incomplete. That is, a proper metaphysics of laws underwriting an account of the asymmetry of time should have a global scope as one of its features. Consequently, I claim that the proper metaphysics of laws have to be universal in scope. There are, however, certain constraints on the universality of the scope of laws. First, I make no commitments to the effect that there is something metaphysically thick about laws—that they govern the physical phenomena. I am not claiming that they should not be seen as governing the physical phenomena. I argue that we have to construct the general structure of laws such that it would not matter one way or another. More clearly, whether laws govern the physical phenomena or they are useful tools to model physical phenomena

should not make a difference to an account of asymmetry of time.³⁰ That is, the asymmetry of time as a physical phenomenon should not depend on the peculiarities of some particular approach to metaphysical structure of laws. Once again, the only necessary constraint is the universality of the scope. This is not a particular requirement for giving an account of the asymmetry of time; this is a requirement for any proposal that deals with physics. Yet, there are different ways to achieve universal scope—or a very broad scope that is universal for all intents. Furthermore, the different ways of achieving a universal scope are not compatible with each other—e.g. one cannot have a system where all the laws are universal and yet limited to particular patches.

First, there cannot be a constraint requiring all laws to be universal in scope. Not every law can be universal. The most relevant example to this project is the status of laws of thermodynamics. They cannot be universal for several reasons. In general, laws of thermodynamics require a target system to interact with—or to be isolated from— other systems. In the case where the target system is the entire universe, one needs to explain, e.g., what could be the system that is heat bath for the entire universe. This requires existence of another system that covers the entire universe. But, if there is such a system, it should have been included in the entire universe. Hence, it is difficult to see how spatially local laws could be extrapolated to cover the entirety of the universe. The laws of thermodynamics are not only spatially local but temporally local as well. For example, the second law of thermodynamics works only for times shorter than Poincare recurrence

³⁰ As we previously encountered, whenever there are serious issues with any account most of these problems have their roots in the metaphysics of laws. This of course does not mean that by merely correcting the metaphysical commitments of Albert's proper remedy or branch systems proposal for that matter one could end up with a viable account of the asymmetry of time. These proposals have physical shortcomings as well as metaphysical ones as the previous chapters identified.

time of the given system. Even though such recurrence times are extremely long, they are nonetheless finite and therefore thermodynamic laws are temporally local. Of course, this does not amount to the claim that no laws could be universal in scope; there are some good candidates for such laws such as laws regarding gravity as well as electrodynamics—whether classical or quantum. Consequently, when it comes to the scope of laws the constraint is that the aggregate of the scope of laws should guarantee coverage of all phenomena by one or more laws, where not all laws have to be universal in scope.

This approach is different from the previously examined ones in the following ways. In contrast to the patchwork model of laws—where all the laws are localized to patches in which they are correct—in the aggregate model we have a constraint that ensures global reach. Even though it is possible to have global scope in the patchwork model when all the patches are taken together, it is not a requirement of the model and leaves the possibility of non-universality of laws. As I mentioned before, it is crucial to ensure that there is no such possibility. Furthermore, in contrast to the framework view—where there is again no requirement of universal scope but only minimal commitment to a very broad scope of laws—the aggregate model would ensure the universal scope of laws taken together. And finally, in contrast to Albert’s proper remedy—where there are strictly universal laws that lead to issues we saw above—the aggregate model ensures universality without requiring all the fundamental laws or a particular set of laws necessarily having universal scope. The importance of the global reach of the totality of laws is to ensure that there is no plausible source of asymmetry of time outside of the scope of the laws of physics.

Nevertheless, there is a more important issue than the scope of laws—the fundamentalist/imperialist faith regarding laws. Recall that even Cartwright’s essentially non-universal system fails not because of the scope of laws, but because it falls victim to the fundamentalist/imperialist faith. In order to ensure the aggregate view does not encounter the same pitfall, it is essential to note that there should not be any fundamentalist/imperialist faith in this view. The most efficient way to achieve this goal is to assume that the aggregate view incorporates elements from Winsberg’s framework view. Particularly, I import the claim that the laws of physics do not govern the physical phenomena. I do not need anything more—i.e., I do not need to say whether the laws are good modeling tools or not. The point is to make sure that we are steering away from fundamentalist/imperialist faith.

Now that I have a commitment to a particular metaphysics of laws, I will examine how appealing to the aggregate view of laws in conjunction with modern cosmology can be a better explanation of the asymmetry of time. But first, I will highlight certain shortcomings of Albert’s proper remedy when we consider the developments in modern cosmology.

4.3 Arguments from Cosmology

Previously, we looked at David Albert’s project that he developed over the course of several works. Barry Loewer (1996, 2007) contributes additional features in conjunction with Albert’s account that aims to provide an understanding of our experiences of the physical world. One of the main problems they tackle is the especially puzzling issue of irreversible (local) thermodynamic phenomena (ALS).

ALS includes two important axioms, the past hypothesis (PH) and equal probability distribution (PROB), which enable ALS to talk about local thermodynamic phenomena. In addition, Albert and Loewer employ the Mill-Ramsey-Lewis (MRL) best system analysis of laws of nature as the foundation of their project. However, MRL is not capable of handling certain issues central to the Albert-Loewer system (ALS) as Lewis developed it, most importantly the time asymmetric phenomena. Thus, the best systems analysis they are using has certain improvements over MRL that are specifically included to increase the tenability of ALS.

