A Conceptual Analysis of Julian Barbour's Time

Maria Kon

Submitted in accordance with the requirements for the degree of
PhD

The University of Leeds

Department of Philosophy

October, 2011

Acknowledgements

Thanks to Steven French for his comments, discussions and patience. And, thanks to Robin Le Poidevin and Mauro Dorato for being examiners and providing highly insightful feedback. Finally, I would like to express my gratitude to K.Diaconu for general discussions, H.Gawad for neurological discussions, T.Kon for fruitful plant propagation information and the From Metaphysics to Ethics *reading group at the University of Nebraska-Lincoln.*

Dedicated to Barbers, with their razors and leeches, or c-space points and best-matching:

Oh, I am a little barber
And I go my merry way
With my razor and my leeches
I can always earn my pay

Though your chin be smooth as satin,
You will need me soon I know
For the Lord protects his barbers,
And He makes the stubble grow.

If I slip when I am shaving you
And cut you to the quick,
You can use me as a doctor
'Cause I also heal the sick.

(Darion and Leigh, *Man of La Mancha*)

Abstract

One of Julian Barbour's main aims is to solve the problem of time that appears in quantum geometrodynamics (QG). QG involves the application of canonical quantization procedure to the Hamiltonian formulation of General Relativity. The problem of time arises because the quantization of the Hamiltonian constraint results in an equation that has no explicit time parameter. Thus, it appears that the resulting equation, as apparently timeless, cannot describe evolution of quantum states. Barbour attempts to resolve the problem by allegedly eliminating time from his interpretation of QG. In order to evaluate the efficacy of his solution, it is necessary to ascertain in what sense time has been eliminated from his theory. I proceed to do so by developing a form of conceptual analysis that is applicable to the concept of time in physical theories and applying this analysis to Barbour's account.

Table of Contents

Preface

The overarching aim of this project is to develop a method by which one can analyse the concept of time as it appears in physical theories. Over the course of this project, I argue that at least for Julian Barbour's account, which is used as a case study, the method of analysis developed here is applicable to time as it appears in this account: it offers an analysis that indicates two ways in which the temporal features of his physical theories may reconciled such that his explicit ontological and metaphysical commitments are maintained.

The motivation for this project's overarching aim is two-fold.

First, there is a general call by, e.g., Butterfield and Isham (1999), for the use of conceptual analysis as a means of merging general relativity and quantum theory. Certain interpretations of these theories offer conflicting concepts of time and space, for example. Thus, it seems that conceptual clean up and development of such interpretations may help point the direction towards a successful merger of the theories.

Second, there has been explicit support for the usefulness of applying conceptual analysis to the particular concepts of time and space that appear in physical theories. For example, DiSalle (2006) champions the reframing of historic debates concerning time and space in scientific theories in terms of concepts.[1] In particular, he argues that the common misunderstanding of Newton as providing inadequate empirical support for time as being absolute can be remedied by modifying Newton's apparent project. Rather than merely assuming metaphysical claims regarding absolute time without justifying them, DiSalle states that Newton should be seen as proposing new theoretical definitions for concepts, such as that of absolute time, within a framework of physical laws. However, though DiSalle illustrates the potential fruitfulness of examining past scientific theories in terms of the defining and defending of concepts, he does not develop or explicitly advocate a systematic means of conceptual analysis for temporal terms.

---

[1] Torretti 2006 provides another example; he argues that we can achieve a better understanding of four historical cases, e.g., the retardation of clocks in special relativity, the problem of time's arrow, through conceptual analysis.

In view of DiSalle's suggestions, I here aim to provide a systematic means of analysing of the concept of time as it appears in physical theories. Additionally, taking aboard the suggestion that such analysis may help merge general relativity and quantum theory into a coherent quantum gravity, I apply my conceptual analysis to the concept of time that appears in Julian Barbour's account of quantum gravity. In effect, his account, as developed up until 2002, serves as a case study to which I apply my conceptual analysis.

I have chosen to use Barbour's account due to his general aim and the allegedly timeless solution he proposes. His aim in part is to solve the problem of time that appears in quantum geometrodynamics (QG). QG involves the application of canonical quantization procedures to the Hamiltonian formulation of general relativity (GR). The problem of time arises because the quantization of the Hamiltonian constraint results in an equation that has no explicit time parameter. Thus, it appears that the resulting equation, as apparently timeless, cannot describe evolution of quantum states.

Barbour attempts to resolve the problem by allegedly eliminating time from his interpretation of QG. In order to evaluate the efficacy of his solution, it is necessary to ascertain in what sense time has been eliminated from his theory. Note that many critics who assess it, e.g., Butterfield (2002), Pooley (2001), Smolin (2001), Dowe (2008), have claimed that Barbour's interpretation is committed to time at some level. However, each of these critics classify Barbour's commitment to time in different ways, e.g., as substantivalist, relationist, A-theorist. Given that each of these classifications of Barbour's theory have plausible arguments supporting them, such disparate diagnoses of time in his theory indicates the general need for examining the methodology behind analysing time in physical theories.

In effect, it seems that Barbour's account would benefit from the application of a systematic conceptual analysis to the concept of time that appears in it. Moreover, due his focus on eliminating time in order to resolve the problem of time in QG, his account makes the role that time may play in it relatively salient. Additionally, his basic ontological and metaphysical commitments are made explicit. This is due to the fact that it is based on Leibnizian and Machian principles. Thus, Barbour's account, which seems to be in need of analysis given the disparate diagnoses of it, offers a case to which we may apply a conceptual analysis of time with explicit ontological commitments as well as a proposed solution of the problem of time in QG that focuses on some sort of timelessness.

I approach my aim of developing a conceptual analysis applicable to the concept of time as it appears in physical theories as follows. In Chapter1, I develop such a conceptual analysis that is somewhat tailored to Barbour's account. To do so, I first present Frank Jackson's conceptual analysis and identify three failings of it if applied to applied to temporal concepts in physical theories. In light of these failings, I develop my alternative account such that these failings are overcome.

In Chapters 2-5, I present Barbour's accounts. In the process, I apply my conceptual analysis' first stage according to which multiple theories must be pounded into a single network, which is assumed to be underpinned by Barbour's principles. Moreover, as will be evident below, the presentation of his accounts requires much elaboration in places, especially with regard to his use of claims made by historical figures and his interpretations of quantum theory (QT) and QG. This is due to the fact that he usually focuses on primary texts and makes his own, and often very quick, interpretations of them that are largely based solely on the primary material. Further, his interpretations of QT and QG are very dense and not as well rehearsed as his GR.

I should also state the manner in which I present his accounts and the rationale behind this approach. I am focusing primarily on Barbour's own texts because I do not want to incorporate ontology or metaphysical commitments that others may read into Barbour's theory when attempting to classify it in terms of standard categories, e.g., substantivalist v. relationist; presentist v. eternalist; A-series v. B-series. Through such focus on Barbour's texts, we can evaluate our analysis' effectiveness without building standard dichotomies into his account. In addition to getting a clearer account of what Barbour's actual claims amount to, such a reading may cause us to re-evaluate these categories as well as their applicability to a certain domain.

Chapter2 presents an overview of Barbour's research and delineates the portion that I am using as a case study. Due to space restriction, I cannot present and analyse his account in its entirety. Thus, this chapter gives my rationale for focusing on a particular stage of its development. Additionally, this chapter provides the Leibnizian and Machian principles on which he bases his account. Finally, his nonrelativistic account is presented in this chapter because its structure mirrors that proposed for his GR. Chapter3 provides his GR and assesses whether it fulfils his principles. In Chapter4, I present an overview of approaches to quantum gravity as well as the problem of time that appear in canonical quantum gravity because he formulates his QT with the specific aim of resolving this problem. Then, I present, unpack and develop his QT, such that his principles are fulfilled. Chapter5 provides and develops his QG such that it is also in accord with his principles and makes clear the manner in which it resolves the problem of time.

In Chapter6, I apply the remaining stages of my analysis to Barbour's accounts. While this application does not result in a single concept of time that appears in his accounts, it does offer two options for further developing his account such that two single yet differing concepts of time are obtained. Lastly, Chapter7 provides a general discussion of the results of our Barbouric case study for my conceptual analysis concerning its development as well as its applicability to non-Barbouric accounts.

Chapter 1: Conceptual Analyses and the Concept of Time in Physical Theories

In this chapter, I examine some methods of analysis and evaluate their applicability to time. In effect, the specific purpose of this meta-analysis of analyses is to legitimate and develop a means of examining time as it appears in Barbour's interpretation. Such examination, in turn, will allow me to evaluate the disparate categorizations of time in his interpretation and will inform my evaluation of the efficacy of Barbour's solution to the problem of time. Thus, the present chapter, while aiming to specify a means of analysis appropriate for Barbour's interpretation, is general in that it surveys some methods of analysis and evaluates their applicability to time in other physical theories in an attempt to expose the analyses' limitations, reveal what modifications are needed for a satisfactory analysis and to develop an initial, working account of such an analysis. Moreover, it must be noted that this alternative analysis will be further developed via its application to Barbour's account and discussed in Chapter7; the present chapter serves as a means of delineating and initially systematizing the facets that an analysis of time in physical theories requires in view of the problems with existent analyses.

This chapter's evaluation of temporal analyses for physical theories focuses on conceptual analyses. Taking aboard DiSalle's (2006a) (2006b) suggestion that our understanding of time as it appears in scientific theories would benefit from reframing temporal questions in terms of conceptual analysis, I structure my meta-analysis in terms of modern conceptual analysis and develop a means of analysing the temporal concepts that appear in physical theories.

To do so, I look at a prominent example of conceptual analysis. While I do not provide a general survey of the debates concerning its plausibility, my criticisms of it focus on its suitability for analysing time across different scientific theories. Ascertaining such suitability is required in order to provide a productive means of evaluating time in Barbour's renditions of two specific theories, namely general relativity (GR) and quantum theory (QT). Furthermore, I limit my meta-analysis to the use of the term 'time' in existent temporal analyses which involve recourse to physical theories. Though I must include our folk use of 'time' since it is part of Barbour's aim to explain such usage with reference to his physical interpretation, *purely* linguistic, metaphorical and phenomenological uses of 'time' are beyond the scope of this work. Lastly, note that when referring to a concept, I henceforth put it in italics, e.g., the concept of time is denoted as ‘*time*’.

In order to develop a conceptual analysis suited for *time*, my meta-analysis is organized into three sections.

The first section provides a number of introductory points regarding my approach to concepts. The remaining two sections present and examine a different conceptual analysis. However, each of these conceptual analyses is a variant of “network” conceptual analysis, i.e., the general proposal that a concept is to be analysed in terms of the role it plays in a network of principles that underpin some theory. In addition to its current prominence, I provide some rationale for limiting my discussion to network conceptual analyses at the end of §1.

The second section presents and examines a form of network conceptual analysis that has been described as “perhaps the most explicit and detailed account [of conceptual analysis] available” (Laurence and Margolis 2003, 254): Frank Jackson’s (1998) conceptual analysis (JCA).[2] While most of his framework appears straightforwardly applicable to features of *time* that appear in certain temporal debates, e.g., *the present*, *A-theory flow*, the allegedly *a priori* status of his concepts and the referents of such concepts severely limit the scope of its applicability. The problems associated with the *a priori* restrict Jackson’s conceptual analysis to *time* that is known *a priori*. Further, the presupposition that a concept must, at some level, have a property or object referent limits this analysis to *time* that has certain metaphysics and ontology and, thus, excludes, e.g., time as purely geometrical.

Jackson’s view is also shown to suffer from assuming that we can just read our metaphysics and ontology off our best scientific theory. I term such practice ‘naïve metaphysical and ontological realism’. Further, I illustrate that this practice is problematic

---

[2] One may think that since my goal is to find some conceptual analysis applicable to scientific theories, Jackson’s conceptual analysis, as focusing on folk concepts, is an inappropriate place to start. However, because his analysis is one of the most developed regarding folk theory and since, as is later argued, the analysis applied to folk theory may be, with some modification, applied to scientific theories, Jackson’s conceptual analysis naturally offers the first step in our enquiry.

since it risks ignoring alternative metaphysics and ontologies that may be associated with the theory. Additionally, this practice appears to lack a schematized means of obtaining its metaphysics and ontology. Moreover, the problems of naïve realism suggest that a conceptual analysis of scientific concepts is needed.

The third section consists of the development of an alternative conceptual analysis that overcomes JCA's problems and that is applicable to *time* in Barbour's view. To do so, I first develop a folk analysis that addresses JCA's problematic focus on *a priori* concepts that are supposed to have referents. Since Miscevic offers some apparatuses to deal with such problems, I use them to obtain a working analysis of folk concepts. Then, I initially use this Miscevic-driven conceptual analysis as a model for the analysis of concepts in physical theories. However, this model has three central problems.

First, it suffers from the problem of identifying concepts without relying on naïve metaphysical and ontological realism regarding scientific theories.

Second, since it gives no explicit way in which one should incorporate more than one theory into one's analysis, it may give rise to concepts that are limited to a single theory. This is exemplified by Esfeld's discussion of *directionality* in QT and special relativity (SR). From the apparent clash of *time* as defined by QT with that of SR, I argue that this form of analysis potentially limits *time* to a particular theory. Such a limitation will be problematic for our later examination of *time* in more than one theory, namely in Barbour's GR and QT. Because, as we shall see, his account of GR is not explicitly intertwined with the interpretations he gives for QT and QG, we must do some work in evaluating whether these separate accounts are able to be unified on a conceptual level in the manner he suggests they are.

Third, the application of Miscevic's conceptual analysis to only scientific concepts creates a gap between our commonsense concepts and the scientific concepts. I use *time*'s feature of *directionality*, which highlights this problem since it gives rise to a gap created between *time* as defined by experience and the *time* of SR. Further, I argue that this gap needs to be bridged since Barbour's view includes an explanation of our everyday *time*.

After laying out three desiderata, which result from the three problems with our application of Miscevic's analysis to physical theories, I proceed to develop an alternative network analysis that has the desiderata.

The alternative overcomes the problem of concept identification through initially picking out features of the theories involved that seem to be temporal. However, rather than stopping there, we examine our list of temporal features, determine whether they clash or are apparently redundant with other features on the list and with apparently non-temporal features. Thereby, we add in the ability to modify our list of temporal features. Such modification allows us to stave off the problem of naïve metaphysical and ontological realism. Furthermore, we assume that the theories under consideration, both folk and scientific[3], are parts of a single network. With this setup, we can have interplay between the theories. This interplay can be developed via the process of analysis and offers a means of bridging the gap between commonsense, folk concepts and scientific concepts. Additionally, by considering these theories as forming a single network, the analysis can accommodate any number of theories by adding them to the network.

Thus, as fulfilling the desideratum and overcoming the problems of JCA, this alternative analysis is shown to provide a means of analysing *time* in Barbour's view.

1 Preliminary Remarks on Concepts

Before presenting the conceptual analyses, a number of preliminary points regarding concepts are required.

First, since I am examining the use of the term 'time', I am focusing on analyses that examine lexical concepts, i.e., concepts like *bachelor, hall* and *town hall* that correspond to lexical items in natural languages. Admittedly, 'lexical item' is rather vague; however,

---

[3] While such a distinction may not be as clear cut in practice, I here mirror Jackson as well as the literature on conceptual analysis generally in making such a distinction. Moreover, it does provide a useful means of referring to theories that focus on concepts that we gain and develop in view of our day-to-day experience, e.g., *belief, knowledge, reference,* and distinguishing them from theories that are less concerned with accounting for such concepts.

adopting Laurence and Margolis' (1999) usage, such lexical items are usually single morphemes that can be phrases, e.g., being a vehicle, or a single word, e.g., vehicular.

Second, I am bracketing the question of the ontological status of concepts; though some identify concepts with abstracta and others with particular mental representations, I do not take a stand on this issue. However, I follow Jackson's identification of concepts with the meanings of terms.[4]

Third, I am assuming that certain concepts are complex. The concepts that lack such complexity are called 'primitive' or 'atomic'. A complex concept is composed of a set of features, and I assume that these features just are concepts.[5]

Fourth, the manner in which the features compose a complex concept depends upon the structure one adopts for concepts. For example, a dual theorist holds that a complex concept, say, *car* necessarily has the core, essential features of *having wheels, being a vehicle* and *used for transport* which is accompanied by other features, like *being a coupe*, that an occurrence of the concept is likely, rather than necessarily, to have. While there are allegedly a number of different kinds of concept structure, e.g., classical theory, dual theory, prototype theory, I here focus on network theory, which, Jackson claims, is informed by theory theory.

Theory theory is the view that concepts form a web in which they are inter-related, and a concept's structure consists in its relations to other concepts as specified by a mental theory. The theory theory structure of concepts is derived in view of the interconnections among concepts in a scientific theory.

---

[4] Nevertheless, some advocates of concepts qua abstracta hold that concepts are just senses, e.g., Peacocke 2005. However, I do not believe that my equation of concepts with meaning presupposes the abstracta view since it seems to be a further question as to whether such meanings are cashed out in terms of particular mental representations or in terms of abstract objects. Margolis and Laurence 2007, who argue against the rationale behind the equation of sense with abstracta and formulate a view in which senses correspond to mental representations, provide some support for my claim.

[5] This division between primitive and complex concepts follows that of Margolis and Laurence 1999. Furthermore, I follow Margolis and Laurence's 1999 use of 'feature'. While they note that 'feature' is sometimes used to denote some primitive sensory concept, e.g., *red*, they adopt the concept component use since, they claim, this is the prevalent usage.

'Network theory' is coined by Jackson (1994, 102-7) in his characterization of his particular use of the Lewis-Ramsey-Carnap theory of reference of theoretical terms. He uses this theory of reference to put the theory-theory-structured concepts of folk theories in propositions. So, just as, according to some accounts, e.g., Lewis (1970), the meaning of a theoretical term is determined by its role in a scientific theory, the structure of a concept is determined by its role in a theory. This role can then be put in terms of a definite description, and the referent of this concept is whatever satisfies the description.[6]

Jackson applies this setup explicitly to folk theory. Thus, folk theory is considered to be a network of interlocking concepts, and it is by spelling out this network that one discovers the content of one's folk concepts. However, while Jackson limits the scope of network analysis to folk concepts, I use 'network analysis' below in a more general sense: analyses in which a concept is examined in terms of the role it plays in a network of principles that constitutes some theory(s), regardless of whether such theories are folk or non-folk.

Fifth, one may object that my focus on theory theory structured concepts omits discussion regarding alternative concept structures that may possibly be better applicable to our target concepts, i.e., temporal concepts. In reply, since I am looking for a conceptual analysis that incorporates scientific theories, theory theory seems the obvious choice since it is modelled after scientific theories. In effect, it will be easier to combine some theory-theory-type analysis of our folk concepts of time with a similar treatment of time in scientific theories. The reason for wanting such a combination will later be evident in view of a problem suggested by Esfeld and the need to include our experienced, commonsense *time* in our analysis of *time* in scientific theories.

Further, theory theory's metaphysics brings on certain problems associated with its concepts' structures. For example, the concepts in theory theory, as usually lacking some core, defining feature, face the problem of how one should identify them. Since I am explicitly using theory theory structured concepts, I do raise and address this pressing

[6] Although there are problems with this approach to terms in scientific theories, I do not address them here: see Papineau 1996 for discussion.

problem of concept identification in §3.2.1. So, standard issues regarding concept structure are not completely ignored and do inform the development of my alternative conceptual analysis.

2 Jackson's Conceptual Analysis

As Jackson (1998, 130) eventually frames his 1998 analysis in terms of network analysis, I am reading Jackson's own conceptual analysis (JCA) as a form of network analysis. I note this at the outset since Jackson's analysis of *water*, the main example I use below, does not explicitly incorporate network analysis. However, his subsequent analyses of *colour* and *ethics* do make recourse to network analysis explicitly. So, in my presentation of Jackson's *water* example, I have supplemented it with considerations from the network analysis in a fashion that parallels his presentations of *colour* and *ethics*.

JCA is introduced as the required means of solving the location problem, i.e., the problem of showing the manner in which any given phenomenon can be reconciled with one's lower-level ontology. In other words, this is the problem of, so to speak, locating a place for some entity in one's worldview given one's ontological commitments. The resolution of this problem is needed, Jackson argues, for doing serious metaphysics.

'Serious metaphysics' refers to metaphysics, i.e., the field that concerns what there is and what it is like, that seeks a comprehensive account of some topic in terms of a limited number of ingredients and that investigates where these limits should be set. Jackson uses physicalism as his primary example of serious metaphysics. Physicalism attempts to give a complete account of the world with only physical properties. Due to serious metaphysics' limited ingredients, certain upper-level phenomena will not explicitly appear in one's more fundamental, lower-level account. For example, some higher-level psychological claims may not in appear one's physicalist description of the world. It is from the apparent juxtaposition of upper-level phenomena with one's sparse lower-level account that the location problem arises; from the lack of apparent correspondence between psychological claims with a physicalist description, there arises the problem of showing how psychological claims are to be reconciled with one's physicalist description of the world.

According to Jackson, the relation between true upper-level claims about the world and lower-level descriptions is one of entailment; the truth of upper-level claims is entailed by lower-level descriptions. Thus, in order to show that a particular claim about the world is acceptable, one must show that it is entailed by the lower-level description. However, if such entailment is lacking, then one must be an eliminitivist regarding the upper-level phenomena. (Jackson 1998, 4-5, 41-2)

To assess the relation between claims and lower-level descriptions and, in effect, to solve the location problem, Jackson argues that conceptual analysis is required. Since I am more concerned with JCA itself, I will not here present or defend Jackson's argument for JCA as *the* required means of solving this problem; however, see Stalnaker (2001) for criticism of this argument.

Jackson claims that the first step towards solving the location problem is to find out what exactly counts as the referents of the upper-level and lower-level terms. In order to determine the scope of these terms, one must make recourse to concepts, e.g., to determine what counts as water, one must examine *water* through conceptual analysis. Moreover, unlike, e.g., the conceptual analysis of Bealer (1996) that only applies to philosophical concepts like *truth* and *knowledge*, Jackson's conceptual analysis is supposed to apply to at least all commonsense concepts.[7]

The form of conceptual analysis that Jackson advocates involves examining our armchair intuitions to determine what users of a language mean by a term. Because concepts just are terms' meanings, this practice establishes and refines our concepts. As a form of network analysis, JCA is committed to these meanings being identical with the role a concept

---

[7] While Miscevic 2001 limits JCA's range to all common sense concepts, Laurence and Margolis 2003 state that JCA is supposed to apply to just about any concept, including *proton* and *molybdenum*. While Jackson 1998 provides no such examples or explicit claims to the effect that JCA applies to the wider range of concepts, he (1998, 46-7) does briefly mention the possibility of restricting the domain of the folk to the set of scientists: if our audience should happen to be, say, theoretical physicists, and our subject happened to be phrased in terms local to theoretical physics, it would be the intuitions and stipulations of this special subset of the folk that would hold centre stage. Yet, though this is introduced as a proviso for how one can better address the concerns of one's audience, he does not pursue this line further. With such specialized domains of folk, the alleged scope of JCA may be broadened to include the concepts Laurence and Margolis mentioned. However, I will not pursue the implications of the application of JCA to such concepts since, as I argue below, JCA does not even work for Jackson's exemplified common sense concepts.

plays in our folk theory. So, these armchair intuitions must serve to reveal the role played by our concept in our folk theory.

JCA employs intuitions to do so as follows. In network analysis, a concept is the role it plays in a theory. So, to determine what these concepts are, one must first establish our folk theory. Jackson claims that appealing to our intuitions about possible cases, e.g., our intuitions about Twin Earth, reveals our folk theory about, e.g., *water*. He reasons that each individual's intuitions about such cases reveal one's theory regarding the concept. For example, what guides an individual in describing a substance as water is revealed by the individual's intuitions regarding whether certain substances in possible cases are water. Furthermore, the extent to which the intuitions of individuals coincide reveals our shared folk theory and, in effect, the role of a concept in the folk theory. These roles can then be put into a definite description that is indicative of some of the properties that a referent of the concept must have. Jackson notes that while it is not necessary that a referent of, say, *water* have all the properties specified, it must have at least some of them. For example, the role that water plays in our folk theory that involves *water* can be stated as the following definite description: the stuff that fills lakes, falls from the sky, is colourless, is odourless, etc., or which satisfies enough of the foregoing. Thus, the role of intuitions about possible cases is to make explicit our implicit folk concept, to reveal what role in a theory constitutes *water* and, in effect, to show which properties are central to something being correctly described as water.

Furthermore, Jackson links intuitions with *a priori* knowledge. Since Jackson does not provide a clear definition of *a priori*, I adopt the following definition of *a priori* knowledge:

> (K) S knows *a priori* that p iff S's belief that p is justified *a priori* and the other conditions on knowledge are satisfied, and
>
> (J) S's belief that p is justified *a priori* iff S's belief that p is nonexperientially justified, i.e., justified by some nonexperiential source.[8]

---

[8] This is Casullo's 2003 definition. See Casullo 2003 for defence of it against alternative specifications of the standard Kantian definition, which involves an unspecified notion of dependence. I am using this definition

A motivation, which Jackson (1993) advocates, for the link to the *a priori* is due to the presupposition that *a priority* is the hallmark of conceptual analysis. The nonexperiential justification that Jackson uses in JCA is obtained solely from the armchair and, thus, does not involve going out into the world to obtain empirical data.[9] Thus, in maintaining the *a priority* of conceptual analysis, Jackson can better carve out a niche for philosophical analysis that is neatly separated from empirical work via its strictly armchair method of enquiry, which allegedly allows one to derive substantial *a priori* truths. However, as is argued below in §2.2.1, this combination of acquiring substantial truths through JCA's armchair analysis and of maintaining the *a priori* status of these truths is problematic.

---

because Casullo has convincing arguments against proposed alternatives for (J) and since, as using a feature of experience that both rationalists and empiricists hold, namely experiential justification, its coherency does not require me to take a position in this debate.

However, Chalmers and Jackson 2001 offer some definition of *a priori* knowledge, i.e., knowledge that is possible to have with justification independent of experience. Save for the presence of 'possible', this definition parallels the traditional Kantian definition (Casullo 2006): (K) and (KJ) S's belief that p is justified *a priori* iff S's justification for the belief that p does not depend upon experience.

I have not incorporated 'possible' in the above definition of '*a priori*' because it is not explained by Chalmers and Jackson and may merely work in capturing the sufficient condition Jackson suggests, i.e., being known independently of which world is actual. I will elaborate a bit on this condition in what follows. Moreover, a straightforward way of incorporating 'possible' into their definition is problematic. Suppose that one adds 'possible' to the traditional Kantian definition of '*a priori* justification', i.e., S's belief that p is justified *a priori* iff *it is possible that* S's justification for the belief that p does not depend on experience. Using Tidman's 1996 modification of Plantinga's example, it is possible that there is an invisible pink elephant in the room emitting radiation which invokes certain *a priori* knowledge. Given such possible sources of *a priori* justification and their lack of connection with truth, Jackson would not likely incorporate 'possible' with his a definition of *a priori* justification. So, I merely assume that 'possible' is supposed to capture Jackson's sufficient condition and have opted for Casullo's general definition of *a priori* here.

[9] I am assuming that empirical justification is a type of experiential justification. This assumption is not without precedence; see, e.g., Henderson and Horgan 2001. Further, while I acknowledge that there may be problems with this assumption because I have not specified what counts as experiential, I do not here offer such a specification because of Casullo's 2003 argument to the conclusion that, at least in the standard epistemic debates, there is no unproblematic way of demarcating the experiential from the nonexperiential.

Jackson forges this link between intuitions and *a priori* knowledge as follows. He reasons that the best explanation of our ability to evaluate possible cases is that competent speakers have implicit *a priori* knowledge of the conditions required for a concept to refer. Our evaluation of possible cases makes these implicit *a priori* conditions explicit via giving rise to certain shared intuitions. In effect, Jackson legitimizes and explains our shared intuitions by claiming that they have an *a priori* source.[10]

In what sense are the conditions of reference known *a priori*? Jackson (1998, 51) provides a sufficient condition for the *a priori*: that which we know independently of the actual world. So, to have *a priori* knowledge of the conditions required for a concept to refer, the conditions can be known without recourse to the actual world. This world-independent criterion is supposed to be *a priori* in the sense of being knowable from the armchair alone. Consider the following claim: Water is the watery stuff of our acquaintance. According to Jackson, the following claim is knowable *a priori* in this sense because one does not need to make recourse to the empirical features, e.g., being H_2O, that distinguish the actual world from the possible ones. To make this clearer, consider the claim: 'I' refers to the speaker.[11] This claim is *a priori* knowable since one needs not make recourse to empirical facts, e.g., ascertaining who the speaker actually is, to know that the claim is true. Likewise, one does not need to consult empirical facts about what the watery stuff of our acquaintance actually is in order to know the claim. Thus, Jackson's *a priori* can seem to be legitimately termed since such statements are allegedly knowable from minimal semantic competence alone, rather than being dependant on particular empirical features of the world.

Moreover, regarding (J), the armchair means of gaining *a priori* knowledge that fulfils this sufficient condition highlights JCA's heavy reliance on armchair reflection as its source of allegedly nonexperiential justification; by considering possible worlds from the armchair,

---

[10] While I do not here discuss this inference to the best explanation rationale for linking intuitions with the *a priori*, see Dowell 2008 for criticism.

[11] This parallel example is drawn from Laurence and Margolis 1999.

we can come up with a certain subset of propositions that are known *a priori*, i.e., propositions known independent of which world is actual.[12]

To summarize JCA's first step towards solving the location problem: one's intuitions, which are indicative of *a priori* conditions required for a concept to refer, are consulted to determine the folk theory involving a concept. From the role it plays in the folk theory, a concept can be given a definite description. This description is indicative of a set of properties, the majority of which must be had by a particular thing in order for that thing to count as a referent of the concept. In this fashion, one establishes what counts as the referents of the upper-level concept in a token of the location problem.

After establishing the content of the concept in question, one can proceed to the second step towards solving the location problem. The second step involves one making recourse to empirical claims to determine whether statements involving the concept are entailed by such claims. Here is an example from Jackson (1998, 81-82) of such entailment regarding the statement that water covers most of the Earth.

(P1) H_2O covers most of the Earth.

(P2) H_2O is the watery stuff of our acquaintance.

(P3) Water is the watery stuff of our acquaintance.

(C1) So, water is H_2O.

(C2) So, water covers most of the Earth.

(P1) is a premise that is a partial physical description of the world and assumable provided that one accepts physicalism. (P2) is an empirically established claim; one must empirically investigate what the actual watery stuff of our acquaintance is in order to know (P2). (P3) is known *a priori* as a result of JCA's first step. Furthermore, (P2) establishes to what *water* refers in our world given (P3)'s condition as to what counts as water. With the resulting

---

[12] Though this subset of necessary truths may suggest the need to explore the link between knowledge and modalities, I do not address such issues here. See Casullo (2003, Ch7) for discussion of the relations between necessity and the *a priori*.

(C1)'s identification of water with H_2O, (C2) follows given (P1). Thus, (C2) is entailed by our lower-level descriptions of the world in conjunction with our intuitive *water*. In this fashion, one can use JCA to determine whether some higher-level descriptions can be reconciled with one's lower-level ontology and, thereby, to solve the location problem.

What one does with the result of such enquiry depends upon the role one gives to conceptual analysis. Jackson states that conceptual analysis can have one of two roles: a modest role or an immodest role. Suppose that a folk concept is not entailed by one's lower-level description. In this case, modest conceptual analysis would merely point out the incompatibility. Immodest conceptual analysis, on the other hand, would, in addition to citing the incompatibility, reject the lower-level description. (Jackson 1998, 42-4)

Jackson (1998, 43) explicitly advocates modest conceptual analysis because, he claims, immodest conceptual analysis gives such intuitions too big a role in determining what the fundamental nature of the world is. Nevertheless, despite Jackson's apparent allegiance to the claim that conceptual analysis can only have either a modest role or an immodest role, there is at least one[13] more-than-modest role that conceptual analysis may have: if a folk

[13] There may be two other more-than-modest roles, depending upon one's theory of concept identity. First, one may modify the folk concept in view of the lower-level description with the aim of making the modified folk concept entailed by the lower-level description. Second, one may modify one's lower-level description in a fashion that allows the folk concept to be entailed. This option is suggested by Laurence and Magnolis. They exemplify this suggestion by stating that one's conceptual analysis may result in one modifying the set of primitives in order to account for the folk concept. However, the modification involved in these alternatives does not seem accommodatable in JCA alone. The first is problematic since the folk concepts of competent speakers are *a priori*. As such, they seem immune to modification in light of conflicting with a lower-level description. If Jackson assumes a characterization of the *a priori*, e.g., that of Putnam 1983, as being immune to all refutation or if he follows suit of, e.g., Kitcher 1983 who hold that the *a priori* is characterized as immune to experiential defeaters, then such *a priori* concepts cannot be modified in view of at least empirical findings. See Rey (2004, 9-10) for further discussion. The second option is beyond the scope of JCA. JCA does not deal with determining and defining one's fundamental ontology. Rather, it clarifies one's folk concepts and determines whether such concepts are entailed by the fundamental ontology. To be compatible with this option, JCA would require some means of modifying concepts in response to incongruities. Moreover, one may not regard such options as viable since one may have a stringent view of concept identity, e.g., modification of a certain property that the referent of a concept is supposed to have leads to a different concept. Nevertheless, because I am more interested in an analysis' ability to take into account empirical data, which may manifest

concept is not entailed by a lower-level description, one may eliminate the folk concept. Stalnaker (2001) highlights this as the only alternative to modest and immodest to which Jackson alludes. Jackson implicitly endorses this alternative with his claim that one should eliminate folk concepts that are not entailed by the lower-level description, as cited earlier. Call this alternative 'immodest folk eliminativism'.

Jackson's adherence to immodest folk eliminativism is further supported by his assumption that all concepts have referents that are actual physical properties or objects, e.g., water, colour. This assumption is widespread in current literature on concepts due in part to its focus on concepts that have referents that exist in the world.[14] In view of at least his major examples of *solidity*, *water*, *colour* and *ethical properties*[15], Jackson follows suit by focusing on concepts that have existent referents at some level.[16] Further, given this assumption, a concept must have a referent that is a physical property or object in order to be a legitimate concept. In effect, this assumption can be seen as an impetus for Jackson's practice of immodest folk eliminativism, which allows him to reject concepts which do not have such corresponding referents.

---

itself through the elimination of certain concepts or modification of concepts that conflict with the physical theory, and since I do not have room to discuss the implications of concept identity here, I bracket these issues.