There are, however, several objections questioning the way ALS uses PH and PROB. In this section, I will construct a two-part objection that uses results from modern cosmology in order to show that PH has to be a member of a larger set of laws of nature in order to achieve what it is supposed to in ALS. Furthermore, I will also argue that PH cannot be used in ALS without going against one of the fundamental principles of the best system analysis, the balance between simplicity and informativeness.

In the first section, I will give a brief overview of ALS. I will examine different models regarding the initial conditions of the very early universe from modern cosmology. I will give an argument for why PH is not as innocent as it looks. My objection, which takes its cue from modern cosmology, aims to show that ALS cannot sustain its bite under this method of considering the status of PH.

In what follows, I will construct my objection specifically regarding the status of PH in two parts. I aim to show that the way PH is employed in ALS is unjustifiable. In the first part, I claim that although PH is simple, the increase of informativeness is not due solely to including it in ALS. That is, PH cannot be considered independently of a

large package of constraints and laws about the very early universe. PH has to be a member of this larger set in order to achieve what it is supposed to in ALS. Hence, to use PH in ALS we have to add this entire set to our best system. This extra baggage diminishes the claims of simplicity of ALS. The second part of my objection argues that even if we concede that PH is simple, it is an arbitrarily chosen state, i.e., selected merely for its simplicity rather than its ability to explain the time evolution of physical systems in conjunction with time reversal invariant dynamical laws. I aim to show that in some proposals for the origin of the universe, such as quantum tunneling, there are states of the universe before PH. Furthermore, these states are more complex than the low entropy condition of PH. Hence, they cannot be as simple as PH. In either case, incorporating PH into a system that makes use of best system analysis cannot be justified by appealing to a good balance between simplicity and informativeness.

In order to show that PH cannot be considered as a simple addition to ALS that only minutely increases the complexity of the overall system while leading to a great increase in informativeness, I will investigate several different scenarios regarding the initial conditions of the universe taken from modern cosmology. By using these cases as counterexamples, I aim to show that the extraordinary increase of informativeness of ALS is not due merely to adding (the very simple) PH, but obtains mostly because of the set of complex criteria, laws, and assumptions regarding the very early universe. Hence, I will argue that claims of increased informativeness cannot be sustained without the inclusion of this complex set into ALS.

4.3.1. Against the Past Hypothesis: Arguments from Cosmology

In this section, I will construct a two-part objection against Albert's proper remedy. The focus of my objection is on Albert's metaphysical commitments regarding the status of the fundamental laws of physics. For the purposes of the present discussion, I assume that the best systems analysis is a viable approach to the metaphysics of fundamental laws. Of course, this is a contested claim. However, I want to show that even from within the confines of the metaphysics to which Albert appeals, it is possible to argue against the status of the past hypothesis, such that it does not fit into the constraints of the best systems analysis. Albert considers the past hypothesis as a fundamental law of physics because it increases the informativeness of the system with minimal increase in complexity of it. Thus, it strikes a good balance between simplicity and informativeness, a central constraint that a statement must fulfill to be a fundamental law according to the best system analysis. Two issues threaten the status of the past hypothesis as a fundamental law.

First, even though the past hypothesis is simple, the increase in informativeness is not solely because of including it in Albert's proper remedy, but rather the increase is a result of the implicit help the past hypothesis gets from the laws of cosmology. It is not plausible to consider the past hypothesis independently of a large package of constraints and laws about the early universe. The past hypothesis has to be a member of this larger set in order to achieve what it is supposed to do in Albert's proper remedy, which is to explain the global asymmetry of time while bestowing lawfulness to special sciences' statements. I argue that if one wants to include the past hypothesis in an account of the

asymmetry of time, one also has to add an entire set of laws of modern cosmology to the best system of laws. This extra baggage diminishes the claims of simplicity.

Second, even if I concede that the past hypothesis is a simple statement, I argue that Albert includes it in the best system of laws because he is more concerned with the simplicity quota than providing an actual global account. That is, the past hypothesis is not about the first instant of the universe, but it is a relatively simple way of expressing a specific early state of the universe that looks good in a best system analysis. According to most, if not all, models of inflationary cosmology, there were states of the universe earlier than the past hypothesis and these states could not be stated as simply. This raises suspicions about Albert's motivation to include the past hypothesis in the best system analysis. Is the past hypothesis included in the best system because it is genuine boundary condition or because it is a (relatively) simple statement satisfying the simplicity quota? I maintain that it is included in the best system only because it helps the simplicity quota. Besides these issues, there is another criticism against trying to raise the status of boundary conditions from statements about the world to fundamental laws of the world. The argument goes like this. Whenever scientists encounter specific initial conditions in the course of theory construction, they presume that there is a mechanism to explain these initial conditions and the statements for these initial conditions are temporary placeholders. That is, in the practice of science, whenever one encounters a fine tuned boundary condition, the first reaction is to try to explain it with some set of laws of physics. In contrast, Albert's proper remedy requires such a boundary condition to be a fundamental law of physics. For example, John T. Roberts (2008) argues that. in cosmology, in order to explain certain global properties of the universe at first it seemed