[14] Fodor (1998, 165), for example, makes this assumption explicit for at least all primitive concepts when he claims that there can be no primitive concept without there being a corresponding physical property. See Rey 2004 for further support of the wide scope of this assumption.

[15] Since Jackson advocates a form of moral naturalism, according to which ethical properties just are physical properties, e.g., the action that is the right thing to do just is the action that is apt to produce the most overall pleasure, ethical concepts are supposed to have a physical property as a referent.

[16] Jackson's (1998, 8) use of physicalism appears to be the primary explicit reason he makes this assumption; he states that he is focusing on physical properties and relations, while setting aside mathematical properties, e.g., being a set, since their status in physicalism is debatable. Another reason he may make the assumption is because of his use of the causal descriptive theory of reference. However, such rationale is irrelevant for my later criticism of his inclusion of this assumption since, I argue, that the assumption itself is limiting if JCA is applied to *time* because *time* or its features may not have physically existing referents. Thus, I do not here explain or object to the rationale behind this assumption.

Thus, due to Jackson's implicit endorsement of immodest folk eliminativism, I here assume that JCA is to play a role in which entailed folk concepts are considered to be supported and unentailed concepts are eliminated.

To sum up, in JCA one first provides *a priori* sourced concepts via the assessment of one's intuitions regarding possible cases. Then, one uses these concepts in conjunction with lower-level claims in order to assess whether claims involving one's higher-level concepts are entailed by one's lower-level ontology. If there is such entailment, then the higher-level concept is given some support. However, if there is no such entailment, then the higher-level concept is to be eliminated. Note that to simplify this discussion slightly and to make it relevant to our analysis of concepts that appear in physical theories, I henceforth only deal with cases in which the lower-level descriptions and ontology are those associated with a physical theory.

2.1 Application of JCA to a Temporal Example

Now that I have presented JCA, we are in a position to apply JCA to a specific temporal concept. For the purpose of simplicity in this example, I am assuming that *the present* is the only feature constitutive of our folk *time*.

The first step of JCA is to specify the properties required by *time*'s referent. To do so, we examine our folk theory and figure out what role *time* plays in it. Suppose that after engaging in armchair reflection upon our reactions to possible cases, we come up with a folk theory regarding *time* that is indicated by the following:

> People commonly believe that the present is an objective feature of the world. They talk, think and behave as if there were a global now shared by all, and they talk, think and behave in a manner different from the way they do about what is here. (Callender forthcoming)

We know *a priori* that time is the timey stuff of our acquaintance.[17] From this folk theory, we derive the following specification of this role:

---

[17] If 'timey stuff of our acquaintance' seems to be an odd way to talk about time, then it can easily be translated into something more palatable. Given JCA's network analysis, the content of *water* or *time* is supposed to be

(Rt) Time is an objective feature of the world, is a global now shared by all and is different from here.

In accord with JCA, (Rt) is indicative of a set of properties, the majority of which must be had by something in order for that thing to be the referent of *time*.

Now that we have our results from JCA's first step, we can move to its second step. In the second step, we make recourse to empirical claims to determine whether such claims entail *time*. An example that is parallel to the earlier *water* example can be constructed for identifying our folk *time* with the *time* of some neo-Lorentzian interpretation of SR, which involves a preferred reference frame and absolute simultaneity [18]. I denote this *time* as '*L-time*'. To make the parallel more apparent, I do not use '*L-time*' in the argument; just as the *water* example uses 'H_2O', which can be regarded as a description of a chemical compound, the following example involving *time* uses the description 'something that is characterized by a preferred reference frame and absolute simultaneity'. Moreover, I am not presenting a parallel to the entire *water* argument above, rather I am omitting a parallel to (P1) and (C2) above to make the ensuing discussion less complex.

(Pt2) Something that is characterized by a preferred reference frame and absolute simultaneity is the timey stuff of our acquaintance.

(Pt3) Time is the timey stuff of our acquaintance.

(Ct) So, something that is characterized by a preferred reference frame and absolute simultaneity is time.

Assuming for the sake of this example that there are empirical reasons to favour the neo-Lorentzian interpretation, (Pt2) is an empirically established claim. Since I am only using

---

filled out by determining what plays the water role or time role at each world. So, such timey stuff can be translated into: whatever plays the time role in our world. Moreover, I have used 'timey stuff' above to make the parallel with Jackson's explicit example more apparent. However, some commentators, e.g., Miscevic 2001, do use the translated version for *water*.

[18] Craig 2001 is advocates this interpretation to defend presentism. However, this is a nonstandard view of SR: see Wüthrich 2010 for discussion.

this interpretation in order to mirror the *water* argument in which a folk concept is identified with something, I do not argue for the legitimacy of the interpretation.[19] (Pt3) is known *a priori* as a result of the previous step. Moreover, (Pt2) establishes to what *time* refers in our world given the conditions as to what counts as water according to our folk theory, as laid out in (Rt). Since the preferred reference frame and absolute simultaneity of *L-time* can provide us with folk *time*'s objective, global now that is shared by all, we can conclude by identifying *L-time* with our folk time.

Furthermore, suppose that we consider the *time* of the Einsteinian interpretation of SR (E-SR), which lacks a preferred reference frame and absolute simultaneity. The time of (Pt3) is specified by (Rt). If we assume, for the sake of this example, that E-SR's lack of a preferred reference frame prohibits time from being an objective feature of the world and that its lack of absolute simultaneity entails that there is no global now that can be shared by all, then there is no feature of the world that is picked out by our folk *time*. Thus, there is no identity between *time* and E-SR's *time*. Moreover, according to JCA, since nothing corresponds to our folk *time* given the truth of E-SR, this folk *time* must be eliminated.

In effect, JCA seems as applicable to *water* as to at least this version of folk *time*. However, JCA faces several problems.

2.2 The *A Priori* and Referent Problems for Temporal Concepts

There are two major problems with JCA in regard to its application to temporal concepts. The first concerns JCA's focus on the *a priori*, and the second deals with the standard referents of the concepts that are used in JCA. Below, I present each of the problems, apply them to our temporal example and state their ramifications for an analysis of *time* in scientific theories.

2.2.1 JCA and the *A Priori*

The *a priori*, as explained above, plays a key role in Jackson's development and legitimization of conceptual analysis. He wants JCA to combine *a priority* and informativeness, i.e., substantial content, in a fashion that gets at substantial truths through

---

[19] See Balashov and Janssen 2000 for criticism of Craig's arguments for this interpretation.

armchair analysis and that, as an *a priori* enquiry, is demarcated from empirical enquiries. In my exposition of JCA, following Jackson, I glossed over specifying which claims are supposed to be known *a priori*. However, Miscevic (2001) argues that once this gloss is spelled out, the application of JCA to empirical matters results in claims that are either informative yet known *a posteriori* or are known *a priori* yet non-informative.

Miscevic's (2001) argument, supplemented with Henderson and Horgan's (2001) links among armchair analysis, epistemology and concepts, goes as follows. In view of the considerations above, it appears that statements such as, (P3) 'Water is the watery stuff of our acquaintance' and (Pt3) 'Time is the timey stuff of our acquaintance', are *a priori*; on the *a priori* reading of (P3), 'water' denotes the watery stuff of our acquaintance regardless of what the list of properties that the watery stuff of our acquaintance turns out to have. However, such statements, though known *a priori*, are tautologies and non-informative.

In order for JCA to provide substantial *a priori* known truths, the *a priori* must not be limited to statements such as (P3) and (Pt3). Recall that the first step of JCA is to refine the target folk concept. This is done by determining the role of a folk concept in our folk theory. Once this role is specified, a list of properties of the concept's referent, e.g., being wet, filling lakes, etc., can be acquired. Jackson (1994, 105) does state that this step of JCA is to be done in the armchair *a priori*.

As Miscevic (2001, 23) points out, Jackson suggests that the resulting specification of the folk concept's role, e.g., (R) Water is the stuff that is wet, fills lakes, etc., must be considered *a priori*. While he is vague regarding the status of (R) in his water example, Jackson makes explicit in other examples that the resulting specification of a concept's role is supposed to be known *a priori*.[20] This seems reasonable given that (P3) is known *a priori* and that one uses nonexperiential armchair justification to get (R) from (P3); from the *a*

[20] For example, as Beaney (2001, 527) points out, Jackson spells out 'Yellowness is the yellowy stuff of our acquaintance' with these two claims which Jackson (1998, 89-93) indicates are also known *a priori*: Yellowness is the property of objects putatively presented to subjects when those objects look yellow, and The property of objects putatively presented to subjects when the objects look yellow is at least a normal cause of their looking yellow. In effect, Jackson suggests the specification of a concept's role is also known *a priori*.

priority of the starting point of P3 and of the nonexperiential mode of analysis used to derive (R), (R) seems also, thereby, known *a priori*.

Provided that he can legitimately claim that the process used to derive (R) provides nonexperiential justification and that informative (R) is known *a priori*, Jackson can maintain that JCA is demarcated from empirical modes of enquiry and results in substantial truths for even empirical matters.

However, the claim that armchair analysis is nonexperiential is problematic. Recall that Jackson claims one utilizes only armchair activity in the first step. The justification obtained from "'the agent's armchair,' without 'going out' and collecting empirical evidence regarding what the actual world is like" is termed 'epistemic justification by reflection' by Henderson and Horgan (2001, 2-3). So, in JCA, one justifies (R) by means of epistemic reflection.

This epistemic reflection used in JCA's first step requires an experiential source. Henderson and Horgan argue that it incorporates experiential justification. According to them, a requirement for justification by epistemic reflection to yield *a priori* truths is that it must "draw on only what is accessible by virtue of having acquired the relevant concepts" (2001, 2). This requirement is supposed to allow the justification to be nonexperiential by allowing one to only use meanings that are available in the armchair and, thus, by bracketing off such concepts' empirical origins.

However, Henderson and Horgan point out that the means with which one 'acquires the relevant concepts' depend upon experience in most cases. While it is beyond the scope of this chapter to explore the various means of 'acquiring a concept', a particular means is required in JCA's epistemic reflection given its use of folk theories. Because a folk concept just is the role it plays in a folk theory in JCA, 'acquiring the relevant concepts' amounts to 'acquiring the relevant folk theory'.

How does one acquire the relevant folk theory? As stated earlier, Jackson claims we establish our folk theory by appealing to the consensus on the intuitions about possible cases. This consensus is supposed to establish claims like (R) by revealing that our shared intuitions indicate that our folk *water* refers to something that falls from the sky, is wet, etc. Nevertheless, contra Jackson's claim that these intuitions must have an *a priori* source, these shared intuitions and the folk theory that allegedly reveals these intuitions appear to have an experiential origin.

In the case of water, as Miscevic (2001, 24) argues, the folk theory itself has experiential origins since it is, or is at least based on, an empirical folk-hydrology. This folk-hydrology relies on a community of speakers who are able to pick out the salient cases of water in local environments as the clear, wet stuff that falls from the sky, etc. At the very least, the factual assumptions regarding water that are part of this folk-hydrology, e.g., fills lakes, falls from the sky, are appealed to while in the armchair examining our intuitions about possible cases. In effect, to know to what stuff *water* refers one needs empirical information about one's or a community's local environment; to know that *water* refers to the stuff in lakes, one needs at least information about one's or the community's surroundings.

So, to evaluate possible cases and, thus, establish our folk theory, the armchair analyst initially requires some empirical knowledge as to what stuff a community of speakers refer to with *water*. Moreover, though a folk theory may be internalized in the sense of referring to one's beliefs about water or upon one's beliefs about the beliefs of a community of speakers, the folk theory is still initially obtained through experiential means. Furthermore, rather than through appeal to *a priori* known intuitions, the apparent consensus regarding our shared intuitions can be explained by our shared experience of the wet, clear stuff that falls from the sky and fills lakes.

Miscevic's argument can be extended to our earlier folk *time*. Like the folk theory that involves *water*, the folk theory that involves *time*, which is supposed to be characterized in the earlier Callender quote, is based on experience. This can be exemplified with (Rt)'s component of having a shared global now. There being a shared global now can be considered to be a generalization of the apparent[21] lack of time-lag in our everyday interaction with medium-sized dry goods and people. It seems that the things we experience at a particular time are occurring at the same time we perceive them. For example, it seems that the page that you are currently reading is there with you now. From this, you draw the

[21] See Butterfield 1984 for an attempt to explain away this folk feature of *time* given the pervasiveness of time-lag.

conclusion that you and this page are both occupying the present. In view of tokens of such experience, we draw the generalization that there is a global now shared by all. So, at least this component of (Rt) involves experience since it is based on our interaction with the world; the armchair analyst requires empirical information in constructing a folk theory from which (Rt) is derived.

So, for empirical concepts like *water* and the previously exemplified folk *time*, our intuitions regarding reference rely on experience, and our folk theory is formed through experience. In effect, experience is required to acquire the relevant folk theory and, in effect, to specify the water or time role in this theory. Thus, epistemic reflection provides experiential justification for the propositions that serve to specify concepts, e.g., (R), (Rt), which are part of a folk theory that incorporates experience. Given that the *a priori* must not require experiential justification, epistemic reflection cannot establish *a priori* truths in all cases. Instead, it may establish *a posteriori* truths.[22]

Thus, the specification of the watery stuff of our acquaintance that JCA is supposed to provide is *a posteriori*, though it does establish something informative.[23] Being *a posteriori* is problematic since JCA is supposed to be distinct from empirical means of analysis. Thus, provided that JCA's first stage only uses justification via epistemic reflection, JCA cannot be used to informatively examine concepts whose folk theory involves empirical claims. JCA's commitment to only concepts known *a priori* and its first stage's separation from empirical means of enquiry make its range limited to *a priori* known concepts whose first stage, which

[22] Due to the role of experiential justification in epistemic reflection, Henderson and Horgan opt to distinguish between high-grade *a priori*, which does not require experiential justification, and low-grade *a priori*, which does require some sort of experiential justification, e.g., the type that is involved in epistemic reflection. Since Jackson seems to require the *a priori* to be high-grade in order to maintain the distinction between JCA and empirical enquires, I do not explore the low-grade option here.

[23] While there may be some options for importing the empirical in one's armchair analysis, e.g., Bonjour's 1998 suggestion that after incorporating the empirical features, such as filling lakes, into the concept, statements such as (R), which express this incorporation, get promoted to *a priori*, it is not clear that one can do so in JCA given its commitment to conceptual analysis' *a priori* domain of enquiry being separated off from that of science's empirical domain. See Miscevic 2000, 2001 for discussion of these options and their problematic impact on JCA's exclusive *a priori* analysis.

involves the refinement and specification of the concept, does not require reference to empirical matters.[24]

Regarding temporal concepts, JCA is only applicable to those that are known *a priori*, e.g., perhaps that of Kant[25], and that do not come from folk theories that involve experience. Further, since our target is to provide some means of analysing temporal concepts in empirical, physical theories, JCA, as requiring an *a priori* starting point and analysis, would be severely limiting in this domain. At best, JCA would allow one to refine *a priori* known temporal concepts without reference to the experiential and then to check whether the refined *a priori* concepts would be eliminated in view of, e.g., Barbour's view.

The upshot of JCA's restrictive focus on the *a priori* is that an adequate analysis of *time* in physical theories cannot be limited to the *a priori* and, thus, must incorporate the empirical in the refinement of concepts.

2.2.2 Concepts and Referents

As stated above, Jackson assumes that all legitimate concepts must have referents that are actual physical properties or objects. Following Rey's (2004) use of 'empty concept', I here use this term to refer to concepts that do not have actual physical properties of objects as referents. Regardless of its origins, this assumption is problematic in an analysis of *time*. Below I provide two cases in which *time* or its features may not have such a referent. Then, I discuss such cases' impact on JCA.

First, suppose that whatever fills the time role is something that serves as a measure, is a convention and has equal intervals. The referent of such *time* may turn out to be a measure based on the duration of some apparently regular motion, e.g., the rotation of the

---

[24] Though one may appeal to different theories of reference, e.g., Pettit's 2004 causal descriptivism, or to different formulations, e.g., a conditional formulation in Chalmers and Jackson 2001, in order to maintain the *a priori* status of JCA's claims, whether a claims is known *a priori* is an epistemological matter. So, such strategies only succeed if they can successfully divorce the evidential justification from such claims and are able to provide some rationale for doing so. See Miscevic 2000 for arguments against being able to do so.

[25] See Kant (1996, A30-1/B46-7).

Earth on its axis, supplemented with some mathematical correction for irregularities in this motion, e.g., taking the mean of such rotation, and divided into some equal intervals by convention.

Though such *time* has an empirical basis, namely the rotating of the Earth, its referent can be construed as a line segment divided into intervals of equal length. This purely geometrical construal of *time* is not supposed to have a physical object or property as a referent. As a geometrical object, such a line is, strictly speaking, breadthless and is divided into intervals by dimensionless points. Such objects are uninstantiable and have merely physical approximations.[26] In effect, the concepts that have such geometrical referents are not supposed to have physical objects or properties as referents. A possible reason for having this purely geometrical referent for *time* is that, given that this measure is conventional, there is no natural measure to which *time* refers. So, if one cannot choose a physical object or change as a standard since none exhibit the required features, e.g., they lack equal intervals, then such *time* would lack a physical referent. However, the lack of such a physical referent is not indication that there is no such *time*. Instead, this would suggest that the referent is mathematical or geometrical. Thus, *time*'s features of having equal intervals and being conventional may not specify a physical property or object as its referent.

While I chose the previous example because it more obviously is a folk *time*, one that first year students often provide, the problem of assuming that all temporal concepts have physical referents is clearer in a less obviously commonsense case. Yet, one may dispute that JCA is supposed to apply to this second case since the analysis is only explicitly applicable to folk concepts. Nevertheless, I am adding this example here in order to enhance the need for an analysis of temporal concepts to include an account of empty concepts.

The second and less folky example involves *time* as abstracted from Minkowskian spacetime, which, assuming you're not a substantivalist, can be regarded as mathematically abstract in that it serves as a mere convenient calculational aid that says nothing about

[26] This line of argument appears, among other places, in Plato, e.g., (Republic VII, 529), who states that physical objects can only be imperfect representations of geometrical objects.

ontology.[27] If *time* has a purely mathematical or geometrical referent, then, unless one accepts some extremely strong realism, in which mathematical and geometrical entities are physical, this *time* does not require a physical referent.

These empty referent cases are problematic for JCA. JCA clearly works for concepts like *water* that are supposed to have a physical referent; if, upon empirical investigation, the concept is not found to have a physical referent, then the concept is to be eliminated. However, JCA offers no explicit means of dealing with concepts that are supposed to lack a physical referent. Without an apparatus to deal with such empty concepts, JCA is limited to concepts that specify some physical referent. While it may work for some temporal concepts, such as, arguably, for our earlier folk *time*, that are supposed to have some sort of objective referent that is in the world, e.g., a moving now[28], this limitation is problematic for analyzing *time* generally since it may involve empty features, like those of the previous two examples.

Thus, in order to not rule out such empty temporal features and concepts in our analysis, we need a means of incorporating and examining empty concepts.

2.3 JCA and Naïve Metaphysical and Ontological Realism

If the objections of §2.2.1 and §2.2.2 are correct, then JCA is not applicable, as Jackson claims, to even folk concepts. Rather, its scope is limited to *a priori* known concepts that are supposed to have actual physical referents.

However, even granting that it is just applicable to cases of *a priori*-derived folk concepts with actual physical referents, JCA suffers from the problem of naïve metaphysical and ontological realism[29], i.e., it just presupposes that the metaphysics and ontology of a physical theory are straightforward and, in effect, that one may just read the metaphysics and

---

[27] This example is discussed in Craig (2001, 193).

[28] Dolev (2007, 66) teases out the ontological requirements of the moving now among other temporal features.

[29] This terminology is not without precedence in the domain of physical theories. See, e.g., Dürr et al. 1996, who use 'naïve realism about operators' to refer to various ways of taking seriously that operators are observable, measurable entities, and Earman 2006, who uses 'naïve realism' for the practice of reading our ontology and ideology off the standard presentations of a theory.

ontology of physical theories directly off the theory. For short, I refer to this as 'naïve realism'. In this subsection, I explain the manner in which JCA employs it and, subsequently, illustrate why such use is problematic.

JCA, as an *a priori* domain of enquiry that is supposed to be separate from empirical enquiries, is not applicable to concepts that include experiential justification. This limitation prohibits JCA on its own from offering an analysis of *a posteriori* known concepts. Thus, JCA alone cannot examine the concepts involved in scientific theories. So, without some supplementary analysis of *a posteriori* concepts, JCA cannot examine scientific concepts. This suggests that, at best, JCA brackets off the questions of how to examine scientific concepts and how to determine the properties associated with their referents.

However, rather than merely bracketing off these questions, Jackson seems to answer them by appealing to naïve realism in JCA's second stage. JCA's second stage requires some empirically established premise, e.g., (P2), (Pt2). Jackson claims that such premises are assumed as given through 'empirical investigation'. For example, we know through chemistry that H_2O is the watery stuff of our acquaintance.

How do we establish to what 'H_2O' refers? Jackson provides an answer to this in honing his physicalism:

> [I]t is reasonable to suppose that physical science, despite its known inadequacies, has advanced sufficiently for us to be confident of the *kinds* of properties and relations that are needed to give a complete account of non-sentient reality. They will broadly be of a kind with those that appear in current science. (1998, 7)

In effect, Jackson answers that physical science in its current form can straightforwardly provide us with the kinds of physical properties and relations that exist. So, in the case of *water*, chemistry provides us with the kinds of properties and relations, e.g., being hydrogen, being a covalent bond, and these properties are assumed to exist. In effect, 'H_2O' refers to some chemical compound that exists. Furthermore, since we just read our ontology of elements and their relations off chemical theory, Jackson seems to promote naïve realism.

However, the use of such naïve realism is problematic for two reasons.

First, the sole use of naïve realism risks ignoring other ontological and metaphysical options which a particular theory may have. In the H_2O case, alternative and competing ontologies and metaphysics have been proposed for chemistry's kinds of properties and relations. For example, due to the application of quantum theory to chemistry and quantum theory's lack of such bonds, whether covalent bonds exist and whether their explanatorily relevant properties can be attributed to other chemical entities has been debated. While I do not elaborate on the details of this debate here,[30] it is important to note that even in the apparently straightforward case of H_2O, there are other ontological readings, e.g., ones in which covalent bonds are completely eliminated, and metaphysical readings of the theory, e.g., ones in which covalent bonds qua fundamental properties are replaced by covalent bonds qua emergent relations.

This first general problem of naïve realism impacts JCA by potentially limiting its second stage's results. The naïve reading of the theory establishes the second stage's 'empirically established' premise, e.g., (P2), (Pt2). If a theory has alternative metaphysics and ontologies, then JCA is merely evaluating whether a folk concept can be identified with an ontology and metaphysics obtained from a naïve reading. In effect, the conclusions drawn from JCA's second stage are restricted to an ontology and metaphysics from a naïve reading of the theory; JCA, at least given Jackson's preceding quote, only allows one to draw identities between folk concepts and a physical theory's naïve ontology/metaphysics.

Second, by creating one's ontology and metaphysics with whatever can be read off the physical theory, naïve realism risks incorporating entities or metaphysics that are redundant, irrelevant or inconsistent.[31] Though one may reply that one could be a slightly less naïve realist by, e.g., rejecting certain salient redundancies or resolving select inconsistencies, the primary issue that I want to emphasize about such approaches is their lack of a systematic analysis. Without some principled means of assessing the commitments of being a naïve realist about a theory, one has little guidance as to exactly which ontological and metaphysical tenets one should accept. Naïve realism offers no such means explicitly.

---

[30] See Hendry 2008 for a detailed discussion of this debate.

[31] Dürr et al. 1996 point out this specific problem in the context of naïve realism about operators.

Nevertheless, in order to illustrate how naïve realism's lack of a clear method can cause an inconsistency, I borrow a means of assessment from Saunders and apply it to a quantum example.

Saunders (2006) offers some procedure for the naïve realist. He claims that we should list the allowable predicates and terms that are dictated by grounds internal to the theory, e.g., only allow predicates of measurable properties and relations. From this list, we can establish our ontology by admitting only the entities that are required by the distinctions that these predicates and terms establish. For example, suppose when talking about fermions and bosons, we use 'fermion' and 'boson' as subject terms that have predicates, e.g., 'has charge'. This use indicates that fermions and bosons are objects and charge is a property that is attributable to such objects.[32] Thereby, we can get our ontology from how we refer to our theory.

Further suppose that all objects are individuals. This supposition can easily be imparted to our quantum objects, e.g., their corresponding subject terms normally refer to individual objects. Can we get some metaphysical apparatus that secures such particle's individuality? Saunders proposes a weak form of discernibility that all fermions can satisfy, while elementary bosons cannot. In effect, assuming that this is the weakest form of discernibility available and that discernibility is indicative of individuality, fermions are individual objects, while bosons are non-individuals and, thus, are not objects. I am not presenting the details of the case here since this characterization is sufficient to establish that such naïve readings' lack of method can cause, in this case, an inconsistent metaphysics in

[32] Saunders 2003, 2006 would likely object to my use of the subjects of sentences to establish the *objects* of our ontology. His approach in this case is to establish the *properties* and *relations* in view of the predicates relevant to a theory. Then, he proceeds to determine whether the set of properties and relations predicated of a particular subject term are discernible from other sets of the same properties and relations. Since he claims that individuality, which is indicated by such discernibility, is the mark of objecthood, the discernible fermions are objects, while indiscernible bosons are not. However, this difference between Saunders' naïve realist approach and the naïve realist approach suggested above indicates that metaphysical presuppositions, e.g., taking properties, rather than objects, to be fundamental, guide naïve realism and can result in various ontologies. If this is so, the need for some method of assessing the commitments of being a naïve realist about a theory is even more pressing.

which bosons are and are not objects.[33] Moreover, it is not clear what one should do at such an impasse. Should one reject the initial ontology and/or metaphysics that was read off the theory, the metaphysical supposition that all individuals are objects or the link between discernibility and identity?

Since there does not appear to be a principled way of answering this question or, generally, a systemized means conducting a naïve realist reading of a theory, naïve realism in its present form does not offer an adequate means of providing a theory's metaphysics and ontology.

JCA relies on naïve realism, yet it merely assumes that naïve realism offers a consistent, non-redundant, relevant ontology and metaphysics. Since naïve realism does not appear to have a principled means of providing such an ontology and metaphysics, naïve realism's ontology, metaphysics and concepts, which may indicate its ontological and metaphysical commitments, are themselves in need of analysis. This suggests that the concepts associated with physical theories cannot be taken for granted. In turn, the second problem of naïve realism indicates that the concepts of scientific theories also require a conceptual analysis; a conceptual analysis may provide a method to refine the concepts we associate with scientific theories in order to avoid the problem of incorporating redundant, irrelevant or inconsistent claims about a theory's metaphysical and ontological commitments.

In sum, the upshots of JCA's reliance on naïve realism are as follows. The first problem with naïve realism concerns JCA's ignorance of non-naïve readings. It suggests that we should be aware of alternative metaphysics and ontologies for, at the very least, properly qualifying the conclusions we make relative to the particular set of metaphysics and ontology that one associates with the scientific theory.

---

[33] Though this example has been presented rather crudely, note that are a few options in the literature to deal with this inconsistency. French and Krause 2006, for example, claim that such objects are indeed objects yet are non-individuals. Additionally, Saunders' own view can be read in terms of his Quinean project in which variables correspond to objects. In view of such objects, he formulates a means of individuating them, and rejects bosons as objects because they are not individuals given the individuation criterion.

Moreover, there is no reason, other than Jackson's advocacy of naïve realism, for JCA to be restricted to using the metaphysics and ontology of naïve realism in its second stage of analysis. It could easily exchange its naïve realist commitments in, e.g., (P2), for those of an alternative reading of a scientific theory.

However, the second problem, which may also apply to non-naïve alternatives that have no principled way of maintaining the consistency, non-redundancy and relevancy of their metaphysical and ontological commitments, suggests that one cannot take the concepts that express such commitments for granted. So, a conceptual analysis that is applicable to the concepts involved in scientific theories offers a way to avoid these problems.

Unfortunately, JCA, as dealing only with *a priori* concepts, cannot be extended to the empirically justified concepts of science. Nevertheless, JCA may be supplemented with a separate conceptual analysis for experientially justified concepts. But, some may find the resulting two-tiered analysis, which requires two sub-analyses, to be unpalatably unparsimonious when compared with a single analysis. Furthermore, in view of JCA's problems concerning the *a priori* and empty concepts, substantial revision of JCA is required to analyse even folk *time*.

3 Towards an Analysis of Scientific Concepts

Since JCA neither provides a satisfactory account of folk *time* nor offers any means of analysing the concepts of scientific theories, I approach developing a working conceptual analysis for *time* in Barbour's view in two stages.

In the first stage, I construct a conceptual analysis of the network theory variety for folk *time*. This analysis aims to resolve the problems associated with JCA's *a priori* and sole focus on non-empty concepts. Such problems are resolved by using portions of an alternative conceptual analysis that is sketched by Miscevic (2005). As inspired by Miscevic, I denote this working folk conceptual analysis as 'MCA'.

In the second stage, I attempt to provide some means of analysing the concepts of scientific theories. Since I am here concerned with analysing *time* in Barbour's view, I focus on developing an account for *time* in physical theories. So, I begin by applying MCA to such *time*. While MCA provides some preliminary method for the analysis of such *time*, its application to physical theories is not without problems; in §3.2, I provide the following three criticisms of such application.

First, I present theory theory's general problem of identifying its concepts. Rips' discussion of this problem suggests a few solutions in the domain of physical theories; however, I argue that these solutions may risk naïve realism.

Second, I examine the problem of MCA being limited to a single scientific theory. I do so by applying MCA to Esfeld's discussion of *time*'s directionality in QT and GR. Since the target of our conceptual analysis is Barbour's view, which involves both QT and GR, I claim that MCA may be problematically limited to a particular scientific theory.

Third, I develop a suggestion made by Esfeld to the effect that the restriction of one's analysis to the concepts of a scientific theory potentially creates a gap between those scientific concepts and our folk concepts. This objection is made salient through its application to *time*'s feature of *directionality*. In view of this gap and the problem it causes in the application of MCA to Barbour's view, which also attempts to explain our everyday experience of time, it seems that our conceptual analysis must bridge this gap.

From these three criticisms, I derive three desiderata for a working conceptual analysis that appears applicable to at least Barbour's view. These desiderata are outlined below in §3.3.

Finally, I modify MCA in a fashion which allows it to fulfil all the desiderata. The amended and extended version of MCA is referred to below as the Alternative Conceptual Analysis, or 'ACA'.

3.1 A Working Analysis of Folk Concepts: MCA

I develop a working analysis of folk concepts, i.e., one which can address JCA's problems of having a focus on *a priori* known concepts and of only being applicable to concepts that are supposed to be non-empty. Since the modifications made to address these problems are largely drawn from Miscevic (2005), I refer to this modified analysis of folk concepts as 'MCA'.

My rationale for developing a folk account is twofold. First, JCA's use of naïve realism reveals the need for an analysis of scientific concepts. However, there appears to be no systematic analysis available for such concepts. Yet, such systematic analyses have been developed for folk concepts. So, I am endeavouring to use an analysis of folk concepts, which addresses the problems of JCA, as an initial model for the analysis of scientific concepts. Second, Barbour considers our folk *time* and offers some explanation of it.[34] So, in order to address this component of Barbour's view, I need a working analysis of folk concepts.

To develop this account, we shall start off by construing MCA as a form of network analysis for reasons given in §1. Thus, a concept is examined in terms of the role it plays in a network of principles that constitutes some theory(s). And, the meanings of terms are identical with the roles concepts play in our folk theory.

The problems with JCA indicate the direction in which we develop MCA. JCA's focus on *a priori* known concepts was found to be too restrictive since many temporal concepts seem to involve experiential justification. In effect, MCA must offer some means of incorporating concepts that involve experiential justification.[35] Additionally, JCA was shown not to address empty concepts, i.e., concepts that are not supposed to have a physical referent. Because such practice excludes empty temporal features, e.g., those that are purely mathematical, MCA must apply to such concepts.

Let's proceed by using JCA as a rough guide for MCA. MCA involves two stages. In the first stage, one starts by specifying the folk theory from our armchair intuitions about possible cases. As argued in §2.2.1, experiential data may inform one's intuitions. So, MCA incorporates both experientially and nonexperientially justified intuitions in the formation of one's folk theory.

---

[34] For example, much of his 1999 as well as his work on time capsules addresses our folk *time*. This account of our temporal experience is presented in Ch5 and discussed in Ch6.

[35] I assume that a naturalistic conceptual analysis is a legitimate form of conceptual analysis. See, e.g., Miscevic 2005b for arguments against the traditional link between conceptual analysis and *a priority*.

While this move seems to be an easy means of incorporating concepts that involve experiential justification, it comes at a cost. JCA's sole use of *a priori* intuitions allowed it to assume that there is a shared set of intuitions, which is revealed by our consensus regarding possible cases. However, when we incorporate experientially supported intuitions, we run the risk of adding a wide range of potentially conflicting intuitions into our folk theory.[36]

Miscevic (2005, 460) exemplifies such conflicts with *number*. Additionally, he suggests a way of addressing them, which will be incorporated in MCA. Suppose we have formulated our folk theory that involves *number* by consulting our experientially supported intuitions. From this, we specify the number role as:

> (Rn) Number is the language in which the book of nature is written and lacks a referent that can causally influence nature.[37]

(Rn)'s components seem to clash; the second portion indicates that the referent of *number* cannot affect nature, while the first portion seems to presuppose such interaction[38]. Thus, we need some means of resolving such clashes. At this juncture, Micsevic (2005, 460) suggests that we engage in metaphysics and epistemology to resolve such clashes in our folk concept. MCA will follow Miscevic's lead by suggesting that one engages in metaphysics and epistemology in an attempt to resolve the clashes that occur from incorporating experientially

---

[36] For the purpose of simplifying this subsection's discussion regarding MCA, I focus on conflicts that are clashes which arise within the specification of a particular concept's role. However, such conflicts may also occur between different roles. Additionally, such conflicts may take the form of clashes, redundancies and irrelevancies.

[37] This example is from Miscevic (2005, 460).