that we needed certain finely tuned initial conditions. Yet, cosmologists resisted including such finely tuned initial conditions as fundamental laws to their theories. Instead, they sought some mechanism that could bring about such initial conditions. One of the most famous of such mechanisms is the cosmic inflation, which aimed to be an underlying mechanism that had its own fundamental laws in explaining a finely tuned initial condition as opposed to accepting the initial condition itself as a fundamental law.³¹ However, Robert's argument assumes that the underlying metaphysics of laws is different from the best systems analysis. He assumes that the correct account of laws is one that assigns governing power to the fundamental laws of physics. Although this is a possible way to argue against Albert and the past hypothesis, it overlooks the problems arising specifically from the central elements of Albert's project. Robert's claims could be a basis for an attack on the plausibility of any approach that depends on the best system analysis in general.

Let me start with the first issue. In contrast to Robert, I argue that if we maintain that the cosmic inflation is the underlying mechanism of overall structure of the universe, then the past hypothesis cannot be a fundamental law of physics even if the best system analysis is correct.

Alan Guth developed the mechanism of cosmic inflation to solve the problems of finely tuned initial conditions of the hot Big Bang cosmology. Originally, Guth proposed that a solution to these problems of the initial conditions, which he called the flatness

³¹ It is a well-known fact that in its original formulation the cosmic inflation requires its own finely tuned initial conditions. This, however, leads to an additional example for not accepting initial conditions as laws but rather searching for mechanisms to explain them. That is, searching for the source of the finely tuned initial conditions for the cosmic inflation itself results in another mechanism that aims to explain those initial conditions. In other words, whenever we encounter fine-tuning of initial conditions, we do not just accept them as is, but rather we search for fundamental laws to explain them.

problem and the horizon problem, was a mechanism that could cause an “exponential growth” of the universe (1981). Despite the technical problems of this initial proposal (for example, inflation itself requires further finely tuned initial conditions), the main contribution of it was to show that there could be states of the universe prior to the state to which the past hypothesis refers. Many proposals were advanced to suggest solutions to the problems of the original inflationary model; here I will focus on the Eternal Inflation models that take their cue from the model Andrei Linde constructed originally in 1986.

In contrast to the hot Big Bang model where there is one expanding region that is the entirety of the universe (even if some regions of it are unobservable), the Eternal Inflation models hold that there are many isolated expanding regions (bubbles) situated in a “still inflating back ground” (Borde & Vilenkin 1993). In such a case, the initial instant of the bubble we find ourselves in is almost certainly distinct from the initial instant of the inflating background.

Although some models maintain the absence of an initial singularity, Borde and Vilenkin argue that it is plausible to construct an eternal inflationary model with one. They show that there must be a past singularity if the universe satisfies certain conditions.³² Given their proof that our universe satisfies all the conditions, it is plausible to assume that there was a past singularity in the eternal inflationary model, where the part we live in is one of many isolated inflationary bubbles. If this is how the universe works, the initial singularity that Borde and Vilenkin talk about is different from the

³² According to Borde and Vilenkin these conditions are past causally simplicity, openness, requirement that the Einstein equations hold, and that “there is at least one point p such that for some point q to the future of p the volume of the difference of the pasts of q and p is finite” (1999, p. 3).

initial low entropy macrocondition to which Albert refers. The former is the initial condition of the entirety of the inflating background in which many different bubbles start to inflate and get isolated from one another because the region in between these bubbles inflates even faster, whereas the latter is the initial macrocondition of one bubble in which we happen to live.

In this model, it becomes more difficult to justify that the past hypothesis is a fundamental law of physics. First, recall that Albert's aim is give a global account for the asymmetry of time. In this model, however, given that the past hypothesis is about a particular bubble that nucleated from the inflation background, the most it can do is to explain the asymmetry of time in one particular bubble. It is highly improbable that the initial macrocondition of one isolated inflating bubble could be the source of the asymmetry of time in other isolated inflating bubbles. Even if we assume that the initial condition of our bubble could be the source of the asymmetry for the other bubbles starting their inflation after ours, it cannot be the initial source of asymmetry for bubbles that had started to expand before our bubble even came into existence. This diminishes its claim to be a fundamental law of physics, because it is limited to an isolated part of the universe. Second, in the hot Big Bang model, appealing to the initial singularity has certain merits; for example, it has temporal priority over any other macrostate of the universe. Losing this temporal priority is fatal for the past hypothesis, because it was essential in overcoming central objections that other proposals failed to provide successful alternatives.

Of course, in the hot Big Bang model, appealing to the initial condition of the universe as a fundamental law of physics could be justified in connection with the best

systems analysis and temporal priority (assuming that there are no other problems). Appealing to the past hypothesis as the boundary condition and the input for the equations of motion will yield a great amount of information, and including it in our laws will not increase their complexity. This, in turn, satisfies the conditions of the best system analysis for lawfulness. However, the appeal of this analysis diminishes with the eternal inflationary picture. It is viable to argue that to use an arbitrary state as the initial condition of a region that includes what will become of our bubble before it starts to expand would yield more information, in contrast to the past hypothesis as the initial condition of our bubble. Presumably, by appealing to such a hypothetical arbitrary initial condition prior to the past hypothesis, it is possible to get more information about the immediate region around our bubble as well as what happens to our bubble. Therefore, this arbitrary initial condition, which could be plausibly stated as simply as the past hypothesis, yields more information, and so it should be the part of the best system of laws rather than the past hypothesis.