[38] However, Miscevic's example of number being the language in which the book of nature of written seems to have number serving merely as a means of representing nature, rather than as something interacting with it. To get this example to work in the fashion Miscevic intends, it seems that we should assume a Pythagorean stance on numbers and ratios, e.g., Aristotle's presentation of Eurytus's view in which numbers are causes of substances by being the points that bind things into certain shapes. See Huffman 2005 for discussion of Aristotle's presentation of his account.

justified intuitions in one's folk theory.[39] However, note that since I will be focusing more on the metaphysical issues that arise, I henceforth bracket off discussion of the epistemological feature. Additionally, Miscevic does not state exactly how one should 'engage in metaphysics' here. For the purposes of this chapter, MCA, too, is silent as to how one should proceed metaphysically. Nevertheless, the activity of metaphysics will also be incorporated in ACA below. Moreover, this 'engaging in metaphysics' will be developed in Ch6 primarily in which I apply ACA to Barbour's view and attempt to resolve clashing components of its *time* via seeking alternative metaphysical options. Plus, in Ch7 I discuss the ramifications of this application for this practice of 'engaging in metaphysics'.

In effect, MCA has a procedure to incorporate folk concepts that involve experiential justification. Using both experientially and nonexperientially justified intuitions about possible cases, we can construct a folk theory and, therewith, specify a concept's role in the theory in a fashion similar to that of JCA. However, as (Rn) illustrates, the components of such roles may clash. In such cases, one must engage in metaphysics in an attempt to resolve such clashes.

Before we can leave MCA's first stage, we must address JCA's problematic focus on empty concepts. Recall that the main purpose of JCA's first stage is to establish what can count as the physical referent of a folk concept. Since JCA is only to deal with concepts that are supposed to have physical referent, this purpose of JCA's stage seems warranted. However, since we want MCA to incorporate concepts that are not supposed to have referents, we must make MCA's purpose more generic, i.e., it seeks to specify a concept's role in a folk theory. In effect, the role's specification may or may not refer to physical properties or objects.

This generic purpose of MCA's first stage raises the question of how one can determine whether a concept is supposed to have a physical referent. In some cases, the specification of a concept's role and its metaphysical refinement may reveal whether the

---

[39] I assume that folk theories that incorporate clashing and even inconsistent claims can still be called 'theories'. In the context of classical electrodynamics, see Frisch 2005 for arguments in support of the claim that there are inconsistent theories, and Vickers 2008 for discussion of Frisch.

concept is supposed to have a physical referent. For example, if one assumes the metaphysical claim that the ability to causally interact with physical objects is the mark of something being a physical object, (Rn)'s second component indicates that *number* is not supposed to have a physical referent. In effect, MCA's first stage aims to specify a concept's role in a folk theory, and this role may be indicative of whether the concept has a physical referent.

If we continue to mirror JCA, after we specify the concept, we are to proceed to the second stage of JCA. Recall that this second stage involves determining whether a physical theory posits some physical referent that has most of the properties listed in the specification of the concept's role. As such, JCA's second stage is not applicable to empty concepts.

So, I propose that MCA incorporates JCA's second stage largely as is. When dealing with a concept that is supposed to have a physical referent, one makes recourse to some 'empirically established' claim in order to determine whether a concept refers. If such a concept turns out to have such a physical referent, one may use the physical referent's properties to further specify the concept. Such influence on the concept and the folk theory seems permissible since MCA allows experiential justification to forge its folk theory. If such a concept does not turn out to have a physical referent, then one can either reject the concept or, if there is some reason to keep the concept, attempt to modify the specification of the concept's role through metaphysics. However, when dealing with an empty concept, one does not proceed to the second stage in MCA.[40]

This provides us with a sketch of MCA's second step. Discussion of MCA's second stage has been rather schematic here because, as we'll see in the next section, it, as still incorporating some 'empirically established' premise, suffers from naïve realism. In effect, there is not much need to develop it here. Moreover, I have presented this sketch to show in

---

[40] This modification is inspired by two principles which Miscevic (2005, 449, 451) adopts. These principles are:

Principle of External Definitions: Where there turns out to be a referent to a concept, we turn to an examination of the referent to determine the concept's constitutive conditions.

The Principle of Internal Rule: Where there is no referent, all we have is the internal rule for the concept alone.

§3.4 that much of MCA's second stage schema is present in ACA. So, the preceding sketch should be sufficient for present purposes.

In sum, MCA for folk concepts proceeds in two stages. In the first stage, one uses experientially and nonexperientially justified intuitions about possible cases to construct a folk theory. From this folk theory, one specifies the concept's role in the theory. Due to the incorporation of experience, the components of the resulting specification of a concept's role may clash. One should engage in metaphysics to try to resolve such clashes.

To determine whether one should proceed to MCA's second stage, one needs to ascertain whether the concept is supposed to have a physical referent. This may be done by consulting the specification of the concept's role and its associated metaphysics. If the concept is supposed to have a physical referent, proceed to MCA's second stage. Otherwise, one should stop after the first stage.

Furthermore, due to MCA's incorporation of the experiential and its use of metaphysical enquiry, the results of MCA's second stage have a few more options, in comparison to JCA's immodest folk eliminativism. A concept that is found to have a physical referent may be informed by the referent's actual properties. On the other hand, a concept that is found not to have a physical referent may either be rejected or attempted to be salvaged via the modification the metaphysics associated with its role's specification.

3.2 Applying MCA to *Time* in Physical Theories

I use MCA as an initial model for the analysis of concepts in physical theories. *Prima facie,* since MCA is a form of network analysis that is applied to folk *theory*, it seems rather straightforward to apply at least its first stage to physical theories.

However, MCA faces three pressing problems in this domain.

3.2.1 Theory Theory's Concept Identification Problem

Theory theory faces the problem of not providing an account of how one should identify a concept in a theory. In theory theory, the concept just is the role it plays in a theory. However, this setup provides no means of determining how one should pick out exactly which role the concept should be identified with; since such a concept is completely defined in terms of its role in a theory, theory theory concepts lack any essential feature which would allow one to identify the concept.

As a form of theory theory, MCA suffers from this problem of identifying concepts. While this problem raises many concerns for MCA, e.g., how to identify a concept across theory change[41], I am focusing on the issue of being unable to initially[42] identify a concept in MCA. Since, at this stage, we are attempting develop a conceptual analysis of *time*, we must provide some initial means of identifying *time*'s role in a physical theory.

This particular problem of concept identity can be exemplified through the application of MCA to *time* in GR. MCA's first stage indicates that we are to use GR's theory to specify *spacetime*'s role. However, without further guidance, it is unclear what we should include in *spacetime*'s specification; there seems to be no indication from MCA as to whether one should initially include, e.g., only being a metric, or being a metric and being a manifold.

In the context of general problems associated with theory theory's means of identifying concepts, Rips (1995) discusses a means of resolving this problem.[43] This means consists of identifying a concept via the surface structure of propositions in which the concept is involved. So, one may identify a concept by making recourse to the manner in which it is used in propositions. This suggests two options for MCA's problems of initially identifying a concept. First, one may initially identify *time* via how 'time' is used in the statements that refer to a physical theory. Second, one may identify *time*'s role with whatever role the time variable plays in a physical theory.

---

[41] See Laurence and Margolis 2000 for discussion of this and other concerns linked to theory theory's lack of a means to identify concepts.

[42] I focus on the *initial* identification of a concept to highlight the manner in which it can lead to naïve realism. However, I do acknowledge that, in a fashion similar to that of ACA, MCA may be able to overcome this problem of identification through *later* metaphysical enquiry.

[43] Another prominent option, which is discussed by Laurence and Margolis 2000, is to add some essential core features to theory theory concepts. While the addition of such a core would allow *time* to be easily identified, I do not consider this option here because it would restrict *time* to whatever is characterized by a particular core feature. Additionally, one would require some means of determining what this feature is.

However, such resolutions may run the risk of naïve realism. These resolutions, quite literally, may read the metaphysics and ontology off a theory or the propositions associated with a theory. Moreover, the first option mirrors Jackson's own naïve realism. See §2.3 for problems with such practice.

In view of the MCA's lack of a means of identifying *time* initially and the risk of naïve realism that may accompany straightforward means of doing so, ACA must offer some means of identifying *time* in a fashion which avoids naïve realism.

3.2.2 The Possibility of Limiting Resulting Concepts to a Single Scientific Theory

This is merely a possible problem because it depends upon the manner by which MCA examines concepts across theories. In this section, I am only considering an obvious means of doing so, i.e., by applying MCA to each physical theory separately. If MCA is applied to the *time* of each physical theory separately, it may result in clashes between concepts of time that are not straightforwardly resolvable.

To demonstrate this, I use Esfeld's discussion of directionality in the time of QT and SR. Suppose that we apply MCA to *time* in SR. SR gives us the theory, and we'll assume Esfeld's interpretation. So, in accord with MCA, we must next determine the role of *time* in this theory. SR's laws that describe space-time and its material content are time symmetric in the sense that they allow in principle the time-reversal of all processes they describe. In effect, the laws associated with space-time do not allow us to give a physical signification to the designation of one part of a light cone of a point in space-time as past of that point and another as future of the point. Thus, in SR, the time role seems to include the lacking of a direction.

In contrast, an application of MCA to QT indicates that its time role includes the having of a direction. In order to conceive of definite numerical values as the outcomes of measurements, Esfeld (2006, 89) advocates an interpretation of QT according to which it contains a dynamics that describes processes of state reduction dissolving superpositions and entangled states. He then links this interpretation with temporal asymmetry: If there are processes that dissolve quantum entanglement and superpositions, these are time asymmetric processes at the fundamental level of nature. So, it seems that time's role in QT involves having a direction given this interpretation.

Two separate applications of MCA to SR and QT have resulted in what seem to be two clashing roles for time, i.e., a role which involves having a direction and a role which lacks such a direction. Further, while the sketch has been brief, it is not obvious how this clash should be reconciled, e.g., should one concept be rejected or should some attempt be made to incorporate asymmetry into SR's *time*? Without further guidance in how to proceed, it seems that this application of MCA has resulted in two different concepts of *time* that are only straightforwardly viable in the context of their respective theories.

In effect, the procedure of applying MCA to different theories separately may result in two apparently incommensurable temporal concepts. If such concepts are compared they may be found to clash and to be apparently irreconcilable. Thus, an application of MCA to a single theory may result in a temporal concept that clashes with that of another theory. In turn, the concept that results from an application of MCA to a particular theory may be too limited to that particular theory.

This possible limitation of a concept to a single theory is problematic for the application of a conceptual analysis to Barbour's interpretation. Barbour's view incorporates two theories, namely GR and QT. As revealed above, separate applications of MCA to two different theories may result in two temporal concepts that clash and that cannot obviously be reconciled. A possible means of resolving this issue is to come up with an analysis that can be applied to more than one theory at a time.

3.2.3 Creation of a Problematic Gap between Folk Concepts and Scientific Concepts

Esfeld (2006) argues that if one holds that the ontology and metaphysics that one derives from a physical theory offer a complete description of the world, then one creates a gap between the physical description of the world and one's experience of the world. To exemplify the manner in which such a gap can occur, Esfeld considers time in SR. I here present his example in the context of MCA.

Suppose that one applies MCA to *time* in Einsteinian SR. Further suppose that whatever ontology and metaphysics that result from this application of MCA offer a complete description of the world. E-SR's laws, which describe spacetime and its material content, are in principle time-symmetric. Due to such symmetry, it seems that, barring any other means by which E-SR's *time* may be attributed a direction, having directionality cannot be a feature of E-SR's *time*; *time* does not play a role that involves directionality in E-SR. Given such symmetry and our assumption that E-SR offers a complete description of the world, E-SR's laws show that there *is* no direction of time.

However, as Esfeld (2006, 89) points out with the example of all forms of life involving an apparently irreversible process that stretches from birth to death, our folk *time* does seem to have a direction. This feature of our folk *time* clashes with that of our E-SR *time*. Esfeld regards this clash as indicative of a gap between the scientific view of the world and our experience of the world.

Why is this gap problematic? After all, we can easily adopt JCA's immodest folk eliminativism and just eliminate such folk concepts that clash with MCA's resulting physical description. However, this gap is problematic for the application of a conceptual analysis to Barbour's *time*. Because Barbour attempts to give an explanation of our everyday experience of *time* in view of the physical description of his interpretation, our conceptual analysis must offer some means of bridging such gaps between the concepts derived from folk theories and those derived from scientific theories.

3.3 Three Desiderata for an Alternative Conceptual Analysis (ACA)

From the preceding three problems, I derive the following three desiderata:

> D1. ACA must have some relatively unproblematic means, i.e., a means that avoids naïve metaphysical realism, of identifying *time* in a scientific theory.
>
> D2. A single token of ACA must be applicable to more than one scientific theory.
>
> D3. ACA must include and integrate an analysis of our folk *time* with an analysis of *time* in scientific theory(s).

Note that D2 and D3 are partially motivated above by Barbour's particular interpretation, which involves more than one theory[44], namely GR and QT, and attempts to explain our everyday experience of *time*. While these desiderata may be wanted for more general

[44] Because, as well shall see in Ch5, his GR is not completely and clearly integrated with his QG, some work is required to spell out the manner in which QT and GR may be unified.

purposes, e.g., combining other theories with apparently clashing concepts, examining the compatibility of particular concepts and their features across theories, I do not discuss such purposes here. However, if, apart from giving an analysis of *time* in Barbour, one does not see the need for these desiderata in a conceptual analysis, then one can still find some use for ACA, albeit in a truncated form, e.g., application to . Although I do not further discuss such truncation here, I explore this issue in later chapters where I discuss the scope of ACA's applicability.

Further note that D2 may seem controversial in that there appears be other means of incorporating the analyses of different theories together. For example, apply ACA to the theories separately and subsequently apply ACA again to both theories and to the concepts that resulted from ACA's first application. However, even in this case, there still is a single token of ACA being applied to both theories, though it occurs at the second stage of analysis. In effect, since this analysis still requires some means of applying conceptual analysis to both theories, D2 is still required.[45]

3.4 ACA

In view of these desiderata and the merits of MCA relative to JCA, we can formulate ACA as follows. ACA is a form of network analysis. ACA begins with one obtaining the theory(s) that one is considering. For folk theories, follow MCA's procedure of using experientially and nonexperientially justified intuitions about possible cases. For scientific theories, less work needs to be done at this stage since the theories and their interpretations are largely given.

---

[45] Throughout this discussion, I assume that one should apply a single analysis, rather than, say, using one type of analysis for a single theory, e.g., MCA, and some other type of analysis across theories, e.g., a non-network analysis in which one just compares the concepts that resulted from MCA and, where two theories' concepts clash, eliminate one or both of the concepts in accordance to some criteria specified by the analysis. I do not here explore the possibility of having different sorts of analysis for two reasons. First, I lack the space to go through all the options. Second, I prefer using a single type of analysis that is applicable to both a particular theory and to more than one theory because of parsimony regarding types of sub-analyses involved in one's method of analysis.

If one is dealing with more than one theory, the theories are treated as parts of a single network. Further, while such a network may lack many connections among its theories at this stage, at least some metaphysical connections will be made apparent and developed over the course of the analysis.

After one has the theory(s), determine what role *time* plays in the theory(s). To initially identify time, appeal to what seems to be the theory(s)' temporal role by using the surface structure of propositions made in the theory(s) and/or the role of temporal variables. However, in order to avoid the problems of naïve realism, one does not stop at this point. Instead, one must proceed to determine whether any of the components of the role clash, are redundant or are irrelevant with each other and with other concepts of the theory(s) and their specified roles. If there is no such conflict, and if there seems to be some coherent time role, then the theory has *time*. If not and provided that one wants to salvage *time*, one must engage in metaphysics in an attempt to construct a coherent, relevant and non-redundant *time*.

This engaging in metaphysics may involve modifying the metaphysical and ontological commitments indicated by *time* and other relevant concepts associated with the theory(s). Following Jackson's definition of metaphysics,[46] metaphysical enquiry aims to create a list of what there is that is coherent, complete and parsimonious. So, in order to maintain such coherency and parsimoniousness, engaging in metaphysics may force one to re-examine the metaphysics and ontology of other parts of the theory and, if considering more than one theory, the metaphysics of other theories.

Further, as the metaphysical enquiry may tell us whether certain concepts and their features are supposed have ontological referents and because the theories are informed by empirical information, MCA's second stage is absorbed into ACA's metaphysical enquiry. For example, if a folk *time* requires a referent, then one ascertains whether there is one by looking at the scientific theory's ontological and metaphysical commitments. Then, if nothing seems to correspond to *time*, one can proceed with attempting to salvage the folk concept by examining and modifying the metaphysical and ontological commitments of other

[46] This also roughly follows Esfeld's 2006 view of metaphysics as something that is informed by a physical theory and that constrains a theory's ontology by limiting it to one that is parsimonious and coherent.

parts of the network in a parsimonious and coherent fashion. If this cannot be done, then this concept may have to be rejected.

Now that I have formulated ACA, I show that it can fulfil all of §3.3's desiderata. Through ACA's initial inclusion of all terms and its subsequent metaphysical enquiry into the coherency and parsimony of the relevant metaphysical and ontological commitments of all the theories listed, ACA provides a means of being able to apply a token analysis to more than one theory. This allows a token ACA to be applicable to be applicable to more than one theory and, thus, allows ACA to fulfil D2. Additionally, by initially adding a folk theory to the network, ACA can include and examine a folk theory in a fashion in which it fulfils D3.

Finally, ACA fulfils D1. Though it initially uses means that risk naïve realism to identify *time*, it proceeds to examine the resulting *time* in a manner that allows one to incorporate the alternative temporal features of, e.g., some other theory. Additionally, the ensuing metaphysical enquiry allows one to assess the redundancy, irrelevance and inconsistency of *time*, both among the components of *time*'s specification and in relation to other concepts of the theory(s) involved. In effect, though ACA does initially employ means that might risk naïve realism, its subsequent analysis offers a means around §2.3's problems with naïve realism. Thus, in accord with D1, ACA can identify *time* unproblematically.

Thus, as fulfilling the desiderata and by incorporating the resolutions that MCA offers to JCA's problems, ACA seems to provide a means of analysing *time* that is applicable to the *time* in Barbour's view. In the following chapters, I turn to applying ACA to Barbour's view. When I do so, I focus on ascertaining what plays the time role in Barbour's view and on doing the metaphysical work to try to make this list coherent. Furthermore, in applying ACA to Barbour's view, I develop and refine the above outline of ACA.

In accord with ACA, here is the manner in which we proceed to apply it to Barbour's account through Chapters 2-6.

We start by obtaining theory(s) that one is considering and, if there is more than one theory being analysed, treat them as part of a single network. How can we initially treat a number of theories as parts of a single network? We will see in Ch2 that Barbour's account is based on a number of Machian principles. So, I suggest that we use these principles to serve as our means of initially pounding his theories into a single network; they effectively serve as the overarching principles for his entire timeless view.

He has four main ‘theories’: a Machian nonrelativistic dynamics, a Machian relativistic dynamics, a Machian quantum interpretation and a Machian interpretation of quantum gravity. I am including his nonrelativistic dynamics because it informs us of the manner in which he develops his relativistic account. Along with his principles, his nonrelativistic account is provided in Chapter2. His accounts of GR, QT and QG are provided in Chapters 3, 4 and 5, respectively. Because, other than Barbour (1999) and (1994), he has not explicated in detail the manner in which his interpretations of QT and QG fit with his GR, we must consider exactly the role(s) that *time* plays in each of these accounts. In each chapter, I either highlight the manner in which it is in accord with his principles or, where required, discuss the manner in which it may be able to fulfil the principles. By taking care to note the manner in which his overarching principles do or can dictate the content of his ‘theories’, I effectively treat all the theories as parts of a single Machian network. In effect, these accounts are presented with the aims of treating all these theories as part of a single Machian network and making the surface role(s) that *time* plays in them salient.

ACA requires that once we have the theories and treat them as a single network, we then determine what role(s) *time* plays in the theories initially using the surface structure of these accounts. In Chapter6, these surface roles of *time* that have appeared in the exposition of Barbour’s account are summarized and compared with each other. In accordance with ACA, these roles are then compared and conflicts are identified. Then, some of the conflicts are addressed and attempted to be reconciled by ACA’s practice of ‘engaging in metaphysical enquiry’. With this application of ACA to Barbour’s account, we, thus, have a model of the application of ACA to *time* in physical theories. The ramifications of this application for ACA are discussed in Chapter7.

Chapter 2: Barbour's Machianization Project and Its Application to Nonrelativistic Dynamics

We begin the process of applying ACA to Barbour's account by presenting his overarching Machian principles with which we will draw out in his 'theories' and, thus, be able to treat his accounts as parts of a single Machian network. Additionally, here I discuss the manner in which he develops his nonrelativistic dynamics. It is important to include this account in the course of his unification of GR and QT for a number of reasons. First, it clearly provides an application of metaphysical principles by which he formulates his account. Second, as we'll see in Chapters 4 and 5, his account of QT is presented largely in terms of this nonrelativistic account.

In addition to presenting his principle-based nonrelativistic account, this chapter serves to provide an overview of Barbour's project and the manner in which it has developed. Because his research project is on-going and due to the fact that his present work does little by way of developing his interpretations of QT and QG, I use this overview of his project to delineate a specific period of his research that I expound in the chapters below and, thus, to serve as a model to which I apply ACA.

Following the outline of his project, the manner in which he develops a nonrelativistic dynamics is presented. Because it is principle-based, these principles are first presented and specified. Then, we see the manner in which these principles are applied to Newtonian dynamics in order to generate an account in which time plays no fundamental role.

1 Barbour's General Aims, Method and Rationale

Barbour's overarching project is to develop a Machian version of quantum gravity, i.e., a version of quantum gravity that only recognizes entities in the universe and their relations at the fundamental ontological level. This project, at least as indicated in his (1989), (1992) and (1995), is historically motivated; it is rooted in the role that Machian concepts play in Einstein's development of General Relativity (GR). So, a brief historical exegesis is a necessary prelude to the introduction of the aims that accompany Barbour's overarching project.

1.1 A Brief Historical Prelude and Barbour's Approach

Barbour (1989) (1992) is motivated initially to formulate a Machian GR in view of a goal that Einstein set for his GR but did not successfully accomplish. I should note here that because my main aim is to present what Barbour claims is the motivation behind his approach to a Machian GR as well as the resulting relation between his Machian GR and Machian nonrelativistic accounts, the influence of this Machian task on Einstein is largely drawn from Barbour's own readings of Einstein and Mach.[47]

This aim that Einstein tackles, albeit unsuccessfully, is to provide a relational account of inertia[48]. In this project, he is guided by Mach's criticisms of Newton's account of inertia. However, according to Barbour (1992), Einstein conflates two different concepts of inertia that Mach criticizes on separate grounds. First, Mach criticizes Newton's account of inertial mass[49], i.e., the quantity of matter that a body possesses arising from its density and bulk conjointly, on grounds that this definition is circular.[50] He points out that it is circular because density is itself defined in terms of mass. In response, he offers an alternative definition that is founded on the ratio that results from considering two accelerated bodies, e.g., for two bodies that collide, it is the ratio of the change in velocity of each body.[51] Note that, according to Barbour's reading of Mach, other than the circular means in which it was defined, Mach finds this concept relatively unproblematic. Second, Mach criticizes Newton's account of inertial motion as defined by his first law, i.e., bodies continue in a state of rest or uniform motion in a straight line unless accompanied by external forces. And, it is assumed

---

[47] Though my present purposes do not permit me to evaluate his reading of Einstein in detail, I must note that it is controversial, e.g., see Barbour and Pfister 1995 for alternatives. Also, for alternative readings of Einstein's development of GR see Stachel (2002, Ch5), DiSalle 2006.

[48] While defining inertia is a substantial problem, I am not going to engage with the debate here: I just use Barbour's definitions. But, for further discussion of inertia, see Arthur 2007 regarding its relation to time, Gasco 2003 for its relation to Mach and Brown 2005 regarding its role in GR.

[49] See Harman 1982 for an overview of inertia's role in Newton's account and DiSalle 2006 for discussion of Mach's criticisms.

[50] This sketch of Mach's reception of Newton's notions of inertia is drawn from Barbour 1995, 1989.

[51] Due to Barbour's addition of mass into his account below, which must only be in terms of the relative relations between stuff, I return to Mach's definition below and offer further explication of it.

that this uniform motion or state of rest is with respect to absolute space and time, rather than being relative to some physical body. Mach criticizes Newton's inertial motion on grounds that it should not be defined initially in terms of the motion of an isolated body with respect to an absolute space and time. Instead, one must consider motion in terms of the relative relations among observable bodies in the universe. In effect, Mach has much deeper concerns with Newton's inertial motion arising from him wanting to base motion on the relative relations among bodies in the universe.[52]

With this distinction between two senses of 'inertia', we can return to Einstein's use of the term. Because, by the lights of Barbour's conflation reading, Einstein set out about the task of providing a relational account following what he claims to be a Machian hunch, i.e., he aims to show that inertial properties of local matter are determined by the overall matter distribution of the universe. On Barbour's reading, Einstein is here addressing inertial mass in terms of Mach's proposed relational solution to inertial motion, i.e., in terms of the relative relations of the universe's matter. While he was initially convinced that GR would give full expression of this hunch, Einstein ultimately concludes that he has failed to do so. One reason for his conclusion is because of his assumption of general covariance, i.e., the laws of nature are to be invariant under arbitrary coordinate transformations, in the formulation of GR. As Barbour (2001, 202) cites, Einstein was made aware that this assumption is not based on the relative positions of stuff. Rather, it is just an assumed principle. So though, according to his GR, matter in the universe does influence inertia, Einstein is unable to demonstrate that inertia can be formulated in terms of relative relations alone.

Barbour (1989, 6) (1992, 137) untangles Einstein's task and reformulates it only in terms of the sense of inertia that he, following Mach, finds problematic, namely inertial

---

[52] Though Barbour claims the latter problem is due mainly to Mach's relationist leanings, while the former problem is just one of redefining a term, one could argue that Mach has relationist reasons for his responses to both issues. His reasons for wanting to redefine 'inertial motion' may be two-fold: it is a circular definition, and its definition must be in terms of the relative relations among bodies. His definition, as at least based upon the relative spatial relations that bodies undergo over time, could thereby be regarded as an attempt to redefine it in such relational terms. Although I won't pursue arguing for this here since this criticism is tangential to my present purposes, see Norton 1995 who illustrates an emphasis on re-description in terms of relations among bodies in the world is a persistent theme that runs through Mach's writings.

motion. He deems this task that Einstein fails to complete ‘the Machian problem’, i.e., the problem of finding a dynamical explanation of the inertial motion with reference to only bodies and their relative positions.

In approaching this problem, Einstein takes an indirect route, a route which involves showing that the laws of nature must have a form which can be expressed in the same fashion under all coordinate transformations. This route aims to solve the problem by eliminating the need for coordinate systems to play a fundamental role in the formulation of the laws. If laws that refer only to relative positions of stuff in the world are invariant in all coordinate systems, then the laws would not depend on a specific coordinate system and, thus, would not feature a background structure that is not reducible to relative relations of stuff. In effect, GR would then only fundamentally make reference to its analogues of bodies and their relative positions, i.e., fields and their relative intensities. However, as noted above, Einstein’s formation of this route makes use of the assumption of general covariance, and this assumption is not derived from or reducible to relative relations among fields. With such an assumption, he has not completed the Machian problem.

A direct route would be to formulate relativity in terms of only relative distances; however, Einstein, claims Barbour, rejects this approach. According to Einstein (1918) as quoted in Barbour (1992, 142):

> One’s initial reaction would be to require that physics should introduce in its laws only the quantities of the first kind. However, it has been found that this approach cannot be realized in practice, as the development of nonrelativistic mechanics has clearly shown. One could, for example, think […] of introducing in the laws of nonrelativistic mechanics only the distance of material points from each other instead of coordinates; a priori one could expect that in this manner the aim of the theory of relativity should be most readily achieved. However, the scientific development has not confirmed this conjecture. It cannot dispense with coordinate systems and must therefore make use in the coordinates of quantities that cannot be regarded as the results of definable measurements.

In effect, Einstein asserts that an account of dynamics cannot be cast in terms of relative distances because it ‘has not been confirmed’. Barbour (1989, 6) takes this to mean that

Einstein rejects such a route at least partially because he is convinced that it is impractical to dispense with coordinate systems in view of their necessity in the history of science.

In view of his reading of Einstein's approach to the problem, Barbour (1989, 7) questions the impracticability of the direct route:

> Reflection on these matters led to the conclusion that one ought to go right back to first principles in the Machian problem and attempt the route which Einstein had said was impracticable. In particular, the problem might not appear so insuperable if, as a first approximation, it was attacked in a nonrelativistic approach. After all, Mach had identified and formulated the problem of inertia in the prerelativistic world. Might it not be possible to solve the *nonrelativistic* Machian problem? If this could be cracked, one would at least have some definite theoretical models on the basis of which the full relativistic problem could be attacked.

Guided by the hunch that the direct approach may work if first formulated for nonrelativistic dynamics, Barbour take the direct route by first resolving the Machian problem in a nonrelativistic context. Accordingly, this starting point would offer at least some definite theoretical models on the basis of which the Machian problem in a relativistic context could be articulated. Moreover, this highlights the central role of his process of Machianizing a nonrelativistic dynamics: as we'll see, aspects of such a process and results in the nonrelativistic context are imported to the relativistic context. Whether such imports are problematic for his overall account will be illustrated through the application of ACA to it in Ch6.

This historical prelude provides some of the rationale for the path Barbour takes in developing his view, i.e., he is resolving the Machian problem via a direct route rejected by Einstein. But, to do so, Barbour follows a general method of first Machianizing Newtonian mechanics or some other nonrelativistic[53] theory, i.e., treating only bodies and their relations as fundamental and proceeding to expunge any other apparently fundamental entities, e.g.,

---

[53] I employ 'nonrelativistic' in the sense that Barbour (1989, 7) uses, i.e., to denote a something in which the concept of simultaneity is allowed.

absolute space, time, and subsequently applying these findings to a relativistic account. This method, as is made clear in §2.2, appears to some degree in all stages of his writings.

1.2 Overview of Barbour's Texts and Changing Aims

In the various stages of his writings, Barbour adopts different aims that result from the development of his Machian project. These stages come in a well-defined temporal succession. Since it is useful to delimit the scope of my application of ACA and organize this chapter in terms of these stages, I am introducing them here. The stages are inventively entitled 'Early' (1974-1980), 'Middle' (1980-2002) and 'Current' (2002-present).

During the early stage, Barbour presents and refines Machian principles, i.e., principles required for a theory that is deemed Machian. I am using 1974 as the lower bound because it is this year in which Barbour publishes a paper that first outlines a Machian principle, namely that the dynamical law of the universe must be expressed ultimately in terms only of the relative distances between the observable entities in the universe (1974, 328), and constructs a general model that automatically satisfies this principle. Additionally, working in partnership with Bertotti during much of this stage, Barbour (1989, 7) aims to develop an alternative theory to general relativity that has these principles. Their strategy to do so, which follows this historically motivated method above, is to first develop the Machian nonrelativistic theory and subsequently to incorporate basic tenants of Special Relativity (SR) in a Machian manner. The end goal (1974, 1980) is to develop the resulting theory as a Machian alternative to Einstein's general relativity (GR).

The second stage is marked by a change of the early stage's goal of finding a Machian alternative theory to Einstein's GR. During the first stage, Barbour and Bertotti were expecting to create a Machian geometrodynamics[54] with physical predictions different from those of GR (Barbour 1995). However, Kuchař motivated them to conclude that the Machian

---

[54] Contra Wheeler's 1962 geometrodynamics as an interpretation of GR, Barbour considers GR to be a special case of his Machian geometrodynamics. For instance, regarding GR's action and geometrodynamics, Barbour 1984 holds that GR requires an action which is almost uniquely determined by the requirement that the evolving three-geometries can be stacked to make a 4-d Riemannian space. In effect, GR is a very special theory among all possible theories of the dynamical evolution of g_{ij}. Ch3 further explicates this relation.

principles are already fulfilled by Einstein's GR (1989, 7, 12).[55] Additionally, Barbour and Bertotti (1984) show that they can generate GR's action principle from their Machian geometrodynamics; they can recast GR's action principle, which is usually expressed directly in terms of the 4-d metric $g_{\mu\upsilon}$, as a theory of the dynamical evolution of their geometrodynamics' Riemannian three-geometries q_{ij} (i,j=1,2,3). So, instead of developing a Machian alternative theory to Einstein's GR, Barbour now discovers that the Machian principles of their alternative actually underlie GR, and, in turn, that the basic structure of GR is Machian. Moreover, at least GR's action can be recast in a Machian fashion.[56]

Evidence of this shift first appears explicitly in Barbour 1981, 1982 and especially 1982 with Bertotti. He concludes claiming that he has shown Einstein's GR to be an example of Machian dynamics and, in effect, states that this reverses the Barbour and Bertotti 1977 conclusion, i.e., that Einstein's GR is non-Machian and that Barbour and Bertotti's Machian dynamics offers a path to a Machian alternative to Einstein's GR. Additionally, in subsequent works, notably in his 1994a and 1995, Barbour develops the Machian GR in terms of his geometrodynamics.

Thus, the Middle stage is marked by Barbour and Bertotti shifting from developing a competing alternative theory to GR to developing a Machian version of GR in terms of geometrodynamics. Additionally, he (1994b, 1999) attempts to make this Machian GR more complete by incorporating quantum theory (QT) during this stage.[57] Regarding the development of his GR, his method reflects that of his Early stage: He begins with a Machianization of a nonrelativistic theory and, subsequently, works in some of the key changes made in the nonrelativistic theory into an account that includes gravity. But, from the Early strategy he must proceed to quantize his relativistic theory and give an interpretation in order to provide an account of QT.

---

[55] Details of Kuchař's motivation are to be given in Barbour's unpublished sequel to his 1989.

[56] Ch3 explicates the manner in which the action is Machianized.

[57] As further explained in Ch5, Barbour (1994a, 1994b) incorporates QT by taking a route in which GR is quantized. In this account, he appeals to the time-independent Schrödinger equation and explains away the appearance of time via time capsules.