It is plausible to assume that Albert could modify his account in the light of eternal inflation with an initial singularity to overcome the above objection. If we chose a macrostate prior to the past hypothesis, we would see that it leads to an additional increase in informativeness. However, akin to the case of pushing back the past state that we have to postulate in order to avoid making faulty retrodictions regarding the ice in the glass, we can chose a macrostate further into the past and achieve further informativeness, repeating this step until we get to the first instant of the inflationary background. This suggests that the most informative “best system” must be the one that includes the initial singularity of the inflationary background as one of its axioms. By

contrast, to arrive at the past hypothesis where we had a balance between simplicity and informativeness (recall that the past hypothesis says that the initial state is a low entropy macrocondition), it is not the case that the initial singularity of the inflationary background can be identified as a low entropy macrocondition. It also has to be a macrocondition that could support a background from which many regions could start expanding in isolation from other regions. Even in this case, if we take the initial singularity as a simple statement, the laws of cosmology pertaining to inflation do the additional work. Thus, one has to include the fundamental laws and mechanism of cosmology in Albert's best system in order to explain the asymmetry of time in our bubble, which again goes against the requirement of simplicity to which Albert adheres.

Consequently, according to this model the earlier states of the universe are more complex than the low entropy condition of the past hypothesis, because in addition to being low entropy macroconditions, they must support the eternal inflation model with initial singularity. Therefore, incorporating the past hypothesis into a system that makes use of best system analysis cannot be justified by appealing to a good balance between simplicity and informativeness. This balance is achieved only by ignoring the cosmology, specifically in relation to the informativeness of the past hypothesis. The past hypothesis appears to be exceedingly informative despite its simplicity. Nevertheless, this increase in explanatory power is a result of appealing to the fundamental laws and mechanisms of cosmology. These laws are implicitly taken into account in calculating the informativeness of the best system, yet they are subsequently ignored in calculating the complexity. Winsberg shows that the problem is not limited to only this example. He argues that there is a systematic inconsistency in calculating the balance of

informativeness and simplicity in Albert's account (Winsberg forthcoming). The example I put forward here has the additional advantage of showing that even if Albert overcomes the systematic inconsistencies that Winsberg points out, the issues arising from cosmology in relation to simplicity and informativeness will require him to add laws of cosmology to the best system. Overall, this example shows that in an eternal inflation model with an initial singularity, the past hypothesis loses its temporal priority (this leads to a failure of addressing objections such as the reversibility objection) and the only way to restore the temporal priority leads to an increase of the complexity of the proposal because it needs to include laws of cosmology. Consequently, both alternatives are detrimental to the plausibility of the central features of Albert's proper remedy.

At this point, one could suggest that the status of the past hypothesis may be different in models with an open past of the inflating background. In connection with the current discussion, this leads to the following question. What is the status of the past hypothesis if the universe had no initial singularity and therefore no initial condition? A further question that needs answering is that if there were no first instant what could be the reason for including the past hypothesis in an account to explain the asymmetry of time?

In "Eternal Inflation, Past and Future", Anthony Aguirre argues that it is possible for a universe that eternally expands toward the future to have an eternal past as well (2007). The difficulty that this model presents for a proponent of the past hypothesis is that one cannot push the past hypothesis to a point into the definite past, which was a plausible move in the Borde and Vilenkin model, where one could push the past hypothesis to the beginning of the first instant of the inflating background. One possible avenue open to the

proponents of the past hypothesis is to claim that the initial condition of concern, the one included as a fundamental law of physics in their theories, is the start of the epoch where the inflation ends and the standard model of the hot Big Bang starts to operate properly within our bubble.

Although in this model there is no initial singularity, there has to be a point where the inflation starts. It might be possible to identify the start of inflation with the initial state to which the past hypothesis refers. In such a case, one has to examine whether the past hypothesis, which once again states that such an initial state is one of low entropy, could deliver an eternally inflating universe. In other words, one has to determine if the simple statement of the past hypothesis is enough to explain eternal inflation.

Let's consider the toy-model Aguirre employs. In this toy-model, the eternal inflation of a region of space starts from a false vacuum. A false vacuum associated with a physical system is "a scalar field in a local minimum of its potential energy function" (Guth 2008, p. 2). There is also a global minimum of this potential energy function, which is located at a lower value than the false vacuum. Furthermore, there is a barrier between the false vacuum and the global minimum that the system normally could not pass. Thus, such a system sits at the local minimum in the absence of any outside influence. What happens according to the inflationary model is the following. In contrast to the classical mechanics in which the system will sit at the false vacuum indefinitely, given quantum mechanics the state of the system might "tunnel through the barrier" (Aguirre, p. 4). Given that some region of the universe in the past might have been in such a false vacuum, we could have an eternally inflating region of the universe. The issue at hand is the question of whether the past hypothesis could explain how a false

vacuum tunnels through the energy barrier. In order to explain inflation properly, we need to have values of several parameters associated with it, such as the values for inflationary potential. It is not clear that the past hypothesis, that only specifies the first instance as a low entropy macrostate, could possibly supply the values required to explain the inflationary mechanism. On the other hand, it is possible to modify the past hypothesis to include, in addition to low entropy, the statements of the necessary parameters required for inflation. That is, when inflation enters into the consideration the past hypothesis could work only if the physical laws that explain the inflation supplement it. Therefore, one must add all these laws to the set of laws they already have to explain how the universe works. In that case, however, the system including the past hypothesis loses its claim to simplicity.

There is another difficulty resulting from the absence of an initial singularity. In the absence of such an initial instant, it may still be possible to defend the past hypothesis on the grounds that it provides some boundary condition to work with. It could be possible to argue that the past hypothesis is the initial instant of our bubble. Even though it is not the initial condition of the universe, it is useful in working with some boundary condition in order to limit how much further into the past that the explanation extends. That is, the past hypothesis is a useful addition to the theory, where it is used as an artificial starting point. In this case, rather than being a fundamental statement about the universe, it becomes a practical theoretical tool from which to start some physical explanation. The question is if the ultimate advantage of the past hypothesis is only a practical one, could the proper remedy would still work properly? The answer is in the negative. Albert needs more than a practical justification for using the past hypothesis

given that he wants to use it as a *fundamental* law of physics. The practical usefulness of a boundary condition cannot be a justification for it to be a fundamental law. Thus, even if there were no initial singularity to an eternal inflation model, this does not help to argue for the metaphysical status of the past hypothesis as a fundamental law.

There is one last possible argument that the proponents of the past hypothesis could advance. They may argue in the following manner. They may say, forget about the inflation and forget that the past of the universe is open as well. What we know is that in our bubble, the inflation ended, and from that particular instant onward the region that is of interest to us kept evolving according to the hot Big Bang theory. Therefore, they might argue, we could take the end of inflation and the beginning of what looks like the hot Big Bang as the instant to which the past hypothesis refers. Given this picture, there is no need to change the past hypothesis, there is no need to increase the complexity, everything works swimmingly as if inflation never happened; thus, there are no fundamental issues in regards to the metaphysical status of the past hypothesis. It is a fundamental law of physics that increases informativeness while the increase in complexity is negligible. This is a plausible argument in defense of the past hypothesis with one caveat. This argument works only if one concedes that the solution it produces is not global and it is applicable only to a specific *branch* of the universe. This, then, collapses into a system that resembles the branch systems proposal that Albert adamantly opposes because he is aiming to give a global solution. Thus, saving the past hypothesis by making it local is not an acceptable solution for a global approach.

The preceding arguments demonstrate that the inflationary models of the universe require additional laws for the initial conditions themselves. This, in turn, requires such a

set of laws to be included in a best system analysis if one wishes to understand the universe that evolves from these initial conditions. This diminishes the plausibility of the claim that the past hypothesis itself is a simple yet extraordinarily powerful statement of the initial condition of the part of the universe in which we happen to live. Moreover, this shows that it is possible to trace the increase in informativeness to the laws of cosmology in addition to the past hypothesis.

Consequently, the selection of the past hypothesis as the axiom to be included in the best system on the grounds of simplicity becomes an ad-hoc move. This is because there are states prior to the past hypothesis that cannot be stated as simply. If we use one of these prior states in our physical theories, we lose simplicity; hence, we look for a state in the very early universe that would not hurt the simplicity quota of the best systems analysis. The criteria for including an axiom fails to encourage the search for one that could explain the physical phenomena, but rather turns the processes of axiom selection into a search for finding a state that looks good in the best system.

Of course, one could avoid these objections by maintaining an archaic account of the Big Bang. However, advances in modern cosmology point to the fallibility of such an approach. As Aguirre puts it, “while studiously ignored by many cosmologists eternal inflation has been a central preoccupation of many of inflation’s inventors from the beginning, and appreciation of its profound implications for cosmology have been spreading as inflation passes more and more observational test” (2007, pp. 2-3). That is, eternal inflation is here to stay. Thus, if we were to make claims about the initial condition of the early universe and, more importantly, use it as a crucial component for

our philosophical systems, we do not have the luxury to ignore modern cosmology and its results.

4.4 Dynamics of Inflation as the Source of Asymmetry

In this final section, I defend the position that inflation—in all different forms that were discussed in the previous section—can supply the source of asymmetry when supported by the aggregate view of laws. Recall that one of the main problems that I identified in the last section was the status of the past hypothesis as a fundamental law of physics. Moreover, the main reason why this is an issue for Albert's proper remedy is that modern cosmology shows that the considerations about the initial condition of the part of the universe that is of interest to us are more complicated than Albert assumes them to be. I will present two approaches to remedy the issues of Albert's proper remedy. First, I will develop a hybrid account in the sense that I will make use of parts of best systems analysis in connection with the aggregate view of laws and apply it to different cosmological scenarios to show I can construct a viable generic account—i.e. it could handle different cosmological models—to explain the asymmetry of time. Second, I will investigate a possible solution that does appeal to the best systems analysis. In doing so, I aim to ensure that a viable solution to the problem of the asymmetry of times does not necessarily depend on whether one subscribes to the best system analysis of laws.