The third, Current stage is marked by modifications made to his proposed Machian theory in response to issues raised by some of his collaborators. Notably, Anderson (2003) (2006) (2007) presents criticisms regarding the import of certain formulae from Machianized nonrelativistic theories to relativistic theories and his deficient interpretation of QT. These criticisms cause Barbour to formally revise and reinterpret portions of his quantum geometrodynamics. Such revisions first appear in 2002 and are on-going. Thus, this stage is marked by Barbour continuing to import his interpretation of the Machian relativistic theory from his Machian nonrelativistic theory, while being in the process of modifying his relativistic theory formally by eliminating inapplicable formal imports from Machian nonrelativistic theories.[58]

Despite the developments of his Current stage, I am only going to explicate and analyse Middle Barbour. The reason for this focus is partially due to the fact that while the formulae change from the Middle to Current stages, many of the concepts and conclusions imported from the Machian nonrelativistic theory to the relativistic theory are not altered or developed much. Additionally, his account of the interpretations of QT and QG have not been developed much in the Current stage[59], and, as we see in Chapters 4 and 5, much of what Barbour does say regarding such interpretations during his Middle period is in need of much unpacking and development. Thus, because a most of his interpretive claims are

[58] Because I focus on only the Middle stage below, I note here some of the major changes in the Current stage. First, he along with Anderson attempt to develop formally the manner in which the wavefunction in his QG may be used to pick out time capsules in superspace. Second, he discovers that despite his Middle conclusions to the effect that GR is Machian, he discovers that its use of scale make it 'not quite Machian'. In view of this issue, he 2003 (and with Anderson, Foster and Murchadha 2002) aims to eliminate such scale by developing shape dynamics. In the process of developing this dynamics, he moves from the superspace of his Middle stage to conformal superspace. Each point of this conformal superspace is an instantaneous shape of the universe. Unlike superspace in which, as we see in Ch3, only all diffeomorphisms are quotiented out, this space also quotients out general conformal transformations. Furthermore, with this setup he and Murchadha 2010 claim that they can reconstruct GR, eliminate its foliation invariance, which we encounter in Ch3, and replace it with conformal invariance. Consult his 2008 for a nice summary of the developments in this stage.

[59] For example, even regarding his Current GR account, he 2011 admits that he is just beginning to understand the significance of swapping foliation invariance for conformal invariance and highlights the need to develop the conceptual implications of the recent developments of his account.

presented in the Middle period, it thus provides a relatively cohesive model in terms of it being supplemented directly with an interpretation, rather than, as done in his Current stage, being supplemented with concepts imported from his interpretations that are originally given to earlier formulae. In turn, I focus on presenting and analysing *time* as it appears in the Middle period.

1.3 The Impact on the Structuring of Chapters 2-5

This broad survey of Barbour's work allows me to provide a comprehensive exposition of the aspects of his view relevant to my analysis as follows.

Since I am focusing on the *time* that appears in Barbour's Machian geometrodynamics, I am ignoring Barbour's changing views on the relation between it and GR, which marks the Early and Middle stages. Further, because most of the setup and developments from Early Barbour relevant to his Machian geometrodynamics project are repeated in Middle Barbour, I have not included Early Barbour as a separate section in the organization of these chapters.

Nevertheless, it is important that I provide Barbour's Machianization of nonrelativistic theories, which appears both in Early and Middle Barbour. The historically motivated method of first Machianizing Newtonian mechanics and subsequently Machianizing a relativistic theory in light of the Machianized nonrelativistic theory, is used in Middle Barbour and, at least interpretively, in Current Barbour. Because we must track the origins and development of temporal concepts that appear in his quantum geometrodynamics, I begin my exposition with Barbour's Machianization of nonrelativistic theories in this chapter. Then, I present his Middle moves from Machianized nonrelativistic theories to a Machian GR in the next chapter. Finally, the means by which Middle Barbour quantizes geometrodynamics and timelessly interprets the quantum is provided in Ch4 and Ch5.

2 Machianizing Newton

To motivate and explain his Machianization of Newton, I present Barbour's moves in the framework of his (1974) and (1982) Machian and Leibnizian principle-driven approach.[60]

This approach aims explicitly to address the Newtonian challenge for relationists, i.e., to formulate a relational version of Newton's dynamical laws of motion. Since Barbour holds that the aim of dynamics is to characterize the change of variety quantitatively, a demonstration that one can construct dynamical schemes in which 'the change of variety is described in terms of the variety itself' is needed to meet the challenge.

He (1974), (1982) and Barbour and Bertotti (1982) approach the challenge by first identifying a number of philosophical principles. As will be pointed out, Barbour considers some of these principles essential for the relational case, while others contribute towards the development of such relational dynamics. Then, he proceeds to show how these principles can be used to construct an alternative relational framework.

I shall proceed to present Barbour's account in a fashion parallel to that described in the previous paragraph: First, I provide the principles Barbour mentions. Then, I illustrate the manner in which Barbour uses these principles to construct a relativistic Machian account of dynamics. Furthermore, the account itself, as found in his (1974), (1982) and Barbour and Bertotti (1982), will be supplemented with relevant developments that occur in later Middle Barbour publications. Even though these later publications largely drop the principled approach, most of the relevant developments have precursors in the earlier works. Nevertheless, as we will see in later chapters, these principles play a prominent role in motivating all his of accounts.

2.1 The Principles

As we've seen, his approach of Machianizing Newtonian mechanics first as a means of generating a Machian GR is motivated by his reading of Einstein. However, the means by

---

[60] In later texts he provides a streamlined presentation of his Machian nonrelativistic dynamics without much reference to these principles, and Barbour 1995 provides an alternative manner of motiving his account via two 'Machian requirements'. While these alternative presentations of his account might appear clearer, the Leibnizian presentation of his account makes his metaphysical motivations and intended ontological implications more apparent, which are important given our task of applying ACA.

which he generates this Machian mechanics is principle-based. As mentioned earlier, Barbour uses two types of principles: those that a relational theory must uphold, and those that are used, ultimately, to formulate a relational dynamical theory that fulfils the former principles. I call the former type of principle ‘relational principles’, and the latter ‘fulfilling principles’.

Note, moreover, that Barbour (1982, 254) does not regard the fulfilling principles, “as necessary truths but only as convenient for characterising the manner in which specific theories of motion can be regarded as meeting the relationist ideal.” In effect, it seems that these fulfilling principles are not required for building a relational account. Instead, they are, perhaps, only one among many different sets of principles for building a relationist dynamics. Such contingency is important because all of these principles that Barbour uses are drawn from those of Leibniz. This assumed contingency allows for a more liberal reading of Leibniz’s fulfilling principles because we are not necessarily restricted to Leibniz’s intended meaning and application of his principles; there is not one set of fulfilling principles, e.g., exactly those that Leibniz uses, that Barbour must use.

2.1.1 Relational Principles

Barbour mentions two general relational principles. The first that we’ll discuss is one that provides the minimum ontological requirements for a relationism. The second is a general Machian principle that Barbour subdivides into two subprinciples.

To set the stage for the ontological principle for relationism, we best define what he means by ‘relationism’. A relationist is defined (1980, 2) as one who holds that, “only things (strictly […] *perceived* things) exist, but they bear relations to another. [A relationist] dynamics should therefore be concerned with these relations and the manner in which they change.” In view of this quote, it seems that a relationist holds that only perceived things exist that can bear relations to each other. But, this brief definition gives rise to a number of questions: In what sense are things ‘perceived’, and how does this bear on the issue as to whether a thing is deemed ontologically acceptable for the relationist? What are these relations these things bear to each other, e.g., do these include only relative positions?

To answer these questions, we must consult his 1982 in which he puts this in terms of ‘perceived variety’:

> [P]erceived variety is the starting point of all science. There is however a pronounced tendency in science to degrade variety and operate as far as possible in terms of homogeneous or uniform substances. […] [V]ariety is the starting point of Leibniz's ontology; moreover, I believe that the whole tendency of Leibniz's philosophy is to present science, not as the explanation of perceived variety in terms of something which is as uniform as possible, but rather as the recognition of order and unity within the diversity. (1982, 251-2)

> What I suggest is needed is a demonstration that one can construct dynamical schemes in which the change of variety is described, not in terms of a uniform standard, but in terms of variety itself. (1982, 253)

Given the final quote, it seems the Barbour is following what he claims to be Leibniz's lead regarding ontology: only perceived variety exists. And, in effect, he aims to construct a dynamics in terms of only this variety and the manner in which it changes. The variety, further, is contrasted with 'homogeneous or uniform substances'.

However, his 'perceived variety', what it means to 'be perceived' and how such variety contrasts with things he describes as 'uniform' or 'homogenous' require some unpacking. As Barbour is drawing his general ontological commitments from what is presented in Leibniz, it seems that much of this terminology is borrowed from Leibniz. So, let's turn to some positions attributed to Leibniz regarding variety, its perception and its relation to uniform things.[61]

---

[61] I realize Leibniz's overall metaphysics and epistemology is the subject of much historical debate and was modified throughout his life, e.g., as documented in Mercer et al. 1995, Mercer 2001 and Rutherford 1995. And, I acknowledge that I do not attempt to provide an assessment of the secondary sources I use in order to cash out what Barbour may mean by his Leibnizian terminology. Because his approach to historical texts is to read the source material, Barbour's reading of Leibniz may, ultimately, not reflect either a comprehensive reading of Leibniz or one that is in accord with prominent readings of his view in the secondary literature. So, my use of certain secondary sources here is only an attempt of making sense of the terminology and how the associated concepts may be related. Moreover, I have included quoted passages from Leibniz more for the purposes of illustrating the similar use of terminology than for providing a comprehensive analysis of the passages.

Without going too deep into the details of Leibniz's account, monads are its fundamental entities. Monads are simple, indivisible substances, and something is a substance iff it obeys the Principle of the Complete Notion of a Contingent Thing, which is defined on p.62 below. Each body is made up of an infinite number of monads. Moreover, some of these monads can have perceptions and apperceptions. In the context of distinguishing souls, which are monads in his account, that have both perceptions and apperception from those that only have the former,[62] Leibniz characterizes them as follows:

> It is well to make the distinction between perception, which is the internal state of the monad representing external things, and apperception, which is consciousness or the reflexive knowledge of this internal state itself. (*Principles of Nature and Grace* IV)

In effect, apperception, as the result of a monad reflecting upon its internal state, is contrasted with perception, as the result of the monad representing things that are external to it. So, if Barbour is borrowing Leibniz's terminology here, it seems that 'perceived variety' is variety that is external to the perceiver. Crudely, he merely appears to make reference to stuff that exists in the world of which we can have sensory experience.

But, what exactly counts as 'perceived variety' for the relationist? Does it only include the medium-sized dry goods of our daily experience? If he aims to provide an account of Newtonian mechanics, GR and QT, which standardly are considered to have basic stuff that is not 'perceived' in the same and relatively direct manner as, e.g., tables and chairs, it seems that this variety might refer to, e.g., point particles, matter fields, electrons. In the context of physical theories, these entities could still be regarded as perceived in some sense, e.g., an electron could be detected by one seeing a streak in a cloud chamber. This ambiguity also arises over the course of Barbour's discussion, e.g., he (1995, 224) claims that this stuff can be mass points, fields or matter fields defined on Riemannian 3-geometries, but he elsewhere makes references to relative positions of a pointer on a measuring device that we see in the same manner in which we see tables and chairs. In view of such considerations, it appears that Barbour's use of 'perceived' here to be indicative of a certain type of variety is ambiguous: the variety to which it refers could be either that which we experience in day-to-

[62] For discussion, see McRae 1995 and Rutherford (1995, 137).

day life or that of which our best scientific theories are indicative. Further, as he holds that it is such variety that a relationist regards as ontologically fundamental, determining in which sense he uses this term is essential to his entire project. Nevertheless, I am going to bracket off this issue for now but will return to discussion of it in my Ch6 analysis of his project because his employment of this vague ontological principle varies.

So, given that perception, as Leibniz characterized it, is of stuff that is external to oneself, it seems that we can at least say that such perceived variety is something out in the world. But, what is this variety? Leibniz's distinction between variety and uniformity helps elucidate to what 'variety' may refer.

As echoed in the quotes above, Leibniz makes a distinction between variety and uniformity.

> Things which are uniform, containing no variety, are always mere abstractions, for instance, time, space and other entities of pure mathematics. (New Essays II.1.2)

> [I]n actual bodies there is only discrete quantity […]. But a continuous quantity is something ideal which pertains to possibles and to actuals only insofar they are possible. (1975, 539)

Here, time and space are deemed to be uniform and lacking in variety. As such, they are regarded as 'mere abstractions'. According to McDonough (2007), Leibniz holds that the notion of a fixed, uniform space or time is abstracted from the relative spatial and successive relations that bodies bear to each other. As such, this fixed, uniform space is not ontologically basic. Moreover, as these mere abstractions are contrasted with variety, it seems that variety must be more ontologically basic.[63] Actual things are made up of a number of discrete quantities corresponding to their infinite monads. Thus, it seems actual things exhibit infinite variety. In effect, we get a similar distinction to one that Barbour makes.

---

[63] However, as McDonough 2007 notes, Leibniz's later views as to the basic ontology of the world shifted to an arena of monads in which there is not even relative spatial or temporal relations. So, such relative relations would be one step removed from his fundamental ontology while the fixed, uniform space and time are two steps removed in this later account.

Time and space qua uniform structures are not ontologically basic, while variety in the world is.

From our previous discussion, we know that this variety includes the existing stuff in the world. But, recall that Barbour claims these things bear relations to each other. What relations can be born to each other on the relationist account? Leibniz seems to accept that there are both relative spatial and temporal relations that hold between things. In the Leibniz-Clarke correspondence, Leibniz (1999, 146) states:

> As for my own opinion, I have said more than once, that I hold space to be something merely relative, as time is; that I hold it to be an order of coexistences. As time is an order of successions.

As space and time are just 'orders of coexistences', things can have spatial and temporal relations in the sense of being in relative distances to each other and being related through succession to each other.

If Leibniz's stance on space and time as sketched above is indicative of the notion of relationism[64] that Barbour has in mind, then it seems that the variety is made up of stuff in the external word and this stuff can bear certain relations to each other, namely bearing distances to something and being successive. However, as there is only such stuff, these relations can only be borne among this stuff. In effect, there can only be relative distances and successions between the points. Moreover, time and space qua abstracted uniformities are not ontologically basic. Some examples of such relative relations that Barbour (1995, 224) provides are the relative configurations of a field that are defined by field intensities and Riemannian 3-geometries. While an account remains to be developed of the former by Barbour in detail[65], explanation of the latter is provided in Ch3's presentation of his geometrodynamics.

---

[64] Although I do not compare Barbour's relationism with other forms of it, see Earman 1989 for discussion of different accounts of relationism and his 2008 for discussion as to whether Leibniz is a relationist.

[65] However, see Pooley 2001 for a manner in which such an account can be developed.

Now that we have unpacked 'perceived variety', we can present Barbour's project as well as his relationist ontological principle. As in the quote above, he claims that stuff and their relative spatial and temporal relations is the starting point of all science. However, he notes, there is a tendency in science to operate using the abstracted uniform substances. Some examples of such 'substances' he (1982, 252) provides are Newtonian mechanics' absolute time and space, SR's Minkowskian space-time and GR's use of uniform frames of reference. As these accounts utilize something uniform that is a mere abstraction from the relative spatial and temporal relations that are among the stuff of the external world, he aims to construct a dynamics in which 'the change of variety is described in terms of the variety itself'. That is, he wants to describe the change of the universe's stuff and its relative relations in terms of this stuff and relations. The requirement of such descriptions is specified in his Machian principles below, but let's first cash out his ontological principle.

Here is Barbour's (1982, 254) minimal ontological principle of the relationist standpoint:

> (ONT_0) The existence of things is established through perceived variety and abstract uniformity is nothing.

Given the preceding discussion, this becomes:

> (ONT) Strictly speaking, the ontologically basic things are stuff[66] in the external world and their relative distances and successions to each other, and anything abstracted or derived from this stuff does not exist.

In ONT, note that it is not specified whether the distances and successions are spatial or temporal. I formulated it in this vague manner because, as we shall see below, Barbour formulates what we would consider to be temporal successions of spatial configurations in terms of differences in relative spatial positions alone. This partially results from his choice of static configurations of all the stuff in the universe to feature in his description of

---

[66] I use 'stuff' here to characterize the non-relational entities of Barbour's perceived variety, which, as discussed above, may be medium-sized dry goods or the entities posited by certain scientific theories. It has been chosen because it does not have that much metaphysical baggage associated with it.

dynamics, which is in fulfilment of MP2 below.[67] Such entities are presented as the basic ontological elements of his account. Due to the fact that such a configuration only has relative spatial relations, any temporal relations are not ontologically basic. So, when I mention ONT in the context of Barbour's account, its relative distances and successions are assumed to be spatial ones only or are reducible to them.

Further note that in Barbour's 1980 quote, he states that only things exist and they can bear relations to each other, but his 1982 is in terms of variety: stuff in the world and their relative relations. Due to the vagueness of both of these formulations it is not clear whether the relative relations have the same ontological status as the stuff. Such relations do depend on the stuff to be there for their existence and magnitudes. So, perhaps they are not as basic as the stuff if independence is a requirement of being ontologically basic. However, we will follow Barbour (1982, 255) and gloss over this issue for now, but we return to its ramifications for his view in Ch6.

This brings us to the second relational principle: the general Machian Principle (MP). MP requires that the dynamical law of the universe, i.e., a law that characterises the change of variety in the universe quantitatively, "be expressed ultimately in terms only of the relative distances between observable entities[68] in the universe" (1974, 328). Barbour (1982, 260) uses two specific versions of MP, and we will follow suit since this division provides a useful means of dividing up Barbour's account as follows with §2.2.2 and §2.2.3. The two specific versions are the First Machian Principle, which applies to space, and the Second Machian Principle, which applies to time. In more detail:

> (MP1) The First Machian Principle: The dynamical law of the universe must be expressed ultimately in terms only of the relative distances between stuff in the

---

[67] Additionally, as we'll see in Ch4 and Ch5's presentation of his solution to the problem of time in quantum geometrodynamics, he aims to eliminate any ontologically basic sense of temporality.

[68] In the context of Machianizing Newtonian mechanics, Barbour follows Newton in assuming that observable entities are particles. However, as will be discussed later in the context of GR, these observable entities may be considered to be matter fields; however, Barbour presents his GR in terms of *pure* geometrodynamics in which there are only manifold points and their geometrical relations.

universe, and not ultimately in terms of a space that it is anything over and above the relative distances of the stuff.

(MP2) The Second Machian Principle: The dynamical law of the universe must be expressed ultimately in terms only of the relative distances between stuff in the universe, and not ultimately in terms of a time that is anything over and above the relative distances of the stuff.

These principles are often presented by Barbour in the context of teasing out MP2 from what he claims to be Mach's actual principle, i.e., MP1,[69] for the purpose of Machianizing Newton. But, as 'stuff' is used above, these principles can be used in the Newtonian context to refer to point particles as well as in the GR context to refer to the non-gravitational fields. Moreover, MP1 bans Newton absolute space and time as they were formulated independently of the bodies' relative relations. And, MP2 bans the use of some fixed time parameter that does not somehow emerge from stuff's relative distances.

In effect, with the above division of the general Machian principle into one that refers to space and one that refers to time, it seems to be easy to assess whether such principles are fulfilled by accounts, e.g., certain formulations of Newtonian mechanics, in which space and time can be separated. Moreover, to assess whether an account in which space and time are combined is Machian, one can consider whether the conjunction of the two principles is fulfilled.

Thus, Barbour posits two relationist principles. ONT sets requirements on the ontology, while MP sets requirements on what terms are permissible in one's dynamics.

2.1.2 Fulfilling Principles

---

[69] Rovelli (2004, 76), however, notes that there is no well-defined principle presented by Mach. Rather, the formulation of such a principle(s) is the result of varying discussions of the implication of a suggestion made by Mach, which is in the context of Newton's spinning bucket argument, for GR. Mach's suggestion is that the inertial reference frame for a spinning bucket is determined by the entire matter content of the universe, rather than by absolute space. From discussions of this suggestion, a number of formulations of a principle based on it are presented as Mach's principle. See Rovelli (2004, 76) for a list of eight such principles.

There are four fulfilling principles. All of these are attributed to Leibniz, and all play a role in the development of Barbour's relationist dynamics. However, unlike Barbour, I have augmented the prominence of the second and fourth principles and have changed the order in which all the principles appear, which mirrors their later appearances in §3.2, for the sake of clarity. The principles follow and are explained further where necessary.

The first principle Barbour uses is:

> (CNP) Principle of the Complete Notion of a Contingent Thing: One must attribute to something, *x*, a notion so complete that everything that can be attributed to *x* can be deduced from the notion. (1982, 261)

Leibniz[70] makes a distinction between two kinds of concepts: complete and incomplete or abstract. An incomplete concept is not in nature, strictly speaking, and arises partially from thought, e.g., the abstracted concepts of space and time rejected by Leibniz above. On the other hand, a complete concept is one that is characterized by CNP: it contains within itself all the predicates of the subject of which it is the concept. In other words, if an entity is characterized by such a concept, then all the predicates that are attributed to the entity can be deduced from this concept. Leibniz's monads are characterized by such a concept. As we'll see shortly, Barbour applies CNP to static configurations of the entire universe.

The next fulfilling principle is:

> (UNP) A Principle of Unity: A principle that tells us why a certain plurality is a true unity and not a mere unity by aggregation. (1982, 266-7)

For Leibniz there are two kinds of entity: substance and entity by aggregation. Each of these entities has a different kind of unity. He regards substances, e.g., monads, to have true unity, while aggregates, e.g., a body, have a unity that results from the activity of our imagination on what we perceive. Barbour provides some examples of UNPs, and we can make recourse to these in order to determine what something requires to be a true unity.

[70] This is drawn from McRae (1995, 190, 185).

He (2003, 54) gives the ‘modest’ example of a graph that has its points connected. By expressing the points’ relations to the other points, the graph is supposed to have a UNP. With this example, it seems that a UNP can be cashed out in terms of a description of the relative distances that hold between points at a time.

Another example Barbour (1982, 266) provides is that of Heisenberg’s matrix. Heisenberg discovered similar relations between matrices of numbers, which lead to the development of quantum mechanics. He claims that Heinsenberg considered these matrices to represent relations between quantities that are observable in principle.[71] Thus, Barbour (1982, 266) states that such relations “could be said to express the particular [UNP] that inheres in the given set of data.” Additionally, these congruences are further captured in equations, e.g., Heisenberg’s equation of motion, which Barbour considers to be the mathematical expression of these congruences. Here, it seems that a UNP is obtained in view of only the relative relations between stuff in the world. Moreover, Barbour assumes that this description can be put in the form of an equation. So, it seems that a UNP for Barbour is a description qua equation or mathematical representation of stuff’s relative relations. Given MP, such a description can only refer to relative relations. Thus, Barbour must hold that a UNP must only at base be a description of such relations. Otherwise, if any entities in violation of ONT and any expression in violation of MP are used, i.e., if there are entities or expressions involved that are not of stuff’s relative relations or reducible to them, then the resulting description is not a UNP.

Further, note that though Barbour does not make explicit whether equations incorporate a type of unity that differs from that expressed in the congruences of sets of numbers in, e.g., matrices, he does state that congruences of sets of numbers “are between definite things […] which have been derived from observation of variety” (1982, 266). So, for the purposes of fulfilling our Machian requirements and ONT, it seems that the crucial feature that Barbour is highlighting regarding UNPs is they must at least start from perceived variety, be in terms of the relative instantaneous relations among stuff and not violate ONT or MP in the process of their formulation.

---

[71] For an introduction to the role of observation in the construction of matrix mechanics, see Cushing (2003, 282-6).

Does Barbour imply a similar distinction to that of Leibniz between entities that are true unities and entities by aggregation? It seems that he does have a distinction. As we'll see below, one could say that the instantaneous configurations of all the stuff in the universe are the fundamental entities in his account. In effect, only such a configuration may have true unity. Other accounts of the unity of the world that feature things that are actually abstracted from stuff and their relative positions at an instant, e.g., absolute space, local frames of reference, may be regarded as referring to an entity by aggregation, e.g., Newton's universe in which there is an absolute space plus stuff and relations. Moreover, while it is interesting to draw such a parallel between Leibniz's use of the UNP, Barbour does not explicitly make use of an analogue of entities by aggregation; he mainly employs the UNP, as we'll see below, in his formulation of a Machian non-relativistic mechanics, rather than as a means of drawing a distinction between two kinds of entities.

Next, here is the third fulfilling principle[72]:

> (PII) Principle of the Identity of Indiscernibles: Two things which are completely indiscernible with respect to all their qualities are in fact the same thing. (1982, 254)

Leibniz uses this principle throughout his writings. As McRae (1995, 179) cites, one manner in which he uses it, which is relevant for our purposes, is to serve as a means by which substances are distinguished from each other in virtue of their internal qualities. Though I discuss the ramifications of this principle for Barbour's account in Ch5, we can note here that because his instantaneous configurations of the universe play a role in his account that somewhat parallel that played by substances, it seems that this principle may be used to limit the set of possible configurations of the universe to a set that contains no copies.

Moreover, this principle can have different strengths depending to what these 'quantities' refer. In view of ONT as well as Barbour's use of this principle, which we'll see

[72] For discussion of the role of PII in QT, see Ladyman and Bigaj 2010.

shortly, 'quantities' includes the monadic, non-relational properties of external stuff themselves as well as their relative spatial relations.[73]

Finally, the last fulfilling principle is:

(PSR) Principle of Sufficient Reason: Nothing can be true or existent for which there is not a sufficient reason or cause why it is so.

According to Leibniz, PSR is one of two principles on which reasoning is based.[74] Barbour (1982, 254) mentions it and assumes that it is true in the formulation of his account. However, it is debatable whether certain truths require such reason or whether PSR is even contingently true.[75] Nevertheless, we'll just assume it, along with Barbour, for the purposes of creating a Machian principle-based dynamics.

2.2 The Machianization of Nonrelativistic Mechanics via the Principles

Barbour uses these fulfilling principles in order to construct a nonrelativistic relational dynamics, which, in turn, can be used to derive key Newtonian equations. However, before giving the details of the resulting account, I provide an outline of how the fulfilling principles generate an account which fulfils the relational principles.

Barbour starts by using CNP to carve up the universe into instantaneous configurations. Next, he uses UNP to generate the relational arena, i.e., one in which he can describe the relative relations of each instantaneous configuration of the universe. Then, he uses the resulting configuration space in order to generate a means of quantifying change of variety in terms of variety itself and, thus, provides a start to a dynamics that satisfies MP. This dynamics is further developed, aided by PII and PSR, in order to fulfil MP1. Finally,

---

[73] See Rodriguez-Pereyra 2006 and Black 1952 for general discussion of PII. For a discussion of it in the context of quantum mechanics, see French and Krause 2006. I do not evaluate PII because my main aim is to specify it as it appears in Barbour and evaluate the presence of (or lack thereof) temporal concepts that appear in his resulting account.

[74] The other is the Principle of Contradiction: A proposition cannot be true and false at the same time.

[75] For discussion of PSR, see Pruss 2006 and Parkinson 1995.

the dynamics is developed to fulfil MP2 via insight from PSR. Thus, Barbour appears to develop a nonrelativistic Machian dynamics, a dynamics that satisfies MP1, MP2 and ONT.

2.2.1 The Development and Relationalism of Configuration Space

Barbour begins by specifying the raw material, i.e., the stuff in universe, with which his is going to build his dynamics and satisfy ONT. He uses the CNP to do so by claiming that:

> the position of a body is defined, and moreover completely, by its relation (distance) to *all* the other objects in the universe. (1982, 269-70)

Recall that CNP states that one must attribute to something, *x*, a notion so complete that everything that can be attributed to *x* can be deduced from the notion. Here Barbour claims a body is defined completely in terms of its relative relations to all other bodies in the universe at an instant[76]. Such instantaneous configurations of the universe in which each body is completely defined by is relative spatial relations to all other bodies satisfies ONT; only stuff and their relative spatial relations at an instant are proposed. Moreover, as was mentioned in my presentation of ONT, because such static configurations and their spatial relative relations are proposed as the raw material, he eliminates any sort of temporal relative successions from ONT. Instead, his dynamics is, at base, in terms of spatial relations, with any temporal succession being derived from instantaneous spatial relative relations. I must emphasise here that this lack of fundamental temporal succession is essential in Barbour's overarching claim to be able to eliminate time from his accounts. If he can successfully eliminate or reduce such relations to relative instantaneous spatial relations, then it seems that temporal relations do not play a fundamental role in his account.

Next, Barbour (1982, 268) claims that a UNP is sufficient to develop an entire theory of dynamics. To illustrate this claim and develop his dynamics' key element of configuration

[76] The use of 'instant' is not intended here to refer to some unit of time. Instead, it refers to a static configuration of all the bodies in the universe. Presumably, you can obtain the same configurations if you, e.g., divide a 4-d representation of a universe evolving in accord with Newtonian mechanics by making slices of infinitesimal length along the time axis. The result would be a bunch of 3-d static slices, and it seems to be such slices Barbour has in mind when he uses 'instantaneous configurations' in this context.

space[77], two assumptions are made. First paralleling Newtonian theory, assume that the universe consists of N bodies in a fixed three-dimensional Euclidean space. Second, assume that our knowledge about these N bodies consists of the sets of numbers corresponding to their relative distances at an instant.

So far, only one particular realization of the universe has been described in the form of the sets of numbers. But, this realization of the universe has an UNP in the sense described above; just as with the graph example in which connections of all its points express its UNP, the sets of numbers corresponding to the relative distances of the N bodies provide a UNP of the universe.

How do we generalise the UNP? Barbour claims we can extend it as follows. Any other different relative configuration of the N bodies in Euclidean space would have a different set of relative distances, but they would still have a UNP of the same form. What exactly Barbour means by 'same form' here is not specified. However, in view of our discussion of UNP above, it must be a function of relative distances. In this case, it seems to be a function of the universe's N bodies relative distances at an instant, i.e., $UNP(r, N)$. r represents all possible sets of numbers that correspond to the N bodies' possible relative positions, with each set representing a distinct possible static configuration of the N bodies. Thus, with such a generalised UNP, we are able to consider other possible static configurations of the universe.

It is from all possible static configurations of the N bodies that we obtain a configuration space (c-space). Each point in the c-space corresponds to a set of relative relations of the N bodies subject to the UNP. Moreover, Barbour (1982, 268) claims that each point stands in a one-to-one correspondence with the set of all possible distinct configurations of the N bodies. With this requirement and PII, it seems that c-space contains

[77] Barbour refers to c-space points as 'instants'. However, I will largely avoid this terminology because of its temporal connotations.

no copies[78] of configurations; because each point must represent a possible distinct configuration, c-space cannot contain two c-space points that correspond to the same configuration of the N bodies.

Before moving on, there are two things to note about Barbour's c-space. First, unlike, e.g., the points of a coordinate system or the points of a manifold, Barbour's c-space points are, so to speak, loaded.[79] The points of a manifold are usually[80] considered to be uniform and largely featureless: a manifold is just a collection of points that has topological properties, e.g., being smoothly connected and of a certain dimension, but it lacks geometrical properties. Each c-space point, on the other hand, represents all the relative distance relations of the universe's stuff at an instant. Moreover, in the context of his nonrelativistic dynamics, c-space's structure is unclear: he (1986) characterizes it as a heap of all possible instantaneous configurations of the universe, but below we see he refers to a possible history as a path in c-space. Such tracing may imply that c-space has a structure. We'll see that this ambiguity in the presentation of his nonrelativistic dynamics also reappears if one compares his relativistic account, in which c-space has a structure, with his quantum account, in which c-space is described as a heap. While I do not resolve this ambiguity in his nonrelativistic model, it will be discussed in the contexts of GR and QT in Chapters 5-6. Additionally, the significance of his use of 'heap' is discussed in Chapter3 due to the large role it plays in his QT.

Second, the use of such a space does not *ab initio* violate ONT or MP. Barbour (1982, 267) indicates this when he claims that his use of space merely, "permits an economical and perspicuous representation of the salient data." In other words, c-space is just a means of representing the relative relations that stuff in the universe may have. If such

---

[78] It is important to highlight the requirement that this possible space lacks copies here. We return to this issue in Ch5 since probability in his QT and QG is supposed to be indicative of the number of actualized copies of c-space points.

[79] Such c-space point loadedness is also used in Pooley's 2001 discussion of sophisticated substantivalism.

[80] This is, of course, barring any primitive identity or the like that one may attribute to them in response to the hole argument. See Hoefer 1996 and Stachel 1993 for discussions of such attributing. In Ch3 we'll see the manner in which this setup supposedly avoids this argument.

space is merely playing this representing role, then it seems that the space adds no description that is over and above the universe's relative relations among bodies, which is in accord with MP. And, as a representation of such relations, it does not appear to add any entity that is not reducible to objects and their relative relations, which is in accord with ONT. However, the issue of whether his c-space *only* plays this representing role is questionable given his QG and is taken up in Ch5.

Let's return to Barbour's account of dynamics in terms of c-space. He has some revealing claims about motion. With c-space, he (1982, 268-9) claims that in contrast with conventional dynamics in which the motion of a body in considered in the arena of a, e.g., Euclidean space, in his view we:

> consider *the motion of the universe in its [c-space]*. The first main advantage is that dynamics is immediately restricted to what is observable. One uses in fact the entire [relative spatial relations of the universe at an instant] and nothing more. A possible *history* of the universe is then any continuous curve taken by the universe in its [c-space]. The second main advantage is that Leibniz's idea of time being merely successive order of things finds very simple expression. Namely, we say simply that the passage of time just reflects the fact that the universe is moving along some particular curve in [c-space].

Notice here that Barbour is writing in terms of the universe itself moving through c-space. Recall that each c-space point is supposed to *represent* a possible static configuration of the universe; it is a set of numbers that corresponds to all the relative special distances between stuff in the universe in a possible configuration. But, here Barbour is speaking in terms of the actual universe tracing a path through c-space. With his talk of the universe moving through c-space, he is paralleling conventional dynamics' practice of being in terms of objects moving through space.

Prima facie, this slide from the descriptive arena of c-space to a space in which the actual universe traces a path seems to import temporal order and temporal succession in violation of ONT. If the universe actually does trace out such a path, then it seems that we have a series of temporally ordered c-space points that originated from the universe's movement through c-space. Thus, it seems that there exist temporally ordered c-space points that are arrived at through an appeal to the 'motion' of the universe through c-space. ONT is in turn violated because there is temporal order and temporal succession that is not reducible to relative spatial relations among stuff.

However, this description-to-ontology slide, at least as presented above, does not violate ONT in this manner. As we shall see, he provides a dynamics in which c-space points are stacked in terms of their relative spatial relations only. Such a stacking of c-space points corresponds to what would be termed a 'history of the universe' So, the talk of 'the universe tracing paths' above should be read in terms of the existence of a set of static configurations of the universe. As such histories are constructed only in terms of relative spatial relations, ONT is not violated and any associated temporal succession is reducible to relative spatial relations. So, at least ontologically, such slides from description to ontology do not seem problematic. This is because both MP, which dictates that the description must be at base in terms of relative spatial relations only, and Barbour's ONT, according to which he is committed to there being stuff and their relative spatial relations only, make recourse to relative relations of the spatial kind only. But, recall that ONT, unlike MP, also involves stuff, which can have monadic properties. So, as long as the stuff's monadic properties are not required in MP's description, then such description-ontology slides are acceptable, and I follow Barbour in making such slides. However, later we will discuss whether monadic properties are imported via these slides as a means of getting the resulting description to work.

So, to put the content of the above passage in justifiably less temporally-loaded terms: Through this c-space Barbour provides a means to express time in terms of paths through c-space, but such expression, he claims, does not commit him to some abstract generalization that violates ONT. Rather, time merely corresponds to the ordering of c-space points via their relative spatial relations. A possible history corresponds to any continuous curve through c-space. Thus, Barbour claims that c-space paths can reflect what we would term 'the passage of time'; the passage of time merely reflects the fact there exist a certain set of c-space points that is ordered via their relative spatial relations. Moreover, PSR demands that we find reason for why there exists a set of c-space points corresponding to a certain path in c-space. Thus, to find reasons as to why a particular path manifests, we must turn to Barbour's dynamics.

2.2.2 The Development of Intrinsic Dynamics I: Fulfilment of MP1

Barbour initially develops a dynamics that fulfils MP1 by using c-space and CNP. By c-space and CNP, he obtains a means to quantify change of variety in terms of variety itself and, thereby, establishes the foundation for a dynamics that seems to satisfy ONT. In other words, he seeks to quantify how much the relative relations of the universe's stuff changes when the universe 'passes' from one configuration to another. This dynamics is then further developed in view of PII and PSR in order to fulfil MP1.

To "introduce a bit more variety into the scheme" (1982, 269), Barbour asks us to assume that we are able to associate a positive mass with the N bodies constituting the universe.

Presumably in order to maintain MP, this additional variety must be expressed in terms of the bodies' relative spatial relations. Barbour's (1989, 676 ff.) historical discussions of Mach's analysis of inertial mass, which was mentioned earlier, illustrates a manner in which this can be done.[81]

Recall that Newton defined inertial mass as the quantity measured by a function of a body's volume and density.[82] Newton's discovery of the universal law of gravitation provides some motivation for introducing such a mass concept as distinct from weight. Partially because this concept of mass mutated into some*thing* in matter that measures inertia after Newton[83], Barbour (1989, 684) characterizes Mach as aiming to clear this and other "metaphysical cobwebs out of the kitchen of physics."

---

[81] Plus, Barbour (1982, 269) supports the unproblematic nature of this addition by stating that astronomers can succeed in assigning a positive value to certain bodies. This can indeed be calculated from the rotation of, e.g., a planet around a star, and the distance from the observer to the star. See Zeilik 2002 for the manner in which such mass is calculable.

[82] Barbour (1989, 682-3) suggests Newton has a different notion of density, i.e., one which varies according to how close the pieces of matter, which are all identical, are packed together, that is inherited from the Cartesian plenum.

[83] See Harman (1982, 13-7) for an overview of the development of Newton's inertial mass, which Newton eventually formulated in terms of an inherent force in a body.

Guided by the notion that a successfully functioning scientific theory must rest on experimentally observable phenomena, Mach proceeds to build up the concepts of dynamics by starting with the fundamental geometrical ones; in the context of classifying mass and force, he starts by presuming distance measurement, the existence of clocks as chosen from some convenient standard, e.g., the intervals in which the Earth turns through equal angles, and a frame of reference, which is defined by distant stars, with respect to which all motions are to be defined. Next, Mach begins to stratify this setup for dynamics with an "observational fact" (1989, 685), namely, the law of inertia, i.e., "In the frame of reference defined for practical purposes by the stars, the bodies are usually observed to travel in straight lines with uniform speed."

From this layer, acceleration must be addressed starting, of course, with observed accelerations. The observational facts concerning acceleration are: Normally bodies travel on straight lines relative to the stars, but, under certain conditions, at least two bodies can mutually accelerate each other. One example of such mutual acceleration is collisions.

Consider the collision of $body_1$ and $body_2$ in a straight line. Each body is observed to undergo a change in velocity, i.e., $\partial v_1, \partial v_2$, as a result of the collision. It results that if the pre-collision velocities are varied, then the bodies' change in velocity varies as well. However, the ratio between each set of velocities, e.g., $\partial v_1/\partial v_2$, is always equal to the same number $-C_{12}$.

Further, suppose that there is a third body. Collision experiments are performed between $body_1$ and $body_3$, and $body_2$ and $body_3$. The constants that are found, i.e., C_{13} and C_{23}, have this relationship:

$$C_{12}C_{23} = C_{13}$$

It is the existence of such relationships, Mach claims, that makes the introduction of the mass concept possible via associating with each body *i* a mass m_i such that $C_{ij} = m_i/m_j$.

Supposing that Mach can successfully determine mass by using bodies' relations alone, it seems that mass can at least be described in terms of relative relations alone. As such, MP would not be violated. Does this violate ONT? One could plausibly argue that, due to ontologically parsimony, we can eliminate any sort of mass property because it can be cashed out in terms of relative relations to which we are already committed. In effect, any monadic mass property should be eliminated. Thus, the fulfilment of ONT can be argued for.

However, if such a reduction is in the offing, the introduction of mass *as* variety by Barbour above is odd; it seems more accurate to state that mass is reducible to the objects' relative relations, rather than to introduce mass as an additional type of variety. More importantly, I will later question whether Barbour's initial use of mass here offers a means of identifying bodies across c-space points that cannot be later reduced to objects' relations. So, let's assume for now that 'the variety' refers, strictly speaking, to objects and their relative relations alone and that mass is reducible to this variety. In effect, he aims to solve the problem of quantifying the change in the relations of the N bodies from one configuration to another and fulfilling UNP only in terms of these N bodies' relations, but can legitimately use mass because it is derivable from the N bodies' relations.

With such mass, Barbour (1982, 270) proceeds to give an account of 'change of position'. Since by CNP the position of a body is defined in terms of its instantaneous relations to all other bodies, it seems that change of position ought to also be in terms of its relations to all other bodies. So, CNP and ONT motivate Barbour to give an account of 'change of position' via configurations of all the bodies in the universe. In subsequent works (e.g., 1994a, 1995, 2001), he terms this account the 'best-matching procedure' (BMP).

Before going into the details of BMP, which start in the next paragraph, here is a characterization of BMP in general terms. In BMP, broadly speaking, one considers two points in c-space that only slightly differ in terms of their N bodies' configurations. One aims to move one of these c-space points relative to the other to the position in which the action is a minimum. When the action is a minimum, the two c-space points 'best-match', and the corresponding displacements are the ones that the particles have actually made in passing from the first configuration to the second. Plus, it's important to note for PII later, these displacements cannot be transformed away by coordinate transformations (1982, 270).

BMP is formally derived as follows. Represent a particular configuration r_i of the N bodies in the universe by way of a Cartesian coordinate system. In this coordinate system, each particle i has three coordinates: x_i, y_i, z_i. So, $r_i \equiv x_i, y_i, z_i$.

Consider an arbitrary infinitesimal change r_i' of r_i:

$$r_i \rightarrow r_i' = r_i + \delta r_i$$

Here, δr_i is the change between r_i and r_i'. This change, claims Barbour, must be 'genuine', i.e., it must be change in terms of one or more of the relative distances between the N bodies, rather than a mere shift of the coordinate system. Barbour uses PII in order to support the claim that the change produced by a change of the coordinate frame is not genuine change. Assuming we're dealing with point particles, if all the relative distances among the bodies in two configurations of the universe are the same, then there is no means to discern them. Thus, by PII, these configurations are one and the same. Compare this with the case of shifting the coordinate frame. Suppose we have a certain configuration of the universe with the origin of the coordinate frame at some particle at the centre of the configuration, and we shift its coordinate frame so that its origin is on some particle that is not in the centre of the configuration. As this coordinate transformation makes no difference as to the lengths of relative distances in the configuration except for re-labelling them, PII dictates that the configuration that results from such a transformation is identical to the initial configuration.[84]

[84] Barbour only addresses this issue in terms of the passive transformation, i.e., change of coordinate system on a single configuration. If a configuration of point particles underwent an active transformation, i.e., one in which the particles are effectively pushed around to the positions of other particles in the original configuration, then it seems Barbour's response is not straightforward. By his application of CNP, a particle in a configuration is completely defined by the relative distances it has to everything else in the universe. Further, because of MP, dynamics cannot be described in terms of anything that is over and above relative relations. In effect, dynamics cannot refer to some sort of primitive identity that a particle may have. So, the particle can only be identified in terms of its relative relations. If the configuration exhibits certain symmetry, e.g., the configuration has only two particles, and an active transformation is performed, then the particles retain the same relative distances. PII would thereby entail that the configurations are the same. If a configuration does not exhibit this sort of symmetry, then the active transformation would result in there being the same set of relative relations but holding among different particles. However, since there is no way of identifying these point particles other than in terms of their relative relations, both configurations are one and the same by PII. Moreover, if the particles had different masses, then there would be a way of identifying them in an active transformation provided that the configuration does not exhibit symmetry. In such a case, the configurations would not be identical. And, in effect, this counts as genuine change too. However, Barbour likely did not make reference to active transformations above because he is concerned with the role of coordinate systems, and active transformation does not require such a system.

However, Barbour notes that r_i' could be represented in a different coordinate system, and that this would result in a different δr_i. If he formulated this change by choosing one coordinate system, then he would be reliant on a particular chosen background structure that is not derived from relative relations. Thus, he would not be able to fulfil MP. In order to not be dependent on a particular coordinate system, the genuine change must be measured in a manner that is coordinate-system-free. To do so, we must compare all the different sets of δr_i obtained by comparing the first configuration, which is represented in some fixed coordinate system, with the second configuration, which is represented in all possible coordinate systems j. Doing so results in the sets $\{\delta r_i^j\}$.

Here is the difference between the two coordinate systems δI_j when the second configuration is represented in coordinate system j:

$$\delta I_j = [\sum_i m_i (\delta r_i^j)^2]^{1/2} \qquad \text{(E2.1)}$$

Mass is included as a weighting factor because the particles are not assumed to be of identical mass. Except for exceptional degenerate cases, which Barbour (1982, 270) ignores, there is among the coordinate systems j a single placing of the second configuration relative to the first in which the value of δI_j a minimum. This is what he calls the position of best-match. For this case, $\delta I_{j\,min}$ is the coordinate-free change between the two configurations. Thus, Barbour claims to have a way of quantifying change of variety in terms of the variety itself. Indeed, ONT seems to be intact. Through the effective comparison of the relative distances between two configurations, it only uses relative spatial relations among the bodies and mass, which, as indicated above, may be reducible to bodies' relative relations.

With this setup, we can implement MP1 by constructing an analogue of standard nonrelativistic dynamics' principle of least action. This is the equation that minimizes the action, which is a quantity associated with each of the possible paths a system can take between two points. In nonrelativistic dynamics, the least action is calculated by considering any two configurations with a finite difference, e.g., a particle with a certain position at t_1 and the particle with a different position at a later time t_2. These positions are with respect to absolute space or, qua mathematic representation of such space, some fixed coordinate system. Then, one considers all the possible continuous paths that the particle can take between these two positions. For each path, the action is calculated, and the path with the minimum action is deemed the path that is realized by the particle.

While the details of these calculations are not required for our purposes here[85], notice that such calculations rely on there being some fixed time parameter as well as the ability to make reference to the positions of bodies with respect to a fixed coordinate system. To fulfil MP, Barbour must modify the action principle so as to either eliminate the fixed time parameter and coordinate systems or make them reducible to relative relations of the bodies.

He claims that there is no reason to choose one fixed coordinate system over another. PSR dictates that there is no reason for the least action to be calculated using a certain fixed coordinate system. Instead, such differences among configurations should be measured without reference to a particular coordinate system. E2.1 above allows him to do this. E2.1 determines the change between two configurations, allows one to consider the difference between two c-space points measured from all possible coordinate systems, and the minimum value of E2.1 for all possible coordinate systems is deemed the change between the two configurations. As noted above, E2.1 does not make reference to anything over and above the relative relations of the configurations. Thus, it seems to offer a means of describing something similar to the least action without reference to a fixed coordinate system. In turn, if the principle of least action can be constructed in terms of such a minimum, then MP1 is satisfied. We'll see how Barbour incorporates this best-matching in his version of the least

---

[85] For reference, I present them here. The equation to calculate the action S of a path, which is a function $x(t)$ for t_1<t< t_2, between the particle's initial position at $t_1$and its later position at t_2 is:

$$S[x(t)] = \int_{t_2}^{t_1} L(t, x, \dot{x}) dt$$

Here, x is position, $\dot{x} = dx/dt$, and the Lagrangian L=T-V, where T is the kinetic energy (a function of $\dot{x}$) and V is the potential energy (a function of x).

The principle of least action is calculated by determining the points where the derivative of S vanishes for all t_1<t< t_2:

$$\frac{\delta S}{\delta x(t)} = 0$$

action principle, which is provided in the next section as it requires that we also get rid of nonrelativistic mechanics' presupposed fixed time parameter.

Thus, in view of considerations from PII and PSR, Barbour has some means of describing dynamics in a manner that does not refer to some presupposed fixed coordinate system or absolute space. MP1 can be satisfied in a coordinate-free fashion that only makes recourse to the relative distances of the universe's bodies through determining the best-matching position of one configuration relative to that of another.

2.2.3 The Development of Intrinsic Dynamics II: Fulfilment of MP2

The dynamics of the preceding subsection is further developed to fulfil MP2 using PSR. As stated in the previous section, the standard principle of least action involves using a fixed time parameter. Barbour (1982, 271) and Barbour and Bertotti (1982, 296) point out that this time parameter, however, is not based on the relative relations of stuff in the universe. Rather, one could consider it to be a clock that is exterior to the system. This use of such a clock is problematic when the relative change of the entire universe is considered. Suppose that through best-matching, a sequence of c-space points is generated. Now consider two copies of the sequence, i.e., both have the same sequence of c-space points. If there is an external clock, then one sequence can be sped-up: the sequence occurs but the external clock reads that a smaller amount of time has passed. Because this speeding up does not change the relative relations in the c-space points, it does not result in a discernible difference in the two sequences. So, they conclude that nonrelativistic dynamics has no reason to claim that sequences that are otherwise identical occur at different rates. In effect, their presupposition of there being a time parameter that is external to the system violates PSR.

To overcome this alleged problem, Barbour proposes to eliminate the use of an external arbitrary time parameter. To do so and fulfil MP2, he develops his version of the principle of least action such that it does not make use of such a time parameter and is at base a description only in terms of relative distances between stuff in the universe.

Barbour (1994a) (2001) (1982) bases his action on the Jacobi principle. In the Jacobi principle, time τ is treated as a variable rather than as a pre-established background parameter. It is defined in terms of having a value that increases along any path in a space.

Jacobi's principle is used to calculate a curve in the space. Here is a standard formulation of the principle δI_{JAC}:

$$\delta I_{JAC} = \delta \int d\tau \sqrt{F_E T} = 0 \qquad \text{(E2.2)}$$

Here, τ is any monotonically increasing parameter along the curve. F_E, a conformal factor, is equivalent to *E*-*V*, where *E* is the system's constant total energy and *V*, a function of position, is the potential energy of the system. *T* is the flat kinetic metric, which is equivalent to $\frac{1}{2}\sum_i \; m_i \frac{dx_i}{d\tau} \cdot \frac{dx_i}{d\tau}$, where x_i is a position vector of particle *i*.

To use this principle as a means of calculating curves in c-space, Barbour needs to replace the part of *T* which is dependent on positions relative to a fixed coordinate system. He also eliminates τ. Because it just serves as a means to arbitrarily label a c-space path, it is not required in the Machian version. In effect, $\frac{dx_i}{d\tau} \cdot \frac{dx_i}{d\tau}$ is replaced by the displacement in the best-matching position $\delta I_{j\,min}$from above. To present the equation in a more streamlined fashion, denote this quantity as: Dx_i. Now, we can present the Machian version of E2.2, where V= Σ_i m_i m_j / r_{ij}:

$$BMP = \delta \int \sqrt{(E - V) \; \sum_i \left(\frac{m_i}{2}\right) (Dx_i)^2} \;\; = 0 \qquad \text{(E2.3)}$$

This is what Barbour terms his best-matching procedure (BMP). BMP allows us to define paths in c-space, i.e., sequences of c-space points. Moreover, it is only in terms of relative relations of stuff in the universe. As it makes no reference to a time parameter or space that is not built from the stuff's relative relations, E2.3 satisfies both MP1 and MP2.

How does the BMP affect ONT? To approach this question, I introduce Barbour's horizontal and vertical stacking, which also appear in his relativistic Machian theory as we'll see in the next chapter.

In the context of using BMP to recover trajectories that are usually set against a Newtonian absolute space, he (2001, 206) (1986, 239) proposes a procedure: the 'horizontal stacking' of best-matching c-space points. Here he uses this term to refer to the placing c-space points together such that they are laid out in a space, which is meant to contrast with vertical stacks, i.e., stacks in a time dimension. To horizontally stack, first suppose that you found a sequence of c-space points by means of BMP. He (1986) refers to the c-space points picked out as a solution to E2.3 as a heap.

As we see in the next chapter, his use of 'heaps' appears to be a means of indicating that such a solution doesn't come in, e.g., an ordered 4-d block. For now, just note that use of 'heap' is to emphasize the fact that the order of the sequence is derivative from the relations with in a c-space point, rather than a relation that is given with a solution to the equations. It is presumably due to the lack of such structure that we must stack the points of heaps. Yet, Barbour assumes that the BMP will generate a continuity of changes among the set of c-space points it picks out. This seems reasonable given that the best-matching position is one that minimizes that difference between two c-space points. In effect, BMP picks out a series of points, each of which is slightly different from the one that follows it in the series. These points can thus be uniquely ordered in a horizontal stack. To stack them horizontally, start with one of the extremal c-space points of the series. Take the next c-space point and place it on top of the first such that the difference between them is minimized. This process is repeated for each subsequent point. Thus, we can obtain a horizontal stacking of c-space points.[86]

Before moving onto vertical stacking, note that horizontal stacking seems to be in accord with ONT. Such stacks have an order, but this order is the product of a comparison of their relative spatial relations only. Thus, the succession of the c-space points does not seem to violate ONT.

Vertical stacking further highlights the fact that he only uses relative spatial relations to build temporal successions of configurations. To do so, you start with the horizontal stack as constructed above. Then, you reintroduce the Jacobi's τ as follows:

$$(d/d\tau)\{\sqrt{(E-V)\ \sum_i \left(\frac{m_i}{2}\right)(Dx_i)^2}\ m_i(Dx_i/d\tau)\} \qquad \text{(E2.4)}$$

[86] In the context of using this stacking procedure, Barbour goes further and recovers Newtonian laws in the same form via BMP by placing the stack is placed in absolute space. This allows him to associate each stack with a position relative to absolute space. However, as I am concerned with procedure itself and the implications it has for its use in the context of his relativistic account, rather than with the extent to which he can recover Newton's laws, I do not present such arguments. See Barbour and Bertotti 1982 for details.

Here, τ is an arbitrary parameter that serves to label the stacked configurations with a value that is monotonically increasing up the stack. In this sense, the configurations have a vertical stacking. Barbour (1986) supports the choice of a single monotonically increasing parameter here because in the Newtonian context, the simplest forms of the equations of motion can be obtained with a single parameter that is applied to the entire stack. Does such a parameter violate ONT? The labelling seems to add nothing over and above the relative relations by which the horizontal stacks are constructed. Instead, it merely associates some number with each instantaneous configuration of the universe in the stack. The order of the numbers, moreover, comes from the ordering of the horizontal stack: the horizontal stack is constructed first, and its order comes from comparing relative relations among the c-space points. Then, the horizontal stack is associated with a certain series of numbers. The order of the configurations that the series of numbers labels thus results from the relative relations among c-space points. In effect, apparent temporal sequences are constructed from relative spatial relations among stuff, which is in accord with ONT.

Thus, Barbour formulates a Machian account of nonrelativistic dynamics. This account, as emphasized above, is principle-based. These principles are used in order to construct a dynamics that is in terms of the relative instantaneous spatial relations among all the stuff in the universe. To sum up his account, it is useful first to contrast it briefly with Newtonian dynamics. In Newtonian dynamics, each particle moves with respect to absolute time and space primarily. Barbour's Machian nonrelativistic dynamics, on the other hand, claims that only sets of relative instantaneous configurations of all the particles in the universe exist; a solution to his timeless BMP provides a sequence of c-space points that can be stacked to construct a space and operational sense of time from relative spatial relations among bodies alone.

The fundamental components of this account are his c-space points. These are in accord with ONT as each being made up of only all the stuff in the universe and their relative spatial relations at an instant. Moreover, with these as his fundamental building blocks, temporal relations are excluded from ONT. In this nonrelativistic account, c-space contains a single copy of each possible c-space point, but whether Barbour regards this space as being a heap or having structure is unclear. Because this space is presented as a mere means of representing the relative relations that stuff in a universe may have, it does not seem to violate ONT or MP. Paths through this space represent best-matching sets of c-space points. Moreover, his BMP does not violate ONT or MP: it is not dependent on a particular coordinate system, includes mass that may be reducible to relative relations, lacks a time parameter and, thus, only involves a comparison of the relative instantaneous relations of c-space points. Thus, the order of best-matching c-space points is a product of a comparison of their relative spatial relations alone. Furthermore, such c-space points can be stacked horizontally in virtue of the relations. An arbitrary time parameter can be applied to a horizontal stack and serve as a mere label of the stacked c-space points. Thus, time, qua arbitrary monotonically increasing parameter associated with a horizontal stack, can be introduced in a manner that does not violate ONT or MP.

Recall that his motivation to generate such a Machian nonrelativistic dynamics is to provide a model on which he will develop a version of GR that is clearly Machian. In the next chapter, we turn the manner in which he makes inferences from the above Machian nonrelativistic dynamics to generate his Machian account of relativity as well as expand upon the manner in which it is consistent with the principles.

Chapter 3: Machianizing Relativistic Dynamics

From the model of a Machian nonrelativistic dynamics that he generated such that it fulfilled his relational principles, Barbour proceeds to develop a Machian relativistic dynamics. To do so, he redefines the c-space points such that they do not require a fixed geometry, namely he chooses the Riemannian 3-geometries of geometrodynamics to serve as his c-space points. Then, he constructs analogues of his Machian nonrelativistic BMP, which provides him the means by which to create a 4-d space through horizontal and vertical stacking. Finally, by comparing the extremely similar structures of the version of the Machian relativistic BMP that involves a time parameter with the Baierlein-Sharp-Wheeler formulation of GR's action, he claims that GR is just a special case of his Machian relativistic dynamics.

Compared with his accounts of quantum theory and quantum gravity, which are unpacked in the next two chapters, his account of GR is relativity well-rehearsed. In effect, the first two sections of this chapter are expository and highlight parallels with his nonrelativistic account given in the previous chapter as well as the manner in which MP and ONT are fulfilled. Additionally, §3 explores that status of relations among c-space points given his principles.

One reason Barbour (1992, 142) provides for believing that standard GR is not Machian is its use of distinguished inertial frames, i.e., local frames in which stuff is moving at a uniform velocity. While GR does not rely on some global fixed coordinate system as Newtonian mechanics does with its absolute space and time, it does make use of these frames of reference locally. Each point of spacetime is assigned a local inertial frame in accordance with the value of the metric field tensor. These local inertial frames are assigned a Minkowski vector bundle, i.e., a bundle of 4-vectors that are assigned on the tangent at a point of spacetime to curves in the manifold that pass through the point.[87] Unless these frames emerge from the relative relations among stuff, Barbour rejects such local spacetimes as being anti-Machian; though local, these spacetimes are regarded as nonphysical and defined on points, rather than being clearly derivative from relative relations. Nevertheless,

[87] See Plebański and Krasiński 2006 and Hall 2004 for details about tangent spaces.

despite the presence of these frames, he claims that GR is Machian; it only appears not to be so because these frames have not been explicitly reduced to the stuff and relations of a universe. In turn, he seeks to illustrate that these frames in fact are reducible to such stuff with his Machian rendition of GR. After providing his choice of c-space points in §1 and his Machian relativistic dynamics in §2, we return to the manner in which such local spacetimes are recoverable from stuff and their relations alone.

1 Relativistic C-Space Points

Barbour chooses c-space points for his relativistic dynamics such that they reflect the fact that GR's geometry is variable. The manner in which GR's spacetime is standardly formulated aims to incorporate as few assumptions as possible about the geometry of each representation of a physically possible universe in order to be generally covariant, i.e., uphold the posit that the laws of nature are invariant under arbitrary coordinate transformations. Accordingly, such a representation is $\langle M, g, T \rangle$. *M*, which represents spacetime[88], is a 4-d continuously differentiable point manifold, i.e., a collection of points that has topological properties, e.g., having points that are smoothly connected and being 4-d, but has no geometrical properties, e.g., having a defined notion of length or angle. *g* is a metric field tensor[89] that is defined everywhere on the manifold and represents the gravitational field. This tensor structures the points by defining their metric and geometrical relations, e.g., it defines distance between two points and co-linearity. Finally, *T* is a stress-energy tensor that is defined everywhere on the manifold and represents matter and non-gravitational energy existing in the manifold. With this setup, the geometry across a spacetime varies in accordance with the value of *g*.

---

[88] This depiction of spacetime is in accord with manifold substantivalism, i.e., the view in which spacetime is identified with only the manifold. Contrast this with the view held by those, e.g., Hoefer 1996, who represent spacetime with *M* and *g* in response to the hole argument. While such options will not be assessed here, the hole argument and Barbour's means of replying are presented below.

[89] Generally, a tensor field on a manifold is a mapping that assigns a tensor to every point of the manifold. A tensor can be regarded as similar to a vector except that it has more indices that transform under a change of coordinates. See Friedman 1983 for details.

In his Machian nonrelativistic dynamics, a c-space point is characterized in terms of relations among all particles of the universe in an instant. However, the geometry of all the nonrelativistic c-space points is the same: spatial Euclidean geometry is assumed. Given that a specific geometry is not fixed in GR, the relativistic c-space points must not be in terms of a single particular geometry.[90] So, he replaces his nonrelativistic c-space point, which is a possible set of all the relations among the universe's particles in an instant, with his relativistic c-space point, which is a set of all the distance relations that hold among points in a possible closed 3-d Riemannian space and instanced by one of its 3-metrics q_{ab}. In view of the manner in which these Riemannian 3-geometries are used in the geometrodynamics formulation of GR, Barbour adopts the basic components of this view and uses them to construct a Machian relativistic dynamics in a fashion that mirrors his nonrelativistic dynamics.

To provide some information about what these 3-metrics q_{ab} are, some information about geometrodynamics' setup is required. Geometrodynamics is a way of formulating GR in terms of the spatial dynamics of geometry. In standard geometrodynamics, the 4-d spacetime manifold M is given topology $\Sigma \times \mathbb{R}$, where Σ is a spatially compact 3-manifold and $\mathbb{R}$ is the set of real numbers representing a global time direction. This submanifold is foliated by a family of spacelike 3-d hypersurfaces Σ_t, indexed by the time parameter t. A coordinate system $\{x^a\}$ is defined on Σ_t. In effect, 4-d spacetime is decomposed into instantaneous 3-d hypersurfaces, or spacelike slices, plus t. Each 3-d hyperslice is put in terms of geometric variables that correspond to a Riemannian 3-metric[91] q_{ab} describing the 3-d hyperspace's intrinsic geometry.[92]

---

[90] See Friedman (1983, 185) for details.

[91] A Riemannian metric is a metric having an inner product on the tangent space at each point, i.e., a vector space containing all possible 'directions' in which on can tangentially pass through the point, which varies smoothly from point to point, giving local notions of angle, length of curves, surface area and volume. To define this further as well as 'pseudo-Riemannian geometries', to which Barbour later refers, I contrast them here. Pseudo-Riemannian geometries are generalizations of Riemannian geometries in the sense that their metric tensors need not be positive-definite, while those of Riemannian geometries must be positive-definite. To explain 'positive-definiteness' without getting into the details of bilinear forms that are associated with each tangent space on a metric, it suffices to say that this has to do with the signatures of the manifolds. Both the

It is the Riemannian 3-geometry content of geometrodynamics' hyperslices that serve as Barbour's relativistic c-space points. These 3-geometries have their intrinsic relations cashed out in terms of 3-metrics q_{ab} that are defined on a 3-manifold. However, for any 3-geometry there is a number of 3-metrics[93]; a geometry is an equivalence class of metrics with elements related by a diffeomorphism.[94] To see why this is so, consider a 3-metric defined on a 3-manifold. Shuffling the points of the manifold around results in the same relations holding, but the points are re-labelled or moved. The shuffled manifold, though having the same 3-geometry, has a different metric because the metric defines relations among specific points of the manifold; if the points are shuffled, then a new metric results. But, because a 3-geometry effectively captures the geometrical relations among the points without referring to the labels of the points, the 3-geometry remains the same. Thus, because the points of the 3-manifold can be shuffled around by diffeomorphisms, there are a number of different metrics

---

Riemannian and pseudo-Riemannian geometries are associated with a bilinear form with a fixed signature (p, q), where p is the number of positive eigenvalues of the form, and q is the number of negative eigenvalues. As positive-definite, the signatures of a Riemannian manifold must be (n, 0). Partially because pseudo-Riemannian geometries are not necessarily positive-definite, the signature of the manifold associated with such a geometry is just the signature of its metric, e.g., the signature of a type of pseudo-Riemannian manifold, namely the Lorentzian manifold, is (p, 1) or (1, q), depending on sign conventions. For an introduction to Riemannian geometries, see Boothby 1986.

[92] Note that we are using the common convention in GR of using Greek indices, e.g., $q_{\mu\nu}$, as spacetime indices, which take the values (0,1,2,3), and Roman indices, e.g., q_{ij} as spatial indices, which take the values (1,2,3). Plus, these indices are shorthand for certain matrices, where the element's row is indicated by the first subscript and the column by the second, and q^{ij} is the inverse of q_{ij}.

[93] Also, see Rickles (2008).

[94] A diffeomorphism is a coordinate transformation which is a one-to-one smooth differentiable mapping that takes the points of the 3-manifold to other points of it. In geometrodynamics, a 3-geometry is an equivalence set of such metrics because of its diffeomorphism constraint. This constraint ensures the theory is invariant under spatial diffeomorphisms, which makes the resulting dynamics only dependent on variables that are unaffected by such arbitrary coordinate transformations. And, note that in this context, this is meant to include all diffeomorphisms, i.e., diffeomorphisms interpreted both in the passive sense, i.e., as a change in coordinate system, and in the active sense, i.e., as a change in the relations among coordinates. In §3, we discuss the impact of local active diffeomorphisms on 3-geometries.

that can be associated with a single geometry. Moreover, in view of this exposition of the nature of 3-geometries, the manner in which the 3-geometries parallel the nonrelativistic c-space points is elucidated. Just as a nonrelativistic c-space point is all the relative spatial relations that hold among particles in an instant, a relativistic c-space point is a 3-geometry, i.e., all the relative spatial geometrical relations that hold among points in a 3-d hyperslice.

Additionally, these 3-hyperslices mirror the instantaneous nature of his nonrelativistic c-space points in that they capture a single instantaneous 3-geometry. We will see shortly that Barbour plugs these components into a modified best-matching procedure in order to construct spacetime by stacking the resulting 3-geometries. In effect, he creates a Machian geometrodynamics. The manner in which his project differs from the project of standard geometrodynamics is that the latter, at least in view of Wheeler's motivations, aims to use GR as a model for constructing a dynamics in terms of 3-geometries[95], while the former has the initial aim of creating a Machian relativistic dynamics in which its timelessness is emphasized. In Barbour's project, the action for Machian relativistic dynamics turns out to be able to be cast in very similar form to an action of GR that was formulated in standard geometrodynamics. So, while a similar expression of GR may be derived in both approaches, as we'll see in §3 below, Barbour's approach differs in that it aims to emphasize the Machian nature of relativistic dynamics.

Furthermore, note that he restricts his Machian account to pure geometrodynamics, i.e., one without matter fields. However, he (1995, 225) speculates that matter fields can be added by supplementing the 3-geometries with more degrees of freedom.[96] Because I am more concerned with the role played by time in the general form of his Machian account than whether such fields can be added and because such fields may at least in principle be cashed out in terms of the relative spatial relations among the fields in accordance with MP, I do not consider the implications of adding such matter fields for his Machian geometrodynamics.

---

[95] See Stachel 1972 for details concerning Wheeler's development of geometrodynamics. His development of this account is intertwined with the project of unifying GR with quantum mechanics. Moreover, in Ch4 we will see the manner in which his geometrodynamics is quantized.

[96] Also, see Pooley 2001 for discussion of how fields may be incorporated in Barbour's account.

Moreover, Barbour's c-space points in this context are 'loaded' in a similar fashion to those of his nonrelativistic dynamics. Just as his non-relativistic c-space points are loaded in comparison with the standard points in a coordinate system, these 3-geometry points are loaded in comparison with the points of GR's manifold. Rather than being a largely featureless point that only has topological relations with other points constituting GR's manifold, a c-space point is all the relative relations of a possible 3-geometry. We will see below the manner in which this setup provides Barbour with a reply to a standard issue in GR, namely the hole argument.

Now that we have our relativistic c-space points, we turn to its corresponding c-space. Just as the points of nonrelativistic c-space are all possible instantaneous configurations of the bodies of the universe, the points of c-space are all the possible 3-geometries. However, unlike the heap constituting his nonrelativistic c-space, relativistic c-space is given structure in the context of his relativistic dynamics. He (1994a, 2853) (1995, 225) identifies c-space with the DeWitt superspace, which is the space of all possible Riemannian 3-geometries of the universe of a fixed compact 3-manifold *M*. This space is obtained by quotienting out the group of diffeomorphisms of *M* from the space of smooth Riemannian 3-metrics on *M*. Recall our definition of 'geometries': a geometry is an equivalence class of metrics with elements related by a diffeomorphism. In this context, a diffeomorphism is interpreted as generating a spatial coordinate transformation on *M*. Quotienting out the diffeomorphisms effectively removes the labelled coordinate grid of the metric and leaves the 3-geometries, i.e., all the relative spatial geometrical relations that hold among points. This procedure has a similar effect to our suggested reduction of mass in the nonrelativistic dynamics. By reducing mass to relative relations, we are able to describe dynamics only using relative relations at base and, thus, are able to fulfil MP. Similarly, by eliminating any import of manifold points, we are able to describe dynamics in terms of the relative relations of the 3-geometries alone and, thus, have a setup that allows us to fulfil MP.