Why start with the best system analysis? What I want to demonstrate is that the shortcoming of Albert's proper remedy does not stem from the particular approach to laws. Rather the problem stems from the fact that he is not taking into account the developments in physics and from his addition of fundamentalist faith to the metaphysics

of laws because the past hypothesis cannot work without it. As an umbrella metaphysical approach I will use the best system analysis and supply it with the aggregate view of laws in order to ensure a global scope without appealing to fundamentalist/imperialist faith about laws. The task is to find the set of statements that will balance simplicity, informativeness, and fit. First, we need to replace the past hypothesis as one of the statements of the best system. By contrast, for the purposes of this discussion it is possible to keep the rest—the equation of motion and statistical postulate.

The role of the past hypothesis in the best system analysis is twofold. It provides the asymmetric input to the time reversal invariant laws of physics to explain the asymmetry of time and it provides a simple initial condition that is supposed to increase the informativeness of the system without disrupting its simplicity. There is no controversy about the former role. As I discussed in chapter two, many physicists—including Einstein, Feynman, and most recently Penrose—considered a similar initial condition to be the source of asymmetry. In contrast, the latter role was the source of the problem as I argued both in this chapter and in Chapter Two. In other words, although it seems viable to use a boundary condition to introduce asymmetry—and possibly the most straightforward way to introduce asymmetry—it is not viable to use the very same initial condition as a fundamental law of physics. This is not because assuming an empirical fact to be a fundamental law of physics leads to metaphysical problems; rather, the way Albert uses it cannot stand up to scrutiny of the results of modern cosmology.

In the light of the arguments from cosmology in Section 4.3.1, I argue that we need to replace the past hypothesis—an empirical fact about the initial state of our part of the universe—with a dynamical statement from inflation that yields initial conditions for

particular inflationary parts of the universe that would undergo inflation. In order to show that a dynamical statement—akin to dynamical statement of the equation of motion—can replace the past hypothesis given that we are operating under the constraints of the best systems analysis, I need to show the following: a) that the dynamical statement for initial conditions are not overly complex, and b) the dynamical statement works physically. Let us start with the latter. In order to show that such a dynamical statement works in conjunction with modern cosmology, we need to examine alternative versions of inflation and see whether they could incorporate a dynamical statement about initial conditions of inflationary patches. In section 4.3.1, I examined three different possibilities—of course, this by no means suggests that these are the only possible explanations for inflation; rather they are the most discussed ones. Here, I will critically reexamine these two alternative accounts of inflation in order to see whether it is viable for them to include such a dynamical statement.

The first alternative is inflation with a past singularity. Of course, the first thing to consider is why not use the initial singularity as akin to the past hypothesis and explain the asymmetry of time and still use the best system analysis without complicating it any further. The problem with this suggestion is that if we use the initial singularity, then we have to pack in more than low entropy as the feature of the initial state because low entropy by itself cannot explain the inflationary process. That is, we have to include many other features to ensure the initial singularity leads to inflation, such as mechanisms ensuring rapid expansion of spacetime, reheating after inflation, etc. This, as I argued previously, detracts from the simplicity claims of the past hypothesis. Thus, replacing the initial singularity will not be a viable solution.

In order to proceed any further, we have to distinguish two possible versions of inflationary mechanism with an initial singularity—an initial singularity leading a single region to inflate—the entirety of the universe—and an initial singularity leading to a background from which different regions inflate separately. In the former scenario, the inflationary mechanism expands the spacetime into one comparatively very large region and later at a specific point inflation stops and the universe continues to evolve in the familiar way. In this case, I see only one viable explanation if we appeal to the best systems analysis. We have to use the initial singularity as a fundamental law but add the laws of cosmology pertaining to the inflation to the best system. Indeed, this best system would be more complex by virtue of its appealing to the past hypothesis, but the best system with past hypothesis is simply physically insufficient. Thus, even though the best system that includes laws of modern cosmology is more complex, it is not only a better fit to the world but also it is the proper fit to the world. In other words, the best system with the laws of cosmology trumps the best system with the past hypothesis because the latter is not a proper fit to the world.

In the other case, where there are causally isolated other inflating regions in addition to our region of the universe, it is possible not to appeal to the initial singularity itself and use only a dynamical statement that generates initial conditions for each inflating region. The solution in this case is somewhat simpler. We construct the best system in the following manner. Again, we keep the statement about the equation of motion but instead of the past hypothesis add a dynamic equation to the best system. This equation—given inflationary features as inputs, such as the properties of the initial singularity, properties of the spacetime where the particular bubble is located, etc.—

would yield the initial condition of the particular bubble. That is, there would be a generic method for identifying the properties of initial conditions of inflating regions of the universe. Moreover, given that our aim is to construct a truly global account of the asymmetry of time, then the addition of this equation would yield a simpler best system from the one that includes all the initial conditions for all the bubbles. Furthermore, adding a dynamical statement does not go against the principles of the best system analysis; after all, the equation of motion itself is also a dynamical statement. After all, the equation of motion is a differential equation that yields output depending on the input. Similarly, the equation for initial conditions of the inflationary bubbles would be a differential equation that produces initial conditions for the bubbles depending on the input. Consequently, this best system—let us call it the inflationary best system as opposed to Albert’s best system—would include two differential equations and the statistical postulate. Presumably, a differential equation is more complex than a statement of an empirical fact, although it is never explicitly discussed in Albert’s project. This means that the inflationary best system that includes two differential equations is more complex compared to Albert’s best system, which includes only one differential equation and one empirical fact. Yet, in this example, the inflationary best system with two differential equations is vastly more informative because it can be employed to explain the asymmetry of time for potentially infinitely many inflationary bubbles, whereas Albert’s best system could explain the asymmetry of time for only one bubble. In other words, although the inflationary best system is little bit more complex, the increase in informativeness is more than sufficient to balance the increase in complexity. Furthermore, as previously discussed, in this case Albert’s best systems with the past

hypothesis would fail to explain the physics as well. That is, in the case of eternal inflation with an initial singularity, a best system that appeals to a dynamical statement for initial conditions and jettisons the past hypothesis would be both physically and metaphysically superior to Albert's proper remedy.

Lastly, let us look at the case of eternal inflation without an initial singularity. The main difference between this scenario and the previous ones is that the proponent of Albert's proper remedy cannot appeal to an initial singularity to update her model. The previously probable alternative explanation by proponents of Albert's proper remedy—using the initial singularity instead of the past hypothesis—is not available here. In the scenario, the past of the universe is open; thus, the only initial condition to which they could appeal is the state of our region immediately after the inflation stops for our region. But, as I argued, this is not a viable solution because it is not the past hypothesis doing the explanation of the asymmetry of time but rather the laws of cosmology. By contrast, the inflationary best system analysis that uses two dynamical equations and the statistical postulate could properly explain the asymmetry of time—in a way that is almost identical to the previous scenario. One of the dynamical equations is again the essential equation of motion. The other one is the equation that produces the initial states of the inflationary bubbles. Again similar to the previous inflationary scenario, although we would have a slightly more complicated best system, it would be vastly more informative—even in the case that both inflationary best system and Albert's best system are physically adequate. Now, I will consider these scenarios without appealing to the best systems analysis to show that their success—the success of using a dynamical equation for the initial conditions—does not depend on the particular account of laws one maintains. In order to

demonstrate this I will use a variation of Winsberg's framework view. Particularly, I will assume that the framework view has a commitment to the global scope of laws similar to the commitment I argued for the aggregate view of laws. This means I maintain that the laws of physics are tools useful for modeling and predicting physical phenomena, provided that no physical phenomena fall outside of the scope of these laws—i.e. the laws are not only applicable very broadly but at any point in spacetime one can find a law to model the physical phenomena at that point.

Suppose that the eternal inflation mechanism is the best option we have to model and predict one particular set of physical phenomena. Could we use the dynamics of initial conditions to explain the asymmetry of time? First, the inflationary mechanism should be one of the mechanisms that have a global scope—even if it is the only one. It cannot have non-global scope. The explanation of the asymmetry of time depends on the working principles of eternal inflations—particularly, the dynamics of initial conditions of inflating regions. If the eternal inflation does not have a global scope, it would be plausible for some other mechanism—outside of the scope of the eternal inflation—be the actual source of the asymmetry of time and we would simply misidentify the correct mechanism. Because of this, the one additional constraint to which I have to appeal is that the scope of eternal inflation is universal. Once again, we are faced with two viable views for eternal inflation—one with no initial singularity and the other with the initial singularity. Let us begin with the initial singularity option. Suppose that all we know about laws is that—as Winsberg wants us to think—they are useful in modeling and predicting physical phenomena. We have no commitments beyond that; i.e. they might or might not be governing the physical phenomena, which is no concern to us. This,

however, does not mean that we do not have any equations. It just means that even though we have equations about physical phenomena, we do not assume that physics is somehow governed by these equations—they are just tools. In this case, we have to alternatives. First, we could appeal to the initial singularity as the source of asymmetry, as it is nothing but a more complicated boundary condition than the past hypothesis. Moreover, given that we are committed to framework view with a universal scope patch applied to it, it plausible to construct the explanation for the asymmetry of time by using the following. We start with the initial singularity, followed by laws of cosmology specifically pertaining to how regions inflate from the background whose initial instant is the singularity, and equations of motion to handle the rest of the time-evolution after inflation ends for our bubble. Although this would be more complex than Albert's explanation for the asymmetry of time, it would be physically sound.

Second, suppose that we do not have modelling tools that pertain to the initial singularity. In that case, we lost one boundary condition that could explain the asymmetry of time. Yet, we still have intermediate boundary conditions that could explain the asymmetry of time—the dynamical equation that produces the initial conditions of regions that start to inflate in isolation. Given such an equation for calculating the properties of the initial conditions—similar to being given an equation for calculating the location of particles—we can now explain the source of asymmetry specific to each bubble. All we have to do is to supply the input to the equation of initial conditions and it would yield the properties of the initial condition of a particular bubble—whether it is low entropy, high entropy, or uniform and isotropic, etc. The rest is similar to the previous case; we have the equation of motion, which again handles the

time-evolution after the inflation stops. In the second example, the explanation that appeals to two dynamic equations would not only be physically sound compared to Albert's proper remedy, but also it would be vastly more informative. Where Albert's proper remedy could explain the asymmetry of time for only one bubble, the explanation that appeals to the modern cosmology could explain the asymmetry of time for any bubble provided that the equation for initial condition yields the properties of the initial condition associated with that bubble. Furthermore, because of the requirement that the laws pertaining to the inflation have to be global, there would be no possible bubble whose initial condition cannot be obtained with the equation of initial conditions. Consequently, we could use the equation of initial conditions to explain the asymmetry of time for any bubble in the inflationary universe, which is why it would be vastly more informative. In any case, the equation of initial conditions paired with the equation of motion—two dynamic equations instead of one dynamic equation and one empirical fact—would be a better explanation of the asymmetry of time in inflation with an initial singularity.