Moreover, Giulini (2009) notes that this particular quotienting out procedure results in a space with more than one manifold, i.e., it has a collection of manifolds each of which has a different dimension. This manifold can then be structured such that some of these manifolds serve as strata. While Barbour accepts that c-space does have stratified structure in the context of his relativistic account and, as we'll see in Ch5, in the context of his quantum gravity account, he does not make explicit how exactly it is in accord with ONT and MP. Furthermore, though he does indicate how c-space is stratified in the context of quantum gravity, this structure does not do much work in his relativistic dynamics.[97] So, the presentation of his stratified c-space is not given until Ch5, and its implications for ONT and MP are discussed there.

In sum, by defining a c-space point as a possible 3-geometry, Barbour has a means of describing dynamics in terms of relative spatial relations alone. Moreover, as such 3-geometries are instantaneous and only involve the relative relations among unspecified points, these c-space points fulfil ONT. For now, we consider the c-space just to be the set of all possible c-space points. With these Machian relativistic c-space points and c-space in place, we can move to the manner in which Barbour provides an analogue of his nonrelativistic BMP.

2 The Formulation of the Machian Relativistic BMP

To formulate his Machian relativistic BMP, he follows a method analogous to the one used for formulating his nonrelativistic BMP with some modifications.

2.1 Initial Parallels with Nonrelativistic Best-Matching

Recall that in nonrelativistic case, we begin by considering two c-space points that differ only slightly in terms of the configurations of their N particles. Likewise, in the relativistic case, we start by considering two c-space points that differ only slightly in terms

[97] While Barbour does make references to c-space in the formulation of his relativistic account, e.g., stating that a sequence of best-matching 3-geometries is a geodesic in c-space, it is the relativistic BMP informs us exactly how to 'draw' the geodesic through c-space. His stratified c-space, as we'll see in Ch5, is organized in terms of the relative symmetry and congruence of all possible c-space points. While a c-space structure in terms of such properties may narrow down the set of possible best-matching c-space points given a particular configuration, it does not dictate precisely in which direction a geodesic should be drawn. Because, as noted in Ch5, c-space is multi-dimensional, there are a substantial number of directions in which a geodesic can be drawn. In effect, it seems that the relativistic BMP, like the nonrelativistic BMP, is doing most of the work in establishing a sequence of c-space points that form a specific geodesic in c-space. For this reason, my exposition below focuses on the role of the relativistic BMP in generating sequences of c-space points and makes little reference to c-space.

of 3-geometries among the points of their 3-manifolds. However, in the nonrelativistic case, the relationships of Euclidean geometry are assumed; the geometry of such c-space points is restricted to a single specific geometry. In this case, we are able to start by trial matching by using rigid body transformations and rotations, i.e., we can simply shift around the two c-space points, such that the particles and relations of the respective points largely match up. Because the geometry of the relativistic c-space points is not similarly restricted to a single geometry, we cannot use such transformations in order to perform the initial trial matching of these points.

Instead, Barbour (2001, 209) suggests that we consider one 3-geometry q^1 and lay out coordinates on it in some arbitrary manner, which gives it the metric q^1_{ij}. Then, consider a second 3-geometry q^2 that differs from the first slightly. Coordinates are put on the second 3-geometry arbitrarily except that the resulting metric q^2_{ij} at the same coordinate values differs slightly from those of q^1_{ij}, i.e.,

$$q^2_{ij} = q^1_{ij} + \delta q_{ij}$$

where the value of their difference δq_{ij} is very small.

Next we consider the 'equilocal' points in these two c-space points. The points of the two 3-geometries are equilocal if each point of the first is paired with a point of the second. In our trial matching, we establish this pairing by definition: the coordinate points on the respective 3-geometries that have the same values are, by definition, equilocal. This gives us a trial equilocality relation among the 3-geometries such that δq_{ij} measures the change of the metric at paired equilocal points. The measure of change at each point can then be integrated over the entire c-space points in order to get a trial value of the global difference between the c-space points.

So far, we have used a couple of arbitrarily chosen coordinate systems, each of which resulted in a single metric for each of our two 3-geometries, and a mapping between the points established by a definition. The arbitrariness resembles that arising from the nonrelativistic approach's initial use of a pair of arbitrarily chosen coordinate systems capturing the relations among bodies in two c-space points. In that case, the coordinate system of the second c-space point had to be varied in order to calculate that difference between the two c-spaces that does not rely on the choice of certain coordinate systems.

Similarly, imposed coordinates, defined mapping between the coordinates and resulting metrics must be varied in order to find the difference between the two 3-geometries such that is does not rely on the choice of a particular coordinate system, mapping between the 3-geometries' points or metric tensor.

Mirroring the manner in which he varied the coordinate systems of the second nonrelativistic c-space point while holding the first fixed in order to achieve the above minimum value, Barbour (1994a, 2865) (2001, 210) advocates changing the coordinates on the second 3-geometry while holding those of the first fixed to find the extremum.[98] Doing so results in a different metric describing the second 3-geometry. However, note that because the new metric is generated via a coordinate transformation, it is a diffeomorphism of the second 3-geometry's initial metric. Moreover, given that the coordinate system is changed, a different set of equilocality pairings results because we defined such pairings in terms of matching coordinate values.

How does this process remove an arbitrary choice of a coordinate system and metric? Recall that a 3-geometry corresponds to a set of metrics that have their elements related by a diffeomorphism. So, if we work through all the possible coordinate mappings on the second 3-geometry and compare the resulting differences between them, then we can find one in which the global difference between the two geometries is extremalized. The two 3-geometries with such a value are deemed to be best-matched, and this value is not dependent on a particular choice of metric or corresponding coordinate system.

2.2 The Addition of a Time Parameter to Relativistic Best-Matching

Unlike the nonrelativistic BMP E2.3 that lacks τ, Jacobi's τ must be introduced before he can formulate the relativistic BMP. According to Barbour (1986, 241), τ must be introduced at this stage of his relativistic account because in the nonrelativistic setting:

---

[98] While we were dealing with fixed notion of length in the Newtonian context and could refer to smallest length without ambiguity via 'minimum', the term 'extremum' is used in this context because length is dependent upon the geometry.

> absolute simultaneity still has meaning. In [the Machian nonrelativistic dynamics] this amounts to the assumption that the simplest form of the equations of motion can be obtained with a single time parameter, this time parameter being the same across the entire universe. In a post-relativistic approach, such a view cannot be maintained; one must consider the possibility that the separation in 'time' between the snapshots is not only unknown but also position dependent in general.

In effect, in nonrelativistic dynamics, we can formulate its BMP E2.3 without reference to τ. This is because, as Barbour implies above, time is usually defined in that context as a background parameter that is monotonically increasing independent of one's position. However, time in the relativistic setting is defined locally and is position dependent.

To elucidate the contrast Barbour is making here, it is helpful to make recourse to different temporal concepts in Newtonian mechanics and GR that Rovelli (2004, 82-8) proposes as well as the manner in which the temporal distance between 3-geometries is formulated in standard geometrodynamics.

Rovelli briefly presents a number of different temporal concepts that appear in various theories. A contrast that he makes between Newtonian mechanics and GR in terms of the uniqueness and global nature of time is most relevant to our present purposes. The Newtonian concept of time exhibits both uniqueness and general globalness. It is unique in the sense that it requires a unique, constant time interval between any two events, and it is global in the sense that every solution of the equations of motion 'passes' through every value of it once and only once.

To exemplify these characteristics, consider Barbour's nonrelativistic dynamics. There the uniqueness of Newtonian time indicated that his time parameter should be chosen such that its values are not repeated. In effect, it was formulated as monotonically increasing, allowing for each c-space point of the horizontal stack to be assigned a unique value. Thus, the arbitrary time parameter was chosen to reflect the uniqueness of Newtonian time. Additionally, it is global. The horizontally stacked c-space points that result from a solution to the action *BMP* amount to a stack of instantaneous configurations of the universe, and a single time parameter is assigned to the entire stack such that each configuration of the universe gets a single value. With this arrangement, the time parameter is global in that each of the instantaneous configurations of the universe is assigned a single value. It is to these temporal concepts that Barbour in the passage above seems to be referring. With his claim regarding the assumption that 'the equations of motion can be obtained with a single time parameter that is the same across the universe', he appears to be referring to Rovelli's globalness. This global aspect allows him to plot a single parameter along the horizontal stack. And, Barbour's quote implies that the separation between time intervals in nonrelativistic theories can be known. This seems to be a reference to the fact that Newtonian time is assumed to have unique, constant intervals, which effectively allows him to choose a monotonically increasing parameter by which to characterize his operational time parameter.

Let's contrast these temporal concepts with those Rovelli associates with GR's proper time in order to further elucidate the quote.[99] Proper time in GR is defined generally in terms of the amount of time measured by an observer with a clock. The observer has a worldline, which corresponds to a continuous 1-d curve in spacetime, and the amount of time measured by a clock he carries is the proper time along the world line. Because geometry is no longer fixed in GR and instead is determined by the metric, the length of such paths and, thus, the time one measures locally with a clock depend on the metric. A solution to Einstein's field equations assigns a metric structure to every worldline. Since proper time is determined by the metric field tensor, there is, as Rovelli points out, a different proper time for each world line or, infinitesimally, for every speed at every point.

Regarding the feature of globalness, it is helpful to recall its general characterization: time is global if every solution of the equations of motion 'passes' through every value of it once and only once. Because each worldline is assigned a metric from a solution to Einstein's field equations, Rovelli claims that along a worldline proper time is 'temporally global', i.e., the events in this worldline 'go through' every value of the time variable once and only once. In effect, it seems that we can apply a single time parameter to a particular worldline. However, Rovelli also states that proper time is not 'spatially global', i.e., it is not

[99] I do not here discuss GR's coordinate time, i.e., the dimension of GR's manifold that is associated with time. Because this notion of time is simply treated like another spatial dimension, it does not pose a substantial problem for Barbour. We'll see shortly that he can recover such time by stacking his c-space points.

possible to define the same time variable in all space points. Here it seems that Rovelli is referring to the fact that a time parameter can only be applied to each worldline, rather than across all of spacetime. Because a solution to the equations assigns a different metric structure to different worldlines, we cannot apply a single parameter across all points of spacetime. Since the metric assigned to each worldline differs from the others, each requires a different parameter associated with their proper time.

How does GR's proper time fare with regard to uniqueness? Rovelli does not specify the role of uniqueness in the context of GR. So, let's examine the manner in which the proper time of a worldline may be unique by considering parts of a single worldline. Recall that in the context of Newtonian mechanics, its time is considered unique due to the assumption that there is a unique, constant interval between any two events. Along a worldline in GR, a clock is supposed to provide the measurement of the length along the worldline. In effect, it provides a monotonically increasing parameter by which we measure this length. But, such length is determined by the metric; because the distance between any two points on a worldine depends on the metric, the length between the points is dictated by the metric and, thus, varies. So, the interval measured by clock along a worldline from one point to another varies in accordance with the length between the points. Thus, though a proper time provides a series of unique intervals along a worldline, it is not assumed that all the intervals are of the same length. Compare this with the uniqueness of Newtonian time: there it is assumed that each temporal interval is unique *and* constant in the sense that they are of equal length. In GR, however, the intervals along a worldline, though measured by a monotonically increasing parameter that provides a series that is unique in the sense that it has a nonrepeating order, are not assumed to be constant.

In view of this characterization of GR's proper time, we can unpack the rest of Barbour's quote above. Recall that he claims that in a relativistic setting, "the separation in 'time' between snapshots is not only unknown but also position dependent in general." By 'snapshots' we assume he is referring to c-space points because he usually uses this term to refer to instantaneous configurations of the universe. In GR, it seems that Barbour's description of the separation in 'time' between c-space points as 'unknown' refers to GR's lack of constant intervals. To construct nonrelativistic dynamics, we assumed that there was a unique constant interval between c-space points. Because such intervals are dependent upon the metric in GR, we cannot assume, as we did for nonrelativistic dynamics, that there is a unique, constant interval between the points of any two 3-geometries. Thus, it seems that Barbour is referring to the variable length of the intervals between GR's points on a worldline; we cannot know the length between two points of two different 3-geometries or, more generally, the overall distance between two c-space points. In effect, his description of them as 'unknown' contrasts with the assumed unique, constant 'distance' between each of his nonrelativistic c-space points.

Moreover, his reference to his relativistic c-space points' separation in 'time' as being position dependent can be cashed out in terms of GR's temporal but non-spatial global aspect. Nonrelativistic dynamics' general global nature allowed us to add a single time parameter to a horizontal stack. However, we cannot just tack on a single time parameter to a stack of relativistic 3-geometries due to GR's lack of a spatial global aspect; there is not a single time parameter that we can assign to the whole of spacetime that corresponds to all the proper times along its worldlines. Yet, proper time is temporally global, i.e., events in a particular worldline go through every value of the time variable once and only once. So, though we cannot assign a time parameter to spacetime as a whole such that it reflects proper time, we can assign a time parameter to each worldline. Furthermore, in this case, the length of a particular worldline and its corresponding proper time depend upon its place in the metric. In this sense, the proper time of a particular worldline in GR is position dependent.

In Barbour's account, such position-dependency is, as we'll see in more detail below, expressed in terms of relative spatial relations. By his account, an example of a worldline is a path from a point in one 3-geometry to its corresponding equilocal point in its best-matching 3-geometry. Recall that the position of a point in a 3-geometry is a function of all the relative spatial relations that the points has with all the other points in that 3-geometry. So, the proper time assigned to such a worldline is dependent upon the points' positions in the 3-geometries. Moreover, in view of the role of proper time in GR, Barbour cannot, as for nonrelativistic dynamics, apply a best-matching procedure that does not initially make use of a time parameter and subsequently apply a time parameter on the stack as a whole. Instead, as we'll see, he must introduce the time parameter into his relativistic best-matching procedure in order to incorporate the variable 'time' separation between two best-matching 3-geometries. However, this parameter, as I explain below, does not violate MP or ONT.

Before moving onto his best-matching procedure, it is informative to see the manner in which GR's proper time is cashed out in geometrodynamics. Echoing Wheeler, Barbour (1999b, 105) provides a useful characterization of the manner in which geometrodynamics stacks hyperslices. The normals of the hyperslice's points can be envisioned as struts that join together the hyperslices. The struts have a certain 'length' that provides the time-like separation between the points and effectively provides the proper time difference between the points. In effect, Barbour must provide a means by which to join certain points together and provide the strut length with reference to the hyperslices' 3-geometries alone in order to fulfil ONT. In other words, because this strut length, or 'lapse', specifies the time-like separation between the hyperslices, Barbour requires a means of specifying this value from the 3-geometries alone. Doing so will allow him to define the local time along a world-line without violating ONT.

In less metaphorical terms, standard geometrodynamics puts the distance between two hyperslices in terms of the lapse function, which gives what Kiefer (2007, 88) calls, "the purely temporal distance between the hypersurfaces." Recall from the brief exposition of geometrodynamics above that GR's 4-d spacetime is decomposed into instantaneous 3-d hypersurfaces plus t, and a coordinate system $\{x^a\}$ is defined on the hypersurfaces Σ_t.

After decomposing GR's spacetime in this fashion, a spacetime is recovered as a stack, i.e., a one-parameter family, of its hyperslices, with $\mathbb{R}$ serving as a time parameter. To recover spacetime, an extrinsic curvature tensor K_{ab}, which provides information on the manner in which $\Sigma_t$is embedded in the 4-d spacetime, in obtained.[100] Additionally, the lapse function N and the shift vector $N^a$are chosen. Each point in the hyperslice's 3-metric has a 3-vector field. The vector that is perpendicular to the hypersurface at a point is termed the normal. The lapse function specifies the amount of normal separation between the hyperslices. The shift vector provides the value of the amount by which a point is shifted on a hypersurface relative to its equilocal point on the successive hypersurface. To have a clearer picture of the relations between these components, suppose that there is a point that

---

[100] For a non-technical introduction to extrinsic vs. intrinsic curvature in this context, see Kuchar 1999. And, see Colosi 2004 for detail on how K_{ab} is obtained.

has one of its vectors, which is not a normal, pointing towards a point with the same coordinates on a neighbouring hypersurface. If we shift our point across its hyperplane using the shift vector, it will be directly under its equilocal point. If we construct a normal at the shifted point, i.e., a vector that is perpendicular to the surface at the point, then the length of this normal is equivalent to the lapse. Furthermore, these components allow us to reconstruct the 4-metric from the 3-metric; the spacetime interval between (t, x^a) and $(t + dt, x^a + dx^a)$ is:

$$ds^2 = -N^2 dt^2 + q_{ab}(dx^a + N^a dt)(dx^b + N^b dt)$$

We'll see below that Barbour uses normals of equilocal points as the means of joining together the hypersurfaces. Moreover, he already has a means of incorporating geometrodynamics' shift function; his equilocality trials above allow him to determine the best-match between the spatial coordinates of two 3-geometries. However, he needs a means of deriving what is specified by the lapse in standard geometrodynamics, i.e., the orthogonal distance from one 3-geometry to its best-matching 3-geometry.

In effect, he (1994a, 2866) defines his Machian relativistic BMP as follows in a form that resembles Jacobi's principle E2.2:

$$BMP_{rel} = \int d\tau \int dx \sqrt{FG^{ijkl}\left[\frac{dq_{ij}}{d\tau} - \varepsilon_{(i;j)}\right]\left[\frac{dq_{kl}}{d\tau} - \varepsilon_{(k;l)}\right]} \qquad \text{(E3.1)}$$

Here, F is a conformal factor. G^{ijkl} is the supermetric.[101] q_{ij} and q_{kl} are the metrics of two different 3-geometries. And, ε_i is an arbitrary 3-vector field[102] that Barbour terms 'equilocality shuffler' because it effectively generates coordinate transformations and new

---

[101] A supermetric is generally a metric of metrics. In this case, it is a generalization of a Riemannian metric q_{ij}, which is used to calculate distances between points of a given manifold, to the case of distances between metrics on this manifold. Additionally, here it is a functional of q_{ij},. Barbour notes that the value of the supermetric here is not given. However, as we'll see in the next section, the GR instance of this equation does specify the supermetric.

[102] Generally, a vector field on a manifold is a smooth function that assigns vectors to every point on the manifold.

trial equilocality pairings between the two 3-geometries.[103] $\frac{dq_{ij}}{d\tau}$ is the derivative of q_{ij} with respect to an arbitrary time parameter, i.e., it is just some monotonically increasing parameter. This specifies the direction of, e.g., a vector of a point on q_{ij} pointing towards its equilocal point on the neighbouring q_{kl}. In effect, the two bracketed functions allow him to determine the manner in which two 3-geometries are matched up in terms of both the equilocality connection between 3-geometries' coordinates and the orthogonal distance between the 3-geometries via the directionality specified by $\frac{dq_{ij}}{d\tau}$. We'll see the role this plays via exposition of his horizontal and vertical stacking.

Before moving on to the stacking, it is necessary to discuss the appearance of τ in E3.1. This use of $\frac{dq_{ij}}{d\tau}$ is required here, rather than a mere function of spatial distance like Dx_i of E2.3, because of the proper time's lack of a spatial global aspect and varying intervals. As mentioned above, Barbour cannot apply a single parameter to a horizontal stack of relativistic c-space points such that it captures the different lengths between neighbouring c-space points. Instead, he needs some means of specifying the lapse between each best-matching pair of c-space points. This time derivative allows him to do so because it specifies the direction in which the vectors of a 3-geometry's points point. However, the appearance of τ here does not violate ONT because it is used to provide the infinitesimal 'velocity' at a point and thereby provide the direction in which one of its vectors is pointing towards a neighbouring hyperslice. So, though Barbour incorporates this as a function of time, he has done so with an arbitrary parameter. And, because this amount is infinitesimal, it parallels the instantaneous nature of his nonrelativistic c-space points. But, unlike the nonrelativistic c-space points, the varying geometry of his relativistic c-space points encodes information about the distance from it to the best-matching c-space point. So, though τ enters into his action and because the 3-geometries have an infinitesimal temporal length, it merely serves as a means of indicating the direction of certain vectors in the c-space points. Thus, MP2 is not violated because τ adds no quantitative value to q_{ij}. Rather, its role in $\frac{dq_{ij}}{d\tau}$ is merely to

[103] The parentheses of $\varepsilon_{(i;j)}$ denote symmetrisation, i.e., the fact that the sign of the metric does not change if its indices are interchanged, and the semicolon denotes the covariant derivative, i.e., it is a partial derivative plus a correction that is linear in the original metric. See Friedman 1983 for details.

indicate the directionality already encoded in q_{ij}. Moreover, because we are still only dealing with instantaneous 3-geometries, ONT is not violated.

2.3 Stacking with the Relativistic BMP

We can use this equation to stack 3-geometries horizontally in a similar fashion to the manner in which we used BMP to stack nonrelativistic c-space points. To stack horizontally and obtain successive 3-geometries, one starts with a given 3-geometry and attempts to calculate the action along a trial sequence of 3-geometries via E3.1. This would provide us with a solution to E3.1, giving us a sequence of 3-geometries. However, doing so involves solving the thin-sandwich problem in order to find the variational principle for the equilocality shuffler. Generally, the thin-sandwich problem for geometrodynamics[104] is put in terms of the problem of solving for a 3-vector field given any given 3-metric associated with a 3-geometry and its tangent vector obtained from its time derivative $\frac{dq_{ij}}{d\tau}$. Once a solution is obtained, it can be used to find the lapse and shift. Since the shuffler of E3.1 is an arbitrary 3-vector field, finding the shuffler's variation principle in order to generate a sequence of best-matching 3-geometries effectively amounts to finding a solution to the thin-sandwich problem. But, as Barbour notes, it is problematic to find this value because of the difficulty in solving the resulting differential equations.[105] Nevertheless, assuming that it can be solved, it can then be used to specify the separation between equilocal points of successive 3-geometries; it can be used to find the local lapse and shift from a single 3-geometry alone and thereby calculate its series of best-matching 3-geometries. This would enable us to horizontally stack these 3-geometries and define an operational local time on the local lapse distances.

---

[104] This problem arises from the difficultly in solving the equations involved in attempts to fulfil the thick and thin sandwich conjectures. According to the thick sandwich conjecture, two 3-geometries determine the lapse and shift between them. Both conjectures were originally proposed by Baierlein, Sharp and Wheeler 1962 and are discussed by Wheeler 1964 when questioning whether two 3-geometries alone can be used to reconstruct Einstein's spacetime. See Bartnic and Fodor 1993 for criticism of the sandwich conjectures.

[105] However, it has been solved locally for certain situations. See Kiefer (2007, 115) for details.

Assuming these sequences of 3-geometries can be obtained by a solution to the thin-sandwich problem, Barbour (1994a, 2867) (1986) illustrates that these 3-geometries can be stacked horizontally to create a 4-d space. Such a solution provides, so to speak, information about the struts connecting 3-geometries' points and their length. To stack, consider two successive 3-geometries. Make them into hypersurfaces that are embedded into a 4-d metric space. Stack them such that the normal orthogonal to the point in one of them pierces through the other 3-geometry's corresponding equilocal point. In effect, we get a bunch of successive 3-geometries and stack them by their orthogonal norms at equilocal points.

Now that we have a horizontal stack, we can vertically stack. Like in the nonrelativistic case, we assume that we have already obtained our horizontal stack prior to vertically stacking them. Doing so ensures that the definition of time is derivative from the spatial geometrical relations because such vertical stacks effectively are built out of horizontal stacks. Recall that in his nonrelativistic dynamics, c-space points are stacked horizontally in virtue of their order obtained from a solution to the *BMP*. Vertical stacking in the nonrelativistic context amounts to adding a time parameter to such stacking that merely serves to label successive c-space points. Similarly, Barbour (1986) vertically stacks in the relativistic context by defining a local time via the affixing of an arbitrary label corresponding to the local lapses between the equilocal points.

The above horizontal stacking here does not seem to violate ONT or MP2. Though the 3-geometries are stacked horizontally in virtue of their orthogonal normal, such relations among equilocal points are given by the solution to the thin-sandwich problem, which only uses a single 3-geometry and its time derivate as input. In effect, given our discussion above concerning the appearance of τ in BMP_{rel}, this stacking is specified by a 3-geometry.

Moreover, MP1 is fulfilled because spatial distances in this constructed 4-d space are those in a hypersurface that are expressed by a 3-geometry. Additionally, this setup allows him to create a vertical stack in the sense of allowing him to define a local time for the distance between each equilocal set of points in an operationalist manner. Given that a solution to the thin-sandwich problem involved in BMP_{rel} provides the distance between such points and because this distance is derived only from instantaneous 3-geometries, an arbitrary time parameter can be affixed to the distance between equilocal points in a similar fashion to which such a parameter was assigned to a horizontally stacked nonrelativistic c-space points. Local time here corresponds to the assignment of an arbitrary parameter of increasing value to distances in the orthogonal direction between equilocal points of the 3-geometries. Because the distance itself arises only from the relations in a 3-geometry, MP2 is satisfied.

3 GR as a Case of Machian Relativistic Dynamics

Barbour (1994a, 2868) claims that GR is indeed Machian because it is one of the 4-d spaces that he can build from BMP_{rel}. GR exhibits foliation invariance, i.e., there is no preferred foliation of space-like hypersurfaces.[106] In effect, there is no single way to slice up spacetime into a certain best-matching sequence of 3-geometries. Barbour conjectures that he can build a 4-space that exhibits this property. Build a 4-d space via horizontal and vertical stacking as described in the preceding section. So that the 3-geometries out of which it is built are not deemed the preferred foliation, allow the space to be foliated such that any foliation results in another sequence of 3-geometries.[107]

In §3.2 below, we'll return to this means of accounting for foliation invariance and address the issue of the extent to which the Machian spacetime must be foliated so that 3-geometries, rather than spacetime, retain their ontologically fundamental status. Further, it is important to note that because, as we'll see in Ch5, Barbour discusses the prospect of quantizing GR, rather than his general Machian dynamics, it seems that at least in the context of quantum gravity he accepts that a Machian GR exhibits this foliation invariance.[108] But, for the time being, let's return to Barbour's evidence for the Machian nature of GR.

---

[106] This issue is linked with that of the relativity of simultaneity. Because whether one regards two events as being simultaneous is relative to one's worldline, there's no single notion of simultaneity that indicates that spacetime should be foliated in a certain manner. For discussion, see Jammer 2006 and Craig and Smith 2008.

[107] While I am focusing on Middle Barbour throughout, note that Current Barbour, e.g., Barbour, Foster, Murchadha 2000, argues that a unique curve can be drawn in conformal superspace such that it corresponds to a single GR spacetime. If his arguments here maintain the Machian nature of his relativistic account, then it seems that there is a single preferred foliation picked out for a GR spacetime and, thus, he is not obviously committed to a proliferation of sets of best-matching c-space points in order to capture GR's spacetime.

[108] However, there have been some proposals regarding the prospect of determining a preferred foliation. See Monton 2005 on preferred foliations in quantum gravity and their impact on presentism.

In addition to having some means of accounting for foliation invariance, he illustrates the Machian nature of GR by noting the similar structures of his BMP_{rel} and of a certain version of GR's action, namely the Baierlein-Sharp-Wheeler form of GR's action (BSW). Baierlein, Sharp and Wheeler (1962) take up the task of specifying a geometry of curved empty space that evolves in accordance with Einstein's field equations if one is given only the 3-geometries of two hypersurfaces.[109] Using Barbour's formulation in order to mirror his BMP_{rel} above, the action they find is:

$$\delta I_{BSW} = \int d\tau \int dx \sqrt{RG^{ijkl}\left[\frac{dq_{ij}}{d\tau} - 2N_{(i;j)}\right]\left[\frac{dq_{kl}}{d\tau} - 2N_{(k;l)}\right]} \qquad \text{(E3.2)}$$

E3.2 is only in terms of 3-geometries and a shift vector N_i. The lapse has been eliminated. R here is the 3-d scalar curvature of q_{ij}. And, the DeWitt supermetric G^{ijkl} has the ultralocal form[110] of $\frac{1}{2}q(q^{il}q^{kj} + q^{ik}q^{lj} - q^{ij}q^{kl})$, where q is the determinate of q_{ij}.

In comparing E3.2 with E3.1, Barbour (1994a, 2868-9) identifies the shift vector N_i with his equilocality shuffler: they both serve the same function in the equation. Moreover, τ is operating in the same fashion as that of his E3.1 and no lapse is used. However, a few components in E3.2 are specified more than their analogues in E3.1: his conformal factor F is specified here by R, and the ultralocal supermetric is used. In effect, he concludes that E3.2 is a specific version of his Machian BMP_{rel}.

3.1 The Recovery of Local Minkowski Vector Bundles

In the introduction of this chapter, we encountered a reason why GR does not seem to be Machian, i.e., it assigns a Minkowski vector bundle at a point tangent to a curve passing through a point. Furthermore, it was stated that Barbour claimed his Machian geometrodynamics could be used to show how such a tangent space could be emergent from stuff and their relations alone. Barbour has not specified exactly the manner in which his

---

[109] For criticism of this approach, see Bartnic and Fodor 1993.

[110] The supermetric is ultralocal if it contains no spatial derivatives of the metric. It effectively specifies the unique distances among the points of the metrics.

Machian geometrodynamics does so. However, we can sketch out how this may work given the preceding account.

Once GR's spacetime is constructed via a horizontal stack that is foliation invariant, i.e., any subsequent foliation of the space results in another sequence of best-matching 3-geometries, suppose that there is a curve through it. Foliate the space such that the curve passes through a series of equilocal points of a sequence of best-matching 3-geometries. Consider one of these equilocal points. The point is on a 3-geometry with a 3-metric. The metric tensor associated with this point by the 3-metric can correspond to the spatial vectors of a Minkowski vector bundle. The local lapse associated with the point corresponds to the temporal vector of a Minkowski vector bundle. Thus, Machian geometrodynamics can show that such tangent spaces emerge from the relative relations of 3-geometries alone.[111]

3.2 Machian GR, the Hole Argument and the Status of Relations Among C-Space Points

Though the hole argument, at least as formulated by Earman and Norton (1987), is targeted at substantivalism about the manifold in the context of GR[112], it is important to present the hole argument here and discuss its implications for Barbour's Machian GR. This is due to the fact that it highlights the role that relations play among c-space points.

---

[111] Further, briefly note the difference, one that is discussed in Ch6, between his nonrelativistic constructed space-time and his relativistic constructed spacetime. In his Machian GR, there are many sets of best-matching c-space points with no preferred set. As c-point set is relative to one's worldline in a similar fashion to the manner in which simultaneity is relative to one's worldline. Yet, in his nonrelativistic dynamics, there is a single set of c-space points with only one means of foliating them. This latter dynamics is assumed in his depiction of QT. So, even though time is cashed out in spatial terms, there are still conflicting notions of spatialized time between the theories. Because he generally puts discussion of his QT in terms of his Machian nonrelativistic dynamics, I discuss in Ch6 whether he has effectively created a timeless version of the problem of time in his quantum gravity through his juxtapositions of these spatialized times.

[112] Because I am focused on determining what role time plays in Barbour's dynamics given his explicit definition of 'relationism', rather than on how to classify his account in terms of the standard substantivalist/relationist distinction, I bracket off the issue of how 'substantivalism' and 'relationism' ought to be defined in GR. See Dorato 2000 for discussion. Furthermore, this is a very live problem in current GR debates; for discussion of Earman and Norton's formulation of the hole problem, see Hoefer 1996, Rynasiewicz 1994,1996.

Additionally, it makes salient the ontological commitments one is saddled with in cashing out foliation invariance via many best-matching sets of c-space points such that GR's spacetime does not play a fundamental role. So, while I do not argue for the claim that Barbour's view is impervious to some version of the hole argument, I here raise it as a means of illustrating the role of spacetime in his account as well as the sorts of relations and ontology to which he is committed; I focus here on teasing out the role of time in Barbour's account so that ACA may be applied to it, rather than on whether his account can generally overcome the hole argument.[113] Additionally, in accord with ACA, I explore the ramifications of his principles for his ontological and metaphysical commitments in GR in order to treat his GR as part of the Machian network that we proceed to analyse in Ch6.

In effect, I provide a sketch of Earman and Norton's version of the argument against manifold substantivalism, and I put the objection in terms of a problematic generation of ontological proliferation by manifold substantivalism. Then, I question whether Barbour's Machian GR faces a similar problem by considering the effects of transformations on relations in a c-space point, on a c-space point in a best-matching stack and on a c-space point in the context of a horizontally stacked space with multiple foliations. It will be shown that while Barbour's account must and can reduce relations among c-space points to each c-space point's internal relative relations, his account of foliation invariance requires there to be an enormous number of horizontal stacks.

With their version of the hole argument, Earman and Norton target manifold substantivalism.[114] Generally, spacetime substantivalism is the view according to which spacetime is a substance, i.e., something that exists independently of objects or processes occurring in spacetime. Accordingly, manifold substantivalism treats GR's manifold as a substance with the identity of the points of the manifold grounded independently of the fields

[113] For formulations of the hole argument for covariant theories, see Iftime and Stachel 2005.

[114] They (1987, 518-20) target manifold substantivalism because they argue that it is the most viable form of substantivalism for GR, e.g., they claim that because the metric carries energy and momentum, it should be treated on par with other fields considered to be the contents of spacetime, rather than spacetime itself. For criticism of this argument and discussion of other forms of substantivalism in this context, e.g., versions of manifold plus metric substantivalism, see Hoefer 1996.

defined over the manifold. Earman and Norton attack this form of substantivalism with their version of the hole argument.[115] Their argument is presented as follows.

Suppose there are two mathematical models of standard GR spacetimes with each represented by a manifold and a metric field tensor. These models are related by a certain diffeomorphism such that it is the identity map for all manifold points outside of a given region, 'the hole', but smoothly comes to differ from the identity map inside the hole. Diffeomorphisms can be interpreted in two ways: passively, i.e., the coordinate system has changed but the same structures are described, or actively, i.e., the coordinate labelling does not change but the metric gets dragged across the manifold and effectively moves the points with certain labels around on the manifold. Earman and Norton make use of this latter interpretation of diffeomorphism in the hole. Using this transformation, the particular points inside the hole of the second model are remapped. Einstein's equations are generally covariant, e.g., if a certain metric is solution to the equations, then any other metric obtained from the first by any diffeomorphism also satisfies the equations. So, if one of the metrics is a solution, then so is the other. If, however, the manifold substantivalist holds that the manifold points have their identity built in, i.e., have their identity independently of physical fields in spacetime, then the substantivalist must claim that the metrics related by a hole transformation are physically distinct.

---

[115] As is well known, a form of the hole argument was originally proposed by Einstein. See Norton 2005 for historical discussion.