Lastly, we have to examine the situation when we have eternal inflation with eternal past. In this case, we do not have access to an initial singularity because there is no such singularity to begin with. Thus, the first option—using initial singularity to explain the asymmetry of time—is not open to us. The second option—using the dynamic equation for initial conditions—is still a viable option. In fact, this would be almost indistinguishable from the scenario where we have an initial singularity but have no access to it for the purposes of explaining the asymmetry of time. There is no beginning to the universe, yet there is a beginning to the inflation of our bubble and for any other

inflationary region for that matter. In order to explain the asymmetry of time, we have to make use of initial conditions of individual inflationary bubbles as the boundary condition to introduce to asymmetry. Of course, we could use Albert's proper remedy to explain the asymmetry of time for our bubble after inflation ends. However, as I previously showed, such an explanation would be at best incomplete because it explains the asymmetry of time for relatively small region of the universe. Furthermore, it would be an explanation of the asymmetry of time not particularly because of the past hypothesis—the state of our bubble after the inflation—but because the inflationary process led to a specific bubble with a specific state at the beginning of the inflation. In other words, the bulk of the explanation would still depend on the inflationary mechanism.

By contrast, we can provide a generic explanation of the asymmetry of time by explicitly referring to the inflationary mechanism in which we would not need to pick out a particular region of the universe in an ad hoc manner. Once again, the explanation would depend on the equation of initial conditions for inflationary regions. That is, even if there is not an ultimate boundary condition towards the past of the universe, if our worry is to give an explanation of the asymmetry of time for the regions of the universe that undergo rapid expansion due to inflationary mechanism, the initial conditions of such regions could be obtained from a dynamical equation. In addition, the equation of motion would handle the rest of the time-evolution of a particular inflationary region. Therefore, by appealing to two dynamic equations instead of one empirical fact and one dynamic equation we would possess an explanation for the asymmetry of time not only for our bubble but also for any region of the universe that would undergo inflation.

Consequently, assuming that there is some inflationary mechanism we could better explain the source of the asymmetry of time by using the dynamics of inflation. In the case where we maintain a framework view patched with universality requirement from aggregate view of laws, we do not even have to commit to the idea that inflationary laws somehow govern the time evolution. All we have to say is that inflation is proved to be a very useful mechanism in solving a plethora of other cosmological solutions, which also provides us with a better explanation of the asymmetry of time. In other words, there is a better explanation of the asymmetry of time in contrast to the one provided by Albert's proper remedy, which can be constructed by adding the dynamical equation(s) from inflation to the dynamical equation that Albert's proper remedy employs.

There is one potentially crippling counter argument to my solution to use laws of inflation in explaining the asymmetry of time—i.e. what if inflation turns out to be not a good way to model the physical phenomena? What will be the alternative if inflation cannot properly describe the time-evolution of the universe—with its isolated regions, bubbles, and everything else? Although the worry is not farfetched, the current state of cosmological research points to a contrary situation. That is, inflation is here to stay at least as a mechanism to explain the rapid expansion of space, if not as a fundamental law. For example, Sean Carroll and Jennifer Chen developed an account that employs inflation to try to explain the arrow of time (2004). Their aim is slightly different from mine—they want to *explain* the source of the source of asymmetry, i.e. they want to explain where the boundary conditions come from, whereas I want to find an explanation for the asymmetry of time by using those boundary conditions. Carroll further develops that account in *From Eternity to Here* (2010). Carroll's approach includes using a

background space—usually they use a de Sitter space—and this background space gives rise to a baby universe through quantum tunneling and eternal inflation. Once again, their aim is to find an explanation for why the universe had a particular boundary condition. But, in trying to understand the origin and “naturalness” of the boundary condition they also appeal to a “dynamical explanation of the arrow of time” (2004, pp. 5-8). Their project has several technical problems identified by Carroll (2006, 2010) and by Winsberg (2010). This makes the project more of an exploration of a possible solution. Of course, this is an exploratory possible mechanism that can do all the things that Albert’s project achieves, and does not shy away from explaining the initial conditions of the part of the universe in which we happen to be. The idea is that if the speculative dynamical from de Sitter background space to our region of the universe is true, or if we find a mechanism similar to it, here is a ready model explaining all these issues at hand. Although my end goal and approach is slightly different from Carroll’s, the procedure we use to understand the asymmetry of time is similar. Most importantly, the explanation for the asymmetry of time requires the use of dynamical equations that would produce the boundary conditions, which would in turn be the source of the asymmetry, and particularly we should not be appealing to empirical facts about one or more of these initial conditions as the source of asymmetry. Consequently, the explanation of the asymmetry of time is encoded in the laws of modern cosmology.

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