This illustrates the untenable nature of manifold substantivalism because it leads to ontological proliferation.[116] Due to assumptions about manifold point individuation[117], it seems that the substantivalist must assert that each model represents a distinct spacetime. However, the two distributions are observationally identical.

With this sketch of the hole argument, it is clear the identity of manifold points plays a central role in making a hole transformation problematic for the manifold substantivalist. Do the points of Barbour's manifolds have any problematic identity? Recall that in his relativistic account, a c-space point is a 3-geometry, which is a set of equivalence class of metrics with elements related by a diffeomorphism. Do the manifold points of a metric that characterizes a 3-geometry have any sort of primitive individuality?

3.2.1 Relations Among the Points of a 3-Geometry

We saw in Ch2 that through Barbour's application of CNP to c-space points, a body in a c-space point must be defined in terms of all the relations that it has with everything else in the universe at an instant. In the context of Machian relativistic dynamics, a manifold point plays the role of the nonrelativistic body in a c-space point. So, it seems that a manifold point must be defined in terms of all the geometrical relations it has with all the other manifold points in a particular c-space point.

Do these manifold points have some sort of primitive identity? While the inclusion of haecceities in Barbour's account would not violate ONT, e.g., it may be considered a monadic property of each manifold point, haecceities, as being independent of relative

[116] Rather than originally referencing the problem of ontological proliferation that arises for the substantivalist, Earman and Norton claim that the hole argument illustrates that manifold substantivalism leads to indeterminism on grounds that the laws cannot pick between the two developments of the field in the hole. But, as it is contentious whether this indeterminism is only an issue for manifold substantivalism in the context of GR, I do not present this issue for manifold substantivalism here: see Melia 1999 for discussion. And, see Belot 1995 for discussion of the relation between ontology and indeterminism.

[117] See Stachel 2005 who makes this assumption explicit in terms of each of the points having a primitive thisness or haecceity, and see Parsons and McGivern 2001 for discussion of other means of individuating manifold points in order to avoid this conclusion.

relations cannot enter into MP's descriptions. But, it is contentious whether the lack of haecceities in such a description is indicative of whether one lacks an ontological commitment to them. Nevertheless, because haecceities are independent of relative relations and since CNP is only defined in terms of the instantaneous relative relations of a thing, a haecceity cannot be part of a manifold point's CNP. It follows that because a CNP is supposed to provide a *complete* description of a thing, a manifold point cannot have a haecceity. Thus, though it is not ruled out by ONT, Barbour's use of CNP dictates that the manifold points do not have some sort of primitive identity built into them. Instead, a manifold point can only be identified, or at least distinguished from a point in a manifold that has a different set of instantaneous relations, in virtue of the instantaneous relative relations it has in a certain 3-metric.

Further, this result is in accord with Barbour's use of 3-geometries. In effect, if we perform a diffeomorphism on the entire metric of a c-space point, then we get another metric. This metric just is one in the set of a particular 3-geometry's set of equivalence class of metrics with elements related by a diffeomorphism. Because manifold points have no built-in individuality, there is no means of identifying particular points across such transformations. Thus, we are not committed to there being an individual manifold for each equivalent metric.

To sum up thus far, even though ONT seems compatible with stuff having primitive identity, Barbour's use of CNP provides a means of denying that manifold points have some sort of relation-independent identity. Doing so allows him to use 3-geometries without any ontological proliferation; 3-geometries are still the fundamental feature of his account each of which can be represented in terms of a set of an equivalent class of metrics.

3.2.2 Relations Between Best-Matching C-Space Points

Let's move on to considering the relation between two best-matching c-space points. But, first we must determine the nature of the relation that holds between them. ONT and CNP are cast in terms of the relative relations among stuff *within* a c-space point. What is the nature of relations, e.g., best-matching, that hold *between* two c-space points? By addressing this question, we can, as we will see at the end of this section, determine the manner in which Barbour must respond to a diffeomorphism being performed on a 3-geometry in a best-matching stack.

In the context of his account of quantum theory, which is presented in Ch4, he makes more use of heaps of c-space points, which we briefly encountered in his nonrelativistic account presented in Ch2. We will see in his quantum account that, rather than using, at least initially, some sort of ordered c-space composed of all possible c-space points, he makes use of a heap of possibilities. In this context, he makes a contrast between heaps of c-space points and 'points on an ordinary manifold' that may reflect the manner in which considers a c-space point to be related to other c-space points.

In his (1994c) outline of his quantum account, heaps are just c-space points that make up a c-space. One would suppose that Barbour uses the term 'heap' in order to emphasize the lack of fundamental relations among the points in c-space. In view of the following quotes, he implicitly seems to do so by presupposing CNP:

> I use the word *heap* because individual objects in a heap are entities in their own right. They can be picked up and examined and have an intrinsic structure which exists independently of the fact that they belong to the heap. (1994c, 409)

> […] I use the word heap to emphasize that its points are very different from points of an ordinary manifold on which, say, a metric has been defined. For the points of such a manifold have no individuality of their own. They can only be individuated by the metric relationships which hold around them. If one were to remove such a point from the manifold, to 'pick it up', so to speak, it would lose all its individuality. In contrast, any relative configuration takes with it all its defining attributes. Each thing in a heap is a self-contained unity, can be picked up, examined in its own right, and inferences drawn from the structures found within it. (1994b, 2881)

The first quote makes clear that the c-space points in a heap have their internal structure and existence independently of whether they belong to the heap. And, as described as a 'self-contained unity', a c-space point seems to be capable of complete independence from other c-space points. From this we can infer that heaps of c-space points do not impose any fundamental relations or structure onto the c-space points. Moreover, this 'self-contained unity' of a c-space point and the claims that it 'takes with it all its defining characteristics' and that 'inferences can be drawn by the structures found within' the point indicate a c-space point version of CNP, i.e., a notion attributed to a c-space point that is so complete that everything that can be attributed to the point can be deduced from the notion. In effect, the CNP of a point seems completely reliant on the contents of the c-space point and, thus, its membership in a heap has no bearing on the c-space point's CNP. In effect, a c-space point in a heap bears no fundamental relations to other points. The second quote indicates that the internal structure of such a point, however, allows us to make 'inferences'. I return to these 'inferences' following a discussion of whether a weaker reading of this passage is possible such that there is room for Barbour to posit fundamental relations among c-space points.

There indeed appears to be an alternative reading of the above quotes. One may claim that, rather than assuming something as strong as CNP, Barbour is only committed to a weaker, less complete analogue of CNP. He is not necessarily committed to something as strong as a CNP that is defined via the point alone because he does not state that *everything* that can be attributed to the point can be deduced from its internally-defined notion. Rather, he is just explicitly committed to the point's *defining attributes* being deducible from its internally-defined notion.

From this reading of the quotes, two objections to the initial reading arise. First, the quotes do not presuppose CNP. Rather, they at most assume what I term a strong internal-CNP, i.e., a notion attributed to a c-space point that is so complete that everything that can be attributed to the point when the point is considered separately from all other c-space points can be deduced from the notion. Second, when a point is considered alone, we can only ascertain its *defining attributes*, rather than, as CNP states, ascertaining everything that can be attributed to the point. For example, even though something is a 'self-contained unity' in the sense that it has all of its constituent stuff and their relations, it could still have relations with other self-contained unities. Such relations, though not defining attributes, may still exist among the self-contained unities. These two objections are interlinked as follows. The latter specifies the type of attributes, i.e., defining attributes, that one may ascertain when the point is considered alone. So, in turn, the former's inter-CNP can be reformulated as: a notion attributed to a c-space point that is so complete that all of its defining attributes can be deduced from the notion.

This reading gives us some room to add relations among c-space points that are not restricted to those within a c-space point. But, can Barbour maintain that there are such relations? Following a discussion of this alternative reading, it seems that he cannot: all such relations ultimately must be reducible to the stuff and relations in a c-space point.

To facilitate discussion of the alternative reading, namely that Barbour assumes the weaker inter-CNP rather than CNP, 'defining attributes' will be specified. This specification will then be used to reply via discussing the second objection's example in the context of Barbour's ontological commitments.

In order for a distinction between inter-CNP and CNP, which is posited by the above objection, to be maintained, the defining attributes must be a subset of the totality of a c-space point's possible attributes. This is required because CNP, which takes into account *everything* that can be attributed to a c-space point, is distinguished from the supposedly restricted inter-CNP, which only includes what may be attributed to a c-space point when the point is considered separately from all other c-space points. Because the alternative interpretation claims that Barbour is committed to inter-CNP, rather than CNP, it is the limited domain of attributes included in inter-CNP to which 'defining attributes' refers. Thus, one who holds the inter-CNP interpretation must provide some account in which the defining attributes are a subset of the totality of a c-space point's possible attributes in order to maintain the distinction between inter-CNP and CNP.

Does the inter-CNP interpretation have such an account in which defining attributes are a subset of all possible attributes? Given his choice of the term 'defining', it seems natural to assume that Barbour's distinction between defining attributes and all other attributes may be equivalent to a distinction between essential properties and accidental properties. I'll define 'essential properties' in the standard modal fashion[118], i.e., a property which an object necessarily has. Such properties are contrasted with accidental properties, i.e., a property, which the object could possibly lack, that the object just happens to have. Thus, it seems at least *prima facie* that the inter-CNP interpretation has an account that prohibits a deflationary reading of inter-CNP and CNP. Let's attempt to develop this account further in view of the passage in order to ascertain whether it is coherent.

[118] Because the proper characterization of the essential/accidental distinction is not my primary concern here, I do not argue for this manner of making the distinction: see Fine 1994 for criticism.

An examination of the contrast made in the second quote between the points of a metric and the points of c-space implies that essential properties are monadic properties and, assuming that relations among objects are ontologically on par with the objects themselves, intra-point relations, i.e., relations among the stuff in a c-space point. It also seems that the accidental properties are inter-point relations, i.e., relations among c-space points.

As in the second quote above, a contrast is made between a point from a standard GR manifold on which a metric has been defined and a c-space point.

If the standard manifold point is considered apart from the rest of the manifold, then the point, as lacking metric relationships, cannot be individuated. The manifold itself, as just a smooth, continuous group of points, is made of points with no properties that serve to individuate one point from another. Contra manifold substantivalism, Barbour assumes in the quote that standard manifold points have no primitive identity. Metric relationships are defined on the manifold as a whole, hold among points and, thus, can be classified as inter-point relations. In considering such a point by itself, Barbour claims that it lacks a means of individuation since, as taken out of the manifold in which the inter-point relations apply, it would 'lose all its individuality'. Thus, in the case of standard manifold points, inter-point relations seem to be accidental; the points may have metric inter-point relations, yet it is possible that these points do not have them.

In contrast, if the c-space point is considered apart from the other points in c-space, then the c-space point is described as still possessing all of its defining attributes. This is because, it seems, the c-space point is a 'self-contained unity' and 'inferences can be drawn from the structures within it'. Unlike a manifold point, a c-space point contains certain structures that are independent of its 'location' in c-space. In view of ONT, these structures are, at base, the stuff and the stuff's relations, which make up a c-space point. In effect, the monadic properties of the stuff in a c-space point and its intra-relations are the defining attributes of a c-space point, i.e., the c-space point's essential properties, as illustrated in this exercise of considering the point removed from c-space. Exactly what 'inferences that can be drawn' from such structures can be surmised in view of ONT. Since c-space intra-relations and their stuff are supposed to be ontologically basic, all things, including those that feature in such inferences, must be reducible to or emerge from the stuff and their intra-relations of c-space points. Thus, due to ONT, even inter-relations, e.g., similarity among c-space points, must be strictly speaking reducible to stuff in c-space points and intra-relations among the stuff in the c-space point. In turn, the inferences that can be drawn from c-space structure are supposed to include ones concerning c-space points' inter-relations. In sum, unlike the thin concept of manifold points from which no manifold inter-relations can be drawn, a c-space point itself is supposedly robust enough to allow one to infer even the inter-relations among c-space points.[119] An example of such 'inferences' is the sequence given by the relativistic best-matching procedure: only a specification of a 3-geometry's metric and its time derivate are required to specify the corresponding best-matching sequence of 3-metrics.

In view of this discussion, it seems clear that, strictly speaking, all inter-relations must be reducible to the monadic properties and intra-relations within c-space points.[120] How does this affect our overarching question concerning the plausibility of the inter-CNP reading: Can a non-deflationary distinction be maintained between essential and accidental properties on Barbour's view? If the set of accidental properties is completely comprised of inter-relations, then the distinction cannot be maintained since these inter-relations are reducible to the set of essential properties, i.e., monadic properties and intra-relations. If this is correct and such a distinction cannot be maintained, then the inter-CNP reading, which requires this distinction in order demarcate inter-CNP from CNP, is not the right reading of the passage.

However, one may consider it contentious to claim that the set of accidental properties is composed of only inter-relations; surely many of the monadic and intra-relations of a c-space point may be considered accidental. For example, the distance between two objects in a c-space point is 10m. It seems possible that the objects may lack this specific intra-relation, e.g., they could be a distance of 10.5m apart, yet still be the same objects. Thus, it seems incorrect to claim that all intra-relations, at least, are essential properties.

---

[119] In Ch6 I discuss whether this conception of a c-space point is robust enough to make such inferences without, e.g., some irreducible relations among c-space points indicated by certain equations chosen.

[120] A similar deflation is also attributed to Leibniz: he arguably held maximal essentialism, i.e., the view according to which all properties of a thing are essential. Given his notion of a self-contained substance, the concept of an individual substance contains in itself all the predicates that the substance has, has had and will have.

I reply that given Barbour's notion of a c-space point, all of a c-space point's monadic properties and intra-relations must be essential properties. Recall that a c-space point is comprised fundamentally of stuff and their intra-relations. If the monadic properties or intra-relations are changed even slightly, then the particular c-space point is regarded as a different c-space point. In effect, the monadic properties and intra-relations of a c-space point must be regarded as essential c-space point properties.

Thus, in view of the above discussion, I conclude that the CNP reading, rather than the inter-CNP reading, is the correct reading of the above passage. In effect, Barbour seems to be presupposing that CNP can be applied to c-space points. From this presupposition he infers that such CNP-governed points do not gain any additional essential properties when grouped together. Such claims appear to be in line with ONT and require that the accidental inter-relations be reducible to the essential monadic properties and intra-relations. Moreover, this exploration of Barbour's intended relation between c-space points and c-space further elaborates his rationale for using 'heap' to describe a collection of c-space points. Just as the things in a heap do not, arguably, acquire different monadic properties and intra-relations in virtue of being in the heap, c-space points do not acquire different essential properties in virtue of being in a heap of c-space points.

In view of this discussion, we can draw some conclusions concerning the relation of best-matching that holds among certain c-space points. The best-matching relation cannot be some fundamental and irreducible relation that holds among c-space points. Instead, it must be derived from the relations within a specific 3-geometry. Barbour's best-matching procedure indicates the manner in which this may be done. A 3-geometry can be described in a number of different metrics. And, for each metric, one can use the best-matching procedure to determine the series of 3-geometries to be associated with that description. In effect, the relation of best-matching among a certain set of metrics is itself specifiable by the relative relations within a single 3-geometry alone. Thus, the relation of best-matching among 3-geometries is reducible to 'inferences' one can draw from the structure of a single c-space point.[121]

[121] Here again we have a parallel with Leibniz: the properties associated with monads are treated in a similar fashion. See Rutherford 1995.

Finally, to return to the issue of whether we can perform a transformation on a best-matching sequence and generate some sort of displeasing ontological proliferation, consider performing a diffeomorphism on one of the c-space points in a best-matching sequence. Suppose a diffeomorphism is carried out on the metric of one 3-geometry's metric that is in a horizontally stacked set of best-matching 3-geometries. Denote the initial best-matching stack as 'stack A' and the stack resulting from the diffeomorphism 'stack B'. Because a diffeomorphism is performed on a 3-geometry's particular metric, the 3-geometries in both stacks are the same except one is described by a different 3-metric. So, stacks A and B have the same series of 3-geometries, but it seems like stack B is a different stack because of the different metric involved. Moreover, due to this difference, Stack B is no longer a best-matching stack. Thus, it seems that the metrics, rather than the 3-geometries, are doing the work in specifying whether two 3-geometries are related by best-matching; because the 3-geometries remain the same, it is particular metrics that must be specifying the inter-relations among 3-geometries. Due to this reliance on 3-metrics, one may claim that the inter-relations are not completely reducible to the relations within a 3-geometry.

Though the presence of such irreducible relations would certainly be ontologically displeasing given the previous discussion, Barbour can argue that they are in fact reducible to a 3-geometry. It is the 3-geometry that encodes the information about which best-matching sequence is associated with each of its metrics: perform the relativistic best-matching procedure on any of them, and the sequence of best-matching metrics associated with it is determined. Stack B is indeed not a best-matching stack. However, the reason for this is that such a stack is not encoded in a particular 3-geometry's intra-relations. In effect, it is particular 3-geometries, rather than their associated metrics, that are ultimately indicating whether a stack is best-matching or not. So, contra the above argument, the relation of best-matching is ultimately reducible to a 3-geometry.

In sum, Barbour must hold that relations among c-space points are ultimately reducible to the relative relations among the stuff in such a point alone. Through his use of 3-

geometries and best-matching procedure, it seems that the relations among c-space points can indeed be reducible to the relations within individual c-space points.[122]

This implies that the presence of a 3-geometry with a certain metric in a horizontal stack must be accompanied by a certain series of best-matching 3-geometries if there is a geometry with a certain metric. In the context of a single foliation of a stack, this doesn't provide much ontological commitment: one is committed to there being a single stack of 3-geometries. However, in a foliation invariant stack, one is committed to a large number of these stacks. Let's now turn to the implications of Barbour's means of cashing out GR's foliation invariance.

3.2.3 Relations Among Foliations

Recall that Barbour attempts to cash out GR's foliation invariance by first building a 4-space via horizontal and vertical stacking and then allows the space to be foliated such that any foliation results in another sequence of best-matching 3-geometries. Presumably we can then vertically stack each of these foliations by defining a local lapse between each of the equilocal points on horizontal stacks resulting from such foliations.

With Barbour's claim that *any* foliation of spacetime must correspond to another best-matching horizontal stack, it seems that Machian GR spacetime requires that there exist all possible foliations of that stack. Because a stack is made up of a series of 3-geometries and since these 3-geometries are taken to be ontologically basic, it seems that this setup commits us to a huge number of stacks and, thus, the existence of an enormous number of c-space points. Is there any way to choose between possible foliations in order to cut down on the magnitude of our Machian GR ontology?

---

[122] Furthermore, a means of distinguishing a single c-space point from others can also be obtained in virtue of a single c-space's relations. Any possible change of the relations in a single c-space point is indicative of a different possible c-space point. The degree to which such a change differs from the c-space point's actual relations can indicate the degree to which such a point differs from a different possible configuration. This process of using only the relations in a single c-space point as a means of distinguishing it from other possible c-space points was also used by Barbour in Ch2 in order to generate best-matching initially.

Pooley (2001) answers this question negatively. Unless Barbour has a metric-independent manner of specifying the time derivative associated with a 3-geometry and, thus, has some means of selectively foliating, he must hold that all possible resulting foliations of the original horizontal stack exist. In the context of illustrating the manner in which Barbour's setup generates a 'thoroughly pernicious indeterminism'[123], Pooley argues that GR's space*time* formulation is more fundamental than an account using geometrodynamics.

In standard GR, an initial point and direction in superspace are all that is required to determine a unique spacetime geometry. In Machian GR, however, a foliation of spacetime is supposed to be regarded as a set of 3-geometries. Unlike standard GR in which a local lapse is effectively specified by one of the vectors at a point, on Barbour's account the lapse is derived from the relations between equilocal points of the best-matching metrics. In effect, between any two hypersurfaces, there is an uncountable number of possible foliations. All of these foliations can be cashed out via the best-matching procedure as follows. Consider one of these hypersurfaces. On Barbour's account, it is a 3-geometry. But, this 3-geometry has a number of different metrics, and with each metric there may be a different time derivative associated with it. In effect, it seems that there can be a number of different best-matching sequences from a specified hypersurface to another. However, it appears that there is no way to choose which sequence there should be between the hypersurfaces without specifying a particular metric and associated time derivative. On the assumption that not all best-matching foliations by a constructed GR spacetime exist, Pooley claims that this illustrates that such a Machian GR is indeterministic. Because there are a number of different paths that can be generated between the two surfaces, it seems that one is unable to determine exactly which sequence should be generated between the points. Due to such indeterminism facing a selective geometrodynamical account of foliations, Pooley claims that GR's space*time* might be regarded as more fundamental than a reconstruction of spacetime with geometrodynamics.

---

[123] See Pooley 2001 for discussion of the manners in which Barbour's account can be regarded as indeterministic. Though such indeterminism is a very pressing issue in Middle Barbour's GR, I bracket off this issue because I am concerned with highlighting the ontological implications and the role of time in his account so that I can apply ACA to it. However, Pooley's claims about the indeterminism of such an account are generated by assuming that not all possible foliations are actualized, and Middle Barbour does not make this assumption.

Nevertheless, he does note that there is a means of constructing spacetime from 3-geometries such that it does not require the specification of its metric and associated time derivative in order to, e.g., provide a single sequence of 3-geometries between two hypersurfaces. This alternative, which mirrors Barbour's suggestion, is to regard GR's spacetime as constructed from all possible compatible sequences of 3-geometries. Thus, given a particular 3-geometry that appear in a foliation of GR's spacetime, it seems that without some means of specifying its metric(s) and time derivative(s) that can appear in the spacetime, we must hold that the sequences associated with all possible foliations of our initial stack exist.

So, by claiming that all possible foliations exist, we have an ontological commitment that is immense in terms of the number of 3-geometries that exist. However, because we do not make recourse to primitive temporal relations, the number of our basic ontological building blocks is still low, i.e., there is only stuff and their relative instantaneous spatial relations fundamentally, and it is in accord with ONT. Thus, it seems that GR's spacetime can be reconstructed in terms of instantaneous 3-geometries alone.

In sum, Barbour provides a relativistic dynamics by mirroring the development of his nonrelativistic dynamics. C-space points again feature as the primary components of his account; however, rather than involving the relations among particles, each c-space point is the relations at an instant among manifold points as given by a 3-geometry. This choice of c-space points seems to be in accord with ONT: only instantaneous relative relations among manifold points are involved. Additionally, the set of all possible c-space points is structured by a stratified manifold, but, again, this seems to serve the function of representing best-matching series of c-space points, rather than determining the exact series of best-matching points. It is his relativistic BMP that indicates the manner in which to match up a 3-geometry given a metric of the 3-geometry and its associated time derivative. Although a time parameter appears in this BMP, it merely serves to indicate the direction of tangent vectors at the manifold points and, thus, does not violate MP or ONT. In effect, the BMP provides a Machian means of determining a series of best-matching 3-geometries given the metric of a single 3-geometry; local lapses and shifts can be obtained from this information alone. These 3-geometries can then be stacked by lining up their equilocal points to create a 4-d space.

Additionally, proper time can be reconstructed from this setup in a manner that is in accord with MP by affixing a monotonically increasing parameter to the path constructed along equilocal points.

With this set up, he can provide a Machian interpretation of BSW and GR such that its assignment of a nonphysical Minkowski vector bundle to a point used to represent a local inertial frame and its foliation invariance emerge from best-matching 3-geometries alone. The former feature is obtainable from the vectors associated with equilocal points, while the latter feature is the result of allowing all the possible foliations of a stack to be a best-matching series of c-space points.

Finally, given our discussion of the various relations in and among c-space points that were made salient by considering the implications of the hole argument for Barbour's Machian GR, it seems that due to his application of CNP to c-space points, their manifold points cannot have a primitive individuality. Moreover, he must hold that all the relations among c-space points must be reducible to the relative relations among the stuff within the c-space point alone. And, in order to avoid using the time of GR's space*time* as a means of specifying particular paths and foliations through his constructed spacetime, he must hold that all possible foliations of a constructed spacetime exist. So, it seems that given his overarching Machian principles, his GR is saddled with these additional ontological and metaphysical commitments.

Because, as we'll see in the next chapter, he proposes quantizing the Machian BSW and Machian account of GR, rather than his general Machian relativistic BMP, henceforth we will focus on his Machian GR. Let us next turn to his quantization project and aims.

Chapter 4: Barbour's Quantum Theory and Setup for his Quantum Gravity

Over the course of the next two chapters, Barbour's quantum theory (QT), proposed method of merging QT with GR and resultant account of quantum gravity are provided. Because of the large role that his QT and its interpretation play in his quantum gravity (QG), I am devoting much of this chapter to the explication of his QT. Additionally, this chapter provides general background and his methodological setup for merging QT and GR. Thus, the subsequent chapter can utilize components of this chapter and focus on the explication of his QG.

Moreover, due to the relatively few places in which he presents his quantum account and the rather condensed manner in which it is provided, much work is done here in order to unpack his QT and make the role of *time* salient in a manner that is in accord with his overarching Machian principles. Thus, the work done here and in Ch5 will allow us further treat his QT and QG as parts of a single Machian network such as to apply ACA in Ch6 to the surface reading of *time*'s roles obtained here.

1 Timeless Quantum Theory

Before elucidating the details of Barbour's treatment of the quantum, I provide here a brief introduction to the manner in which he tackles QT as well as the manner in which it affects his QG, all of which will be explained in depth in this and the following chapter.

Barbour's account of QT is formulated generally in terms of his Machian project of eliminating time's fundamental role in the theory. In addition to being motivated by his principles, his QT is also formulated with an eye to solving the problem of time in canonical QG. As is explained below, this particular problem arises from the 'frozen' formalism when the geometrodynamical Hamiltonian is quantized, i.e., such quantization results in an equation that is supposed to describe temporal evolution but lacks an explicit time parameter.

In turn, this chapter is organized as follows. First, I provide an overview of his approach to QT and QG as it appears in his Middle stage. Then, due to Barbour's method of formulating QT such that it can be interpreted in a timeless manner, unified with a timeless GR and, thus, provide a solution to the problem of time, I present this problem. Next, I spell out his proposed method of resolving it which involves a method of identifying the fundamental features of QT and GR. By finding such features, he conjectures that we can formulate QT in a timeless fashion and, in effect, make the lack of a time parameter in the quantized Hamiltonian unproblematic. Because ONT and MP must be upheld, he proposes an interpretation of QT along the lines of the many worlds Everettian interpretation in which the worlds are replaced with c-space points.

2 Middle Barbour's QT Texts and Approach to QG

Before beginning the exegesis of Middle Barbour on QT, it is necessary make a few notes about the relevant texts. There are three texts from the Middle period in which Barbour substantially developed his QT account: 1994b, 1994c and 1999. 1994b is a relatively technical paper in a peer reviewed journal, and 1994c, from an edited collection on time asymmetry, provides a generalised outline of the content of 1994b. The 1999, however, is written as a work of popular science that is, "self-contained and accessible to any reader fascinated by time" (1999, 5); however, it is the only text during Barbour's Middle period in which he makes certain explicit links among the various portions of his account of QT and QG as well as particular contrasts between his account and more standard interpretations. So, though much of what follows focuses on his 1994b and 1994c, I also incorporate the 1999 in order to supplement some of Barbour's 1994 reasoning, provide his explicit contrasting of his theory with other interpretations and use some examples presented there as a pedagogical aid to illustrate his theory. Additionally, I am careful to qualify and develop the crucial but potentially pop-sci claims presented in his 1999.

As Barbour believes that DeWitt has solved the problem of quantizing GR to some extent, Barbour uses the Wheeler-DeWitt equation (WDE) as a starting point and proceeds to provide an interpretation of QT and the WDE. This interpretation is to be such that QT is reconcilable with GR and that the WDE has a coherent, timeless story. These issues are presented in the next chapter. This chapter focuses on the manner in which Barbour prepares QT for merging with his GR. But, he goes about such preparation assuming a certain approach to QG as well as a certain method of ascertaining of the fundamental components of his QG. So, before going into the details about Barbour's account, it is necessary to provide some background information about his assumed canonical approach to quantum gravity, its relation to the WDE and his method for merging QT and GR.[124]

The main, general project that characterizes quantum gravity is the integration[125] of GR with QT *simpliciter*, rather than with our most successful QT.[126] To provide some background for the difficultly with such integration as well as to give some rationale for the three main approaches, I first present two general difficulties with the merging of GR at QT. Then, I present the three main QG approaches briefly and state how each of them attempts to resolve these difficulties. Next, I go into more detail with a presentation of Barbour's preferred programme, which we encountered in the previous chapter, namely a type of the canonical approach called 'quantum geometrodynamics'. Finally, I state how the problem(s) of time arises for this programme and tease out exactly which problems of time Barbour attempts to resolve.

Following the presentation of the problem of time, we turn to Barbour's method of reconciling QT and GR in a timeless fashion. According to this method, we determine what the most fundamental shared elements of QT and GR are. Unsurprisingly, Barbour identifies the instantaneous relative relations of c-space points as the fundamental shared elements and rejects any fundamental role for time. In the final subsection, we see how he proposes to formulate QT such that it is in accord with ONT and MP.

2.1 Difficulties Arising in QG's Integration and Approaches to QG

---

[124] This overview is admittedly brief as its main purpose is to better delineate Barbour's starting point via providing some contrast with standard views and more orthodox approaches. For overviews of QG, see Isham 1993, Kuchar 1992, Rovelli 2008.

[125] As Rickles (2008, note 9) points out, the meaning of such 'integration', 'unification' or 'merging' is not entirely clear and varies depending on the QG programme adopted. If Rickles' claim is correct, it provides motivation for my entire project of developing and examining means of merging physical theories: it is precisely Barbour's means of integration that I wish to critique and replace with ACA.

[126] This follows Rickles' (2008, §2.3) definition and is similar to that of Isham (1993, 1-2). For a discussion of other uses of 'quantum gravity', see Rickles (2008, 2.1-2).

Amongst many other issues[127], there are two central difficulties that arise in QG's general project of integrating GR and QT.

First, there is the need to reconcile GR's classical treatment of certain physical quantities, i.e., physical quantities such as those having values given by real numbers that represent field strength, particle position and momentum, with QT's quantum treatment of physical quantities, i.e., quantum in the sense that physical quantities can only take a certain set of discrete values. To obtain specific values for physical parameters in QT, the wavefunction is operated on with the operator associated with that parameter. Solutions for the parameter can only take certain values of the parameter, i.e., eigenvalues. The issue arises because: GR is formulated in terms of Riemannian geometry, which assumes that the metric is a smooth dynamical field, while QT requires that any dynamical field be quantized, i.e., at small scales the dynamical field manifests itself in discrete quanta.[128] So, GR's physical quantities are of continuous values, while QT's physical quantities are of certain discrete values.

Second, there is the issue of background independence. GR is background independent in the sense that it does not involve a fixed[129] spacetime geometry with values given *a priori*.[130] Such values are not given *a priori*[131] because one obtains its spacetime

---

[127] See Isham (1993, §2), Butterfield and Isham (1999, 128-9) and Rickles (2008, §3) for other such issues.

[128] This explication of this issue is largely from Rovelli (2004, 3). Also, see Hughes (1989, Ch2) regarding QT and Rovelli (2004, 47) regarding GR.

[129] Butterfield and Isham (1999, 134-7, 147) provide three meanings of 'fixed' for its use in at least QG: (a) indicates that a structure present in a classical theory is not quantized; (b) indicates that a structure is not subject to dynamical evolution, e.g., the spacetime metric is fixed in Newtonian physics but not in GR; (c) indicates that a structure is completely given in the formulation of the theory and is often said to be part of the fixed background. Regarding these definitions, I am here using 'fixed' in sense (b). Additionally, the *a priori* aspect of background independence defined above seems to correspond with meaning (c), and the first difficulty above seems to highlight issues raised by (a). Though I do not have time to map completely and discuss Butterfield and Isham's framing of these issues and ensuing discussion with that given above, there seems to be at least some *prima facie* parallels between the accounts.

[130] This follows Rickles' (2008, §2.6.1) exposition of background independence.

geometry by solving GR's field equations. Such spacetime geometry is not necessarily fixed because GR's spacetime geometry is dynamical. The basic dynamical variable in GR is the metric. The metric determines the geometry of spacetime and acts as a potential for the gravitational field. The curvature of the metric, which determines the spatial lengths and times elapsed along curves in GR's continuous spacetime manifold, is postulated to describe the gravitational field: its value at any point is dependent on the state of matter at that point. Thus, since a dynamical variable is responsible for GR's spacetime geometry, the spacetime geometry is itself dynamical. In effect, GR is not dependant on a fixed spacetime geometry. On the other hand, QT appears to be background dependent necessarily; standard QT is constructed against the backdrop of a fixed spacetime geometry of either Newtonian spacetime or the flat metric of SR. In this context, time is used as a background parameter t in the time-dependent Schrödinger equation, which marks the evolution of the system in the same manner as in standard classical mechanics in the following sense: configurations of particles in standard QT change at rates given with respect to absolute time. Further, these configurations are configurations with respect to absolute space; quantum states are defined on spacelike hypersurfaces and evolve unitarily onto other hypersurfaces. In effect, GR is background independent, while standard QT is background dependent.[132] A viable QG must somehow reconcile QT and GR regarding these disparate spacetime geometries.

There are three main approaches to the general task of QG that merge together QT and GR such that the above two incongruencies are resolved: the covariant approach, the canonical approach and the sum over histories approach.[133] In hopes of making clear what distinguishes the canonical approach, on which we, following Barbour, will focus, I provide general sketches of the other two approaches.

---

[131] For detail regarding the *a priori* nature of spacetime in these theories, see Dieks (2001, 221-3).

[132] This exposition comes largely from Rickles (2008, 17-8, 81), Isham (1992, 10-2) and Weinstein (2001, 69).

[133] This division follows that in Rovelli (2008 and 2004, 393), which is based on the historical roots of the most developed approaches to quantum gravity, and the brief exposition of each approach largely follows that in Rickles (2008, §6). See Isham 1993 for an explicitly pedagogical presentation of quantum gravity, which is divided into four routes, see Callender and Huggett (2001a, 13-14) as well as Butterfied and Isham (1999, 130) for a division of QG approaches into two camps: superstring and canonical.

In the covariant approach, one attempts to construct QG as a theory of the fluctuations of the metric field over a flat, non-dynamical spacetime. To do so, the metric is split into a background part, which is a flat, fixed Minkowski spacetime usually, and a part consisting of a dynamical field that is the deviation of the physical metric from the background part. It is this latter dynamical part that is treated as the gravitational field and quantized. And, the dynamical part is quantized with respect to a fixed spacetime, which parallels the method of quantization in standard quantum field theory.[134] The result of such quantization is a theory of gravitons, i.e., massless 2-spin particles that are the quanta of the gravitational field. A well-developed example[135] of this approach is string theory.[136]

In the canonical approach, one attempts to construct QG as a theory of the fluctuations of the metric as a whole. This is accomplished by first formulating GR with the Hamiltonian formalism. In such formalism, GR is rendered as a dynamical theory of the basic configuration variable chosen to represent space, e.g., spatial geometry, spatial connection, certain Wilson loops[137]. Then, this formulation of GR is quantized by the

[134] Because my overarching project is to evaluate Barbour's view and his version of the canonical approach, I do not list or evaluate the (dis)advantages of the non-canonical approaches. But, see Isham (1993, 16ff) for a list of difficulties with the covariant approach and a comparison with the merits of the canonical approach, and see Butterfield and Isham (2001, 55-8, 65-9) for discussions of problems with both approaches. See Rickles (2008, §6.5) regarding the sum over histories approach.

[135] String theory is classified at least historically as a covariant approach. However, it could be claimed that string theory is a successor to GR, rather than a quantization of GR, due to its radical modification of GR. Though I am not concerned here with such classification of these theories, see Rickles (2008, §6.3) for discussion. Similarly, see Perez 2008 for some considerations as to whether a certain sum over histories approaches, i.e., spin foam theory, is legitimately a third approach or, perhaps, some synthesis of the canonical and covariant approaches.

[136] See Weingard 2001 for an introduction to string theory. Also, see Butterfield and Isham (1999, §3) for an introduction to the superstring route of the covariant approach and to the canonical approach.

[137] A Wilson loop is the matrix of parallel transport along a closed curve that represents gravitational connection. For further discussion, see Rovelli 2004.

application of an adapted standard quantization technique.[138] This results in the quantization of the full metric. And, no fixed metric is involved, but the 4-d spacetime is decomposed into a 3-d space plus time. Some examples of this approach are: the loop dynamics[139], connection dynamics[140] and quantum geometrodynamics. Because this final approach is favoured by Barbour, I provide it in the next section and further explain its resulting Wheeler-Dewitt equation and interpretation in the next chapter. Please consult this information for a detailed and relevant example of the canonical approach.

In the sum over histories approach, one attempts to construct QG as a theory involving the application of some version of Feynman's path integral quantization to GR's metrics. The idea motivating this approach is to quantize GR in a fashion analogous to the manner in which Feynman obtained a formulation of QT in which a system's single trajectory is replaced with a sum, a path integral, over all possible trajectories in order to compute a quantum amplitude. Effectively, this technique is used in QT to compute the probability for a particle to go between two states by summing over all possible trajectories that could connect the states. To go towards obtaining a QG using this technique, apply it to GR's gravitational field: supposing that one wants to calculate the motion of some object from a 3-d hyperslice at an initial time to another 3-d hyperslice at a later time, one sums over all possible paths connecting these slices. The space of these paths, which roughly amount to being evolutions of the metric, contains 4-metrics that have convergent 3-metrics on the initial and final

---

[138] There are two ways to quantize constrained Hamiltonian spaces: quantize and then solve the quantum constraints, or solve the quantum constraints and then quantize. The former, termed as 'constrained quantization' or 'Dirac's canonical quantization programme for constrained systems', is what is used in quantum geometrodynamics and is given in the next section. The latter is mathematically difficult in that one must solve a collection of non-linear, coupled partial differential equations. For a more detailed comparison between the two types of quantization, see Butterfield and Isham (1999, 148-51).

[139] For recent a proponent of this version of the canonical approach, see Rovelli 2004.

[140] For in depth comparison and contrast between the connection dynamics and geometrodynamics, see Kuchar 1993. For detailed discussion of the relation between connection dynamics and loop dynamics, see Ashtekar and Rovelli 1992.

hyperslices.[141] One relatively well-developed example of this approach is the spin foam formulation.[142] In this formulation, one considers a sum over spin foams, which are foam-like configurations that represent a possible history of the gravitational field.

To compare and contrast these three approaches, I now provide and compare the means by which they respond to the two aforementioned difficulties of quantized quantities and background independence.

All three of these programmes, as well as most of the highly developed QG accounts, resolve the first difficulty by quantizing GR.[143] As Isham (1993, 2) states, such quantization amounts to the aim of paralleling the manner in which the classical theory of an atom bounded by the Coulomb potential is quantized via the replacement of some of its classical observables with operators on Hilbert spaces. Though all of these approaches start with classical GR and apply some quantization algorithm[144] to it, they differ on the issues of what type of quantization technique is applied and to what exactly the technique should be applied. In the covariant approach, only the dynamical part of the spacetime metric is quantized with a method that is based upon a classical action, which involves applying the Euler-Lagrange equations to a classical algebra of all functionals over configuration space. The canonical approach usually applies Dirac's canonical quantization procedure to the full metric, which has a manifold decomposed into a 3-d space plus time, after GR is put into Hamiltonian form.

---

[141] For more details on this general approach, see Rickles (2008, §6.5)

[142] For a nice introduction to the spin foam approach, see Perez 2008.

[143] However, as Isham (1993, 16ff) catalogues them, there are three other approaches to this issue: general-relativize quantum theory, get GR to emerge only in some low-energy limit of standard QT, get both GR and QT to emerge in the context of a new theory. See Butterfield and Isham (2001, 40-3) for more elaboration on these issues. As I am only providing the above strategies, which use quantization, to contrast with Barbour's favoured canonical approach, I do not enter into the debate of whether a legitimate theory of QG requires such quantization. See Mattingly 2009, Wüthrich 2005 and Callender and Huggett 2001a, 2001b, for objections to arguments that claim that the gravitational field must be quantized in QG. And, see Rickles (2008, §6.1.1) for the presentation of some such arguments.

[144] For an example of such an algorithm and its application to GR, see the five step canonical quantization procedure below.

The sum over histories approach applies some version of Feynman's path integral quantization to GR's metric that results in a quantization with a focus on entire histories of metrics and manifolds. So, though all approaches use different quantization techniques, the canonical approach differs from the other two in that the quantization technique is applied to a 3-metric, rather than to a spacetime metric.

There are two general means of addressing the second issue of background independence: preserve background independence in QG, or consider background independence to be expendable. The covariant approach uses the latter means: it eliminates GR's background independence. By splitting the metric into a quantized gravity field and a fixed spacetime geometry, the covariant approach has a fixed background structure given with the latter component.[145] On the other hand, the canonical approach adopts the former means by retaining background independence regarding the metric: the full metric is quantized in this approach. However, as Butterfield and Isham (1999, 67) point out, the basic configuration variable with which it chooses to represent 3-d space serves as a 3-manifold background structure. So, while it has no background spatial or spacetime metrics, its 3-manifold is a fixed background structure. The sum over histories approach also seems to be background independent: the histories summed over are not each *in* time. Rather, they each *have* a manifold and metric. So, at least at this global level, the sum over histories approach is background independent.

Now that we've highlighted the distinctive features of the canonical approach, namely its application of a quantization technique to 3-metrics and its elimination of background dependence, let's turn to the details of Barbour's favoured version of canonical approach to QG as it is standardly formulated and the problem of time that arises for it. Further, note that other than some suggestions in 1994a and 1986 as to the manner in which his own Machian geometrodynamics and the BSW can be quantized, Barbour does not present such an account in detail. Instead, as we'll see below, he focuses on reinterpreting QT such that it is timeless in order to overcome the problem of time that arises for standard quantum geometrodynamics.

[145] See Rickles (2008, §6.2) for further explanation of how this approach addresses the graviton's apparent movement through a curved spacetime.

2.2 The Problem(s) of Time

To provide some necessary setup for the problem of time as it appears in Barbour's favoured version of the canonical approach, i.e., quantum geometrodynamics, I here present geometrodynamics in more detail.

2.2.1 Geometrodynamical Formalities

In quantum geometrodynamics, Dirac's canonical quantization procedure (CQP) is adapted and applied to GR. CQP consists of five steps. Though skimming over much detail, I now present each step, putting relevant technical explication in footnotes, and show how each step is applied to GR in quantum geometrodynamics.[146]

> (CQP1) Put the classical theory in canonical form, and identify the conjugate canonical variables[147] that satisfy a Poisson algebra[148].

ADM formalism is used to put GR in canonical form as was presented in Ch3. Recall that the 4-d spacetime manifold M is given topology $\Sigma \times \mathbb{R}$, where Σ is a spatially compact 3-manifold and $\mathbb{R}$ is the set of real numbers representing a global time direction. This

---

[146] These steps are largely drawn from Pullin (2002, 3) and Colosi (2004, 21ff). The entire exposition is a conglomeration of Rickles 2006 and 2008, Isham (1992, 21ff), Colosi 2004 and Pullin (2002, 3-4).

[147] Canonically conjugate variables always occur in complementary pairs, e.g., position and momentum, energy and time. They are defined as any coordinate whose Poisson brackets give a Kronecker delta or Dirac delta. The Kronecker delta function is:

$$\delta_{n',n} = \begin{cases} 0, if\ n' \neq n \\ 1, if\ n' = n \end{cases}$$

And, the Dirac delta $\delta(\omega)$ for an integral with arbitrary function $g(\omega)$ is evaluated as follows:

$$\int_{\omega_a}^{\omega_b} g(\omega)\delta(\omega - \eta)d\omega = \begin{cases} g(\eta), if\ \omega_a < \eta < \omega_b \\ 0, if\ \eta < \omega_a\ or\ \eta > \omega_b \end{cases}$$

[148] A Poisson algebra is a vector space over a field K with two bilinear products: · and {,}, where the product · forms an associative K-algebra, and the product {,}, which is termed 'the Poisson bracket', forms a Lie algebra and acts as a derivation of the associative product '-' such that for any three elements, x, y, z, in the algebra:

$$\{x, y - z\} = \{x, y\} - z + y - \{x, z\}$$

submanifold is foliated by a family of spacelike 3-d hypersurfaces Σ_t, indexed by the time parameter t. A coordinate system {x^a} is defined on Σ_t. In effect, 4-d spacetime is decomposed into instantaneous 3-d hypersurfaces, or spacelike slices, plus t. Each 3-d hyperslice is put in terms of geometric variables that correspond to a Riemannian 3-metric[149] q_{ab} describing the 3-d hyperspace's intrinsic geometry. Spacetime is recovered as a stack, i.e., a one-parameter family, of these slices, with $\mathbb{R}$ serving as a time parameter. To recover spacetime, an extrinsic curvature tensor K_{ab}, which provides information on the manner in which $\Sigma_t$is embedded in the 4-d spacetime, in obtained. Additionally, the lapse function N and the shift vector $N^a$are chosen. These components allow us to reconstruct the 4-metric from the 3-metric.

q_{ab} is the fundamental canonical variable in this formulation of GR. CQP1 requires us to identify the conjugate of q_{ab}, namely momentum ρ^{ab}:

$$\rho^{ab} = \frac{c^3}{8\pi G}\sqrt{q}(K^{ab} - q^{ab}K)$$

Finally, to fulfil the Poisson algebra component of CQP1, here is the Poisson bracket satisfied by the canonical variables of the 3-metric q_{ab} and momentum[150]:

$$\{q_{ab}(t,x), \rho^{cd}(t,x')\} = \tfrac{1}{2}\left(\delta_a^c\delta_b^d + \delta_a^d\delta_b^c\right)\delta(x - x') \qquad \text{(E4.1)}$$

Now that CQP1 has been applied, we can move onto the next step.

---

[149] Recall from Ch3 that a Riemannian metric is a metric having an inner product on the tangent space at each point, i.e., a vector space containing all possible 'directions' in which on can tangentially pass through the point, which varies smoothly from point to point, giving local notions of angle, length of curves, surface area and volume. Pseudo-Riemannian geometries are generalizations of Riemannian geometries in the sense that their metric tensors need not be positive-definite, while those of Riemannian geometries must be positive-definite. See Ch3 note91 for information regarding positive-definiteness.

[150] N and N^a are also identified as conjugate to ρ and must be dealt with according to the procedure. However, I omit such non-dynamical details here. See Colosi 2004 for such details.

(CQP2) Represent these quantities as operators[151] acting on a space of wavefunctions, and promote the Poisson bracket[152] to the status of commutators[153].

To represent GR's classical quantities of momentum and the 3-metric as operators, let the operators $\hat{q}$ and $\hat{\rho}$ act on a functional space F of quantum states. Where $\Psi[q_{ab}]$ represents the wavefunctionals of the 3-metric, these operators are defined as:

$$\hat{q}_{ab}\Psi[q_{ab}] = q_{ab}\Psi[q_{ab}] \qquad \text{(E4.2)}$$

$$\hat{\rho}^{cd}\Psi[q_{ab}] = \frac{\hbar}{i}\frac{\delta}{\delta q_{ab}}\Psi[q_{ab}] \qquad \text{(E4.3)}$$

This second step also requires that the Poisson brackets of E4.1 become commutators:

$$[\hat{q}_{ab}(t,x), \hat{\rho}^{cd}(t,x')] = i\hbar\frac{1}{2}\left(\delta_a^c\delta_b^d + \delta_a^d\delta_b^c\right)\delta(x-x') \qquad \text{(E4.4)}$$

(CQP3) If the theory has constraints[154], i.e., quantities that vanish classically at the classical level, write the constraints as quantum operators, and identify the physical states of the QT with those states annihilated by the action of the constraint operators.

---

151 An operator, very generally, is a rule that tells you to do something with whatever follows it. With every physical observable in QT, there is an associated mathematical operator that is used in conjunction with the wavefunction, e.g., operator $\widehat{\mathrm{Q}}$ extracts the observable value q_n by operating upon the wavefunction that represents the particular state of the system. For further details regarding operators in QT, see Albert (1994, 25ff), which is more philosophical, and Hughes (1989, 14ff), which is more technical.

152 See note148 for the corresponding definition.

153 In QT, the commutative law, e.g., $\hat{Q}_1\hat{Q}_2 = \hat{Q}_2\hat{Q}_1$, does not generally hold for operators. So, 'commutator' is defined as follows. The commutator of operators $\hat{Q}_1$and $\hat{Q}_2$is the third operator $[\hat{Q}_1, \hat{Q}_2]$. The commutator $[\hat{Q}_1, \hat{Q}_2]$ is defined as: $[\hat{Q}_1, \hat{Q}_2] = \hat{Q}_1\hat{Q}_2 - \hat{Q}_2\hat{Q}_1$. If the commutator equals zero, then $\hat{Q}_1$ and$\hat{Q}_2$ are said to commute. But, if the commutator does not equal zero, then $\hat{Q}_1$and $\hat{Q}_2$are non-commuting operators.

154 Rickles (2008, note 98 in §6.4) provides a very nice means of visualizing the general role of constraints. Roughly, constraints are equations that relate some variables to others, some of which are extra in the sense that

In the above form, GR has a total of four constraints: one Hamiltonian constraint $\mathcal{H}$ and three momentum, or diffeomorphism, constraints. Here, I only provide the Hamiltonian $\mathcal{H}$, one momentum constraint $\mathcal{H}^a$ and the full Hamiltonian **H** that results from the sum of all four constraints, where q is the determinate of 3-metric q_{ab}:[155]

$$\mathcal{H} = \frac{8\pi G}{c^3\sqrt{q}}\left(\rho_{ab}\rho^{ab} - \frac{1}{2}\rho^2\right) - \frac{c^3}{8\pi G}\sqrt{q}R \approx 0 \qquad \text{(E4.5)}$$

$$\mathcal{H}^a = -2\nabla_b\rho^{ab} \approx 0 \qquad \text{(E4.6)}$$

$$\mathbf{H} = \int_{\Sigma_t} d^3x(N\mathcal{H} + N_a\mathcal{H}^a) \approx 0 \qquad \text{(E4.7)}$$

Now, as per CQP3, these constraints must be written as quantum operators. In the metric representation, i.e., where Ψ becomes a functional of the metric components q_{ab} and the momentum becomes a certain functional of differential operators, they are:

$$\widehat{\mathcal{H}}\Psi = \left(-16\pi G\hbar^2 G_{abcd}\frac{\delta^2}{\delta q_{ab}\delta q_{cd}} - \frac{\sqrt{q}}{16\pi G}R\right)\Psi = 0 \qquad \text{(E4.8)}$$

$$\widehat{\mathcal{H}}^a\Psi = -2\nabla_b q_{ac}\frac{\hbar}{i}\frac{\delta\Psi}{\delta q_{bc}} = 0 \qquad \text{(E4.9)}$$

E4.9, where ∇_b represents the covariant differentiation on Σ_t, renders the quantum states independent of the choice of coordinates on Σ. E4.8, where G_{abcd} is the DeWitt supermetric[156], is the Wheeler-DeWitt equation. This equation provides the full quantum

---

the formalism has more variables than there are physical degrees of freedom. 'Solving the constraints' is the term for using the constraints to eliminate such variables with the aim of obtaining an unconstrained theory.

[155] I have omitted the other two momentum constraints because they only involve N, N^a and the Einstein Lagrangian.

[156] G_{abcd} is defined by: $[|q|^{-\frac{1}{2}}[(q_{ab}q_{cd} - q_{ac}q_{bd})]]$.

dynamics of gravity. The interpretation of this equation will be a subject in the next chapter. But, for the purposes of this section, note that it lacks an explicit time parameter.

> (CQP4) Define an inner product[157] in the space of the physical states, and then complete to obtain the physical Hilbert space[158] of the QT.
>
> (CQP5) Define a set of observables as those quantities that have vanishing Poisson brackets with the constraints, and provide predictions in order to give a physical interpretation to the states' Hilbert space.

I group these last two steps together because they are problematic to apply to GR in the above formalism. CQP4 requires that an inner product be defined on the space of physical states in order to obtain a Hilbert space of physical normalized state vectors. However, the measure required in superspace to do so cannot be rigorously defined. It is also difficult to carry out CQP5 in this context. This final step implies that observables are invariants under the symmetries of theory and, qua quantum expressions, entails that solutions to the constraints in which they appear are also physical states. However, such an observable is problematic: no such quantities are known for GR generically, and it is difficult to obtain for GR in Hamiltonian form.[159] [160]

---

[157] The inner product (or 'dot product', or 'scalar product') of two vectors, **u**, **v**, for example, is denoted as: **<u, v>**. It enables one to provide the numerical expression of geometrical ideas, e.g., the length of a vector, the orthogonally of vectors. For more details, consult Hughes (1989, 26).

[158] Albert (1994, 21) defines a Hilbert space as: a collection of vectors such that the sum of any two vectors in the collection is also a vector in the collection, and such that any vector in the collection times any real number is also a vector in the collection. In slightly more technical jargon, a Hilbert space is a vector space on which an inner product has been defined and which is complete, i.e., any converging sequences of vectors in the space converge to a vector in the space. The dimension of this space is equal to the number of mutually perpendicular directions in which vectors in that space can point. For further details, see Hughes (1989, 55-6).

[159] See Pullin (2002, 3-4) for further details regarding the problematic implementation of CQP5 in geometrodynamics, and see Matschull (1996, 21ff) for general difficulties with the implementation of this step.

2.2.2 Quantum Geometrodynamics' Problem(s) of Time

The timelessness of the Wheeler-DeWitt equation (WDE) is often regarded as a problem in quantum geometrodynamics since quantum mechanics is governed standardly by the time-dependant Schrödinger equation. In quantum geometrodynamics, the WDE, rather than the Schrödinger equation, describes a system's dynamics. Plus, the Hamiltonian is responsible for describing temporal evolution in classical theory, and the WDE is a quantized Hamiltonian. So, one would expect that, like the Schrödinger equation and the classical Hamiltonian, the WDE, as describing a system's dynamics, would also describe its temporal evolution and, thus, involve a time parameter. However, the WDE is regarded as timeless because it has no time explicit parameter. Such timelessness seems to indicate that the physical states of the system do not evolve at all. Thus, the issue arises: How can the WDE describe a system's dynamics without a time parameter? It is this issue that is referred[161] to as '*the* problem of time'.[162]

It is this conflict which is the problem of time that Barbour is attempting to resolve.[163] Certain discussions of the problem of time catalogue the issues surrounding it in more detail: Isham (1993) provides lists of the disparate roles that time plays in standard QT and GR and

---

[160] It was due to these and other technical difficulties that geometrodynamics was largely abandoned. For historical details, see Stachel's 1972 aptly titled article, "The Rise and Fall of Geometrodynamics."

[161] Though, note that some authors, e.g., Butterfield and Isham 1999, 2001, Isham 1993, Anderson 2011, present 'the problem of time' as either a cluster of or something that arises from incongruencies between the roles time plays in GR and those in QT. The sense of 'the problem of time' used above is particular to the canonical approach, and I refer to any other problems of time without the 'the'. Further note that these disparate, implicitly context-dependent, i.e., dependent on usage in the contexts of discussing QG generally or only canonical approaches, uses of 'the problem of time' occur within single articles, e.g., Rickles 2008, Butterfield and Isham 2001.

[162] For a good technical review of the problem of time as it arises in the context of the canonical approach, see Kuchar 1992, and see Rickles 2006 for a philosophical discussion of the problem.

[163] However, although this is regarded as a substantial problem with time in geometrodynamics, it is not the only problem of time that arises in quantum gravity; see Kuchar 1992 for a list of several temporal problems in various approaches to quantum gravity.

claims that the problem arises from such differences, while Kuchař (1992) names and discusses several problems involving time that arise in the process of deriving and quantizing GR's Hamiltonian. As Barbour initially develops a Machian GR and then proceeds to fit this theory with a timeless account of QT, his programme is far removed from the standard versions of QT and GR and, thus, from many of the issues discussed by Isham and Kuchař. In effect, Barbour does not spend much time explicitly addressing particular problems of time or issues from standard QT and GR that give rise to the problem of time. Instead, he (1999, 15, 167), (1994c, 410), (1994a), largely focuses on providing a resolution to the problem of time, though some of the relevant issues Isham and Kuchař raise, e.g., key roles of time in QT's measurements and the construction of Hilbert space, are addressed in the process and will be explained the following sections.

How exactly does Barbour propose to resolve the problem of time? In much detail, Isham (1992) catalogues various resolutions to the problem of time under three main categories: those in which time is identified before quantizing; those in which time is identified after quantizing; and those in which time plays no fundamental role. In line with his timeless, Machian approach to GR, Barbour's approach to the problem of time in geometrodynamics falls under the third category; he accepts the timelessness of the WDE and attempts to provide an alternative interpretation of dynamics and explain away the appearance of time. The remainder of this chapter and the next chapter explicate the details of this resolution to the problem of time.

2.3 Barbour's Approach to his Problem(s) of Time

His specific approach to the problem, as detailed in his (1994b) and (1999), is as follows. He begins with considerations raised by DeWitt (1967), the WDE and the assumption that we should seek a timeless foundation that is also free of external inertial reference frames. With these elements in mind, Barbour proposes a method that provides a basis for the interpretation of a timeless QT. Next, he elaborates this interpretation and explains away our experience of time via time capsules. Lastly, making use of Mott's explanation of the behaviour of an alpha particle in a Wilson cloud chamber, he shows how time capsules may be implemented and developed in QT. I now turn to presenting this outline in more detail. In this chapter, I develop his timeless QT. Time capsules and his use of Mott are discussed in the next chapter.

2.3.1 DeWitt and Timelessness

Citing his apparent success at developing a Machian GR that has no "external framework" (1994b, 2876), which likely refers to the Barbourian GR's lack of time and frames of reference as fundamental features that are independent of stuff and their instantaneous relative relations, Barbour seeks to quantize GR. Thus, he provides some reason to go the canonical route; given his overarching project of creating a Machian physics and due to the Barbourian GR exhibiting Machian features, the straightforward way of creating a Machian quantum gravity theory would be to quantize his GR. Moreover, note that Barbour (1994a) suggests that we should quantize the BSW version of GR rather than his general Machian dynamics. So, when we compare the roles of time that appear in his account, we will focus on his Machian GR.

Additionally, Barbour approves of DeWitt's (1967) approach to quantizing GR; he claims that, "the problem of quantizing GR already may have been solved in its essentials by DeWitt" (1994b, 2877). DeWitt's resulting quantum theory has a static wavefunction of the universe, the WDE, which is defined on possible relative configurations of the universe. Because Barbouric GR lacks fundamental time and frames of reference, Barbour reasons that DeWitt's static wavefunction on relative c-space is a perfect fit with his GR.

Nevertheless, as Barbour points out, DeWitt's quantization is not regarded as complete by some, e.g., Kuchař (1991), because it does not include the Hilbert spaces and unitary transformations characteristic of QT.[164] He initially responds to this accusation of incompleteness by stating that we should not expect that everything 'belonging' to QT and GR should be brought through when unifying the two theories into a theory of quantum gravity. Then, he develops this response by addressing the question of which elements of GR and QT must be kept even following their merger.

2.3.2 Barbour's Method for Unifying QT and GR

[164] As we'll see below, Barbour rejects Hilbert space and attempts to replace it with heaps of c-space points. For discussion of the spaces used in QT, see, e.g., Albert 1996, Ney 2010, North (forthcoming).

Barbour proposes an apparently simple method, applies it to GR and QT in turn and uses the results to provide a substantial reply to the above incompleteness worry.

With the method, he aims to determine "essential structure" shared by GR and QT given that "time is truly non-existent in the kinematics of both theories" (1994b, 2875-6). So, apparently we must expunge any fundamental, independent notion of time that appears in both theories. But, what else can go, and how do we determine what constitutes the shared 'essential structure', whatever that is? Barbour states:

> Let us first seek the deepest layers of each theory. If we can find them, we shall certainly want them in quantum gravity, especially if they are common to both theories; for then we shall have a *non-trivial intersection* of the two, on which we can attempt out construction. We may be able to jettison the other features and recover them in certain limits. (1994b, 2877)

In view of this quote, we must turn to GR and QT separately and determine what their 'deepest layers' are. Ordinarily, one might believe that the 'deepest layers' of GR and QT are those aspects of the theories that are the most well confirmed. However, Barbour's approach indicates that, rather than appealing to experimental confirmation, the deepest layers of these theories are those that are in accord with his Machian project and/or are not 'arbitrary'. In his application of this method to GR and QT, which I will go through shortly, Barbour rejects 'arbitrary' features of the theories. In view of this practice and the overarching Machian project, it seems that these deepest layers are meant to include a theory's fundamental, essential yet non-arbitrary features and exclude automatically an independent time, space or frames of reference. After determining such features for each theory, we can then compare the theories' sets of features. We keep the common ones, which serve as the foundation on which we build our interpretation of quantum gravity. In effect, rather than being confirmation-based, his methodology here is principle-based.

2.4 The Application of Barbour's Method to GR

Barbour (1994b, 2877-8) argues that classical GR's 4-dimensionality with its time dimension is less fundamental than his timeless GR that is built out of c-space points. He makes his attack on the fundamental status of GR's 4-dimensionality on two fronts.

First, he attacks standard GR's time dimension on grounds that it is arbitrary. Time is usually regarded as a dimension and is identified with the sign opposite to that of the spatial displacements in the signature of standard GR, (+ - - -) or (- + + +). However, Barbour claims that these signatures are arbitrary.[165] He supports this claim by citing the fact that the Einstein field equations are silent as to the proper signatures and by making recourse to geometrodynamics in an apparent attempt to address worries of whether GR would breakdown with such an arbitrary foliation. Though the latter means of support is rather quick, it does provide a route to support the above claim: supposing that one takes any 4-d metric space of any signature that satisfies Einstein's and foliates arbitrarily, e.g., such that signature (- - + +) results, the basic equations of geometrodynamics would still hold, claims Barbour, as long as superspace includes pseudo-Riemannian geometries in addition to Riemannian geometries. The former geometries would allow for play in possible metric signatures in that it is not, like Riemannian geometries, restricted to all positive signatures. Thus, if Barbour's arguments here are correct, such time signatures seem arbitrary and, according to Barbour's method, are not fundamental in GR.

Second, he shows that there need not and should not be a fourth dimension with which coordinate time is identified. He argues that there *need not be* such a dimension since a 4-d space can be constructed from a 3-geometry. This is done by using his relativistic BMP to construct a horizontal stack. In effect, rather than being a fourth dimension, coordinate time could be recast as must the measurement of the interval orthogonal to the hypersurfaces of the foliation. Further, he argues that there *should not be* such a fourth dimension because Barbour's 3-d version of GR is more economical by having fewer basic variables. To support this, Barbour cites the characteristics of his Machian GR that we encountered in the previous chapter: 3-geometries feature as its fundamental components, time plays no fundamental role in that the BMP has no lapse, its shift is just an auxiliary equilocality shuffler, frames of reference are emergent from the 3-geometries, 4-d space is constructed from the 3-geometries and GR's foliation invariance can be cashed out as derivate from 3-geometries in terms of there being a best-matching sequence for all possible foliations.

---

[165] For discussion of this conventionality of GR's signature and its implications for time, see Callender 2008, Norton 2003.

In effect, he claims that the fundamental component of Machian GR is c-space points that are 3-geometries, and he stresses that time should play no fundamental role.

2.5 The Application of Barbour's Method to QT

Barbour (1994b, 2878-80) applies the method to QT to determine its fundamental elements. But, since his goal here is to try to merge GR and QT, he mainly here determines whether QT can have GR's fundamental elements; he determines whether there may be a plausible QT account that is timeless and that features c-space points as fundamental. Note that the sketch of QT made here will be developed in detail below. This method serves to ascertain the fundamental elements shared by QT and GR, rather than to develop a detailed, coherent account of how exactly these elements function in the theories.

To motivate his aim of generating a timeless QT, he claims that if one removes time, then one removes the incompatibility of GR and QT that is generated from the different roles of time in these theories.[166] In turn, the question arises as to whether it is possible to remove time from QT. To address this question, Barbour examines three features of standard QT that involve time: its background dependence[167], use of Hilbert space and role of measurement.

Regarding background dependence, he states that the Schrödinger wavefunction of any system is defined on its possible configurations. But, recall that this involves the backdrop of a fixed spacetime. According to the manner in which Weinstein (2001) describes the roles of space and time in standard QT, a state $\psi(x)$ is a function that assigns a complex-valued amplitude to each configuration x. Such configurations are configurations with respect to absolute space, and the evolution of the state is given with respect to absolute

---

[166] See Isham 1992, 1993, for a catalogue of such problems. This key claim and the related issue of whether Barbour has removed time to this effect are examined in Ch6 once his theory is spelled out in this and the next chapter.

[167] Though he does not address this issue by name, I have taken the liberty of reframing his arguments to the effect that QT can be cast in terms of c-space points, frameless and timeless, rather than dependent on the configuration space of QT that includes a fixed spacetime geometry, in terms of an argument claiming that QT can be background independent yet dependent on configurations of stuff.

time.[168] However, Barbour claims that such dependence on a fixed spacetime can be circumvented by restricting the definition of the wavefunction of the universe to only its relative configurations. So, in accord with his Machian project as well as with the canonical approach's strategy for addressing the background independence issue, he claims that QT's dependence on time may be expunged by eliminating its fixed spacetime background while retaining a dependence on c-space points. How exactly he proposes to do so is the subject of §3 of this chapter.

Barbour addresses Hilbert space, i.e., a vector space[169] that one uses to represent and calculate[170] quantum states in standard QT, on a few fronts. First, to map the vectors onto the Hilbert space, one must presuppose that there is an absolute space and time or Minkowski spacetime. To elaborate, Isham (1992, 10) cites an aspect of Hilbert space in which such time plays a key role: a central requirement of Hilbert space is the selection of a complete set of observables that are required to commute at a fixed time.[171] In effect, such selection requires a time parameter corresponding to that of a flat, fixed spacetime. However, Barbour argues that because GR does not have such background structures, it is unlikely that a Hilbert space may be constructed in QG. Second, Barbour cites that an important role played by Hilbert space in standard QT is to describe time evolution by unitary transformations. Such transformations involve operators that arise from the time-dependent Schrödinger equation. Yet, assuming that QT is a timeless theory, QT would not have such a temporal evolution. In

[168] For more details, see §3.4.2.2 below where the standard presentation of the time-dependent Schrödinger equation is given.

[169] The Hilbert space is a certain type of vector space, which is also detailed in note158 above. Consult Albert 1994 for a nice introduction to the formalism of QT.

[170] Though they are the subject of much debate, the ontological statuses of the wavefunction and Hilbert space are not relevant for our present expository purposes. But, see Monton 2006 for arguments against the existence of the wavefunction, Lewis 2004 who defends its existence and Wallace and Timpson 2009 for an alternative in which states are fundamental.

[171] A Hilbert space is constructed by representing a state of a system at a fixed time *t* by a state vector. This state vector contains all accessible physical information about the system at *t*. The same state at a different time *t'* is denoted by a different state vector. In Hilbert space, operators, e.g., the Hamiltonian, the time evolution operator, serve to map one state vector onto another.

effect, Barbour rejects the need of Hilbert space[172] on grounds that a timeless theory would not have the need for a description of its temporal evolution and, thus, would not have such a role to fulfil.

Intertwined with his rejection of Hilbert space is also a comment on measurement. In standard QT, an observable is something having a value that can be measured at a fixed time. So, the ability of referring to a constant time parameter is a key feature of measurement. Barbour counters this need of a time-dependent notion of measurement by making recourse to a universal wavefunction. In a timeless QT in which there is no fixed spacetime or external references frames by which we could legitimately divide the universe into subsystems, Barbour reasons that the entire universe must be treated as a quantum system. Barring a deity outside of the universe performing measurements on the system, there are not any measurements being performed on this system. In effect, standard QT's time-dependent notion of measurement seems possibly eliminable. Note that this may also be a product of his application of CNP to c-space points. Because such a point is completely defined in terms of all of its relative relations, it does not seem that there is a means of dividing a c-space point that is not arbitrary.

Thus, time, Hilbert space and a time-dependent notion of quantum measurement may not be fundamental to QT and can be eliminated, provided that he can construct a plausible alternative interpretation of QT that is based on c-space points, background independent and applicable to the entire universe as a single quantum system. The manner in which Barbour replaces Hilbert space is explicated in detail below.

2.6 The Results of Barbour's Method

With Barbour's method for merging GR with QT, we have established the basic elements that he claims are common to both GR and QT. In GR, c-space points that are 3-geometries are its fundamental components. In QT, given his rejection of its background dependence, Hilbert space and reference frames, instantaneous configurations of stuff in the universe can be its fundamental components as well. With these fundamental elements in mind, he proceeds to provide a timeless interpretation of QT in terms of c-space points such

---

[172] Though this rejection of QT's Hilbert space is radical, it is not unprecedented: see Albert 1996.

that it can be merged with his Machian GR. The remainder of this chapter presents and attempts to clarify his interpretation of QT. In the next chapter, we see how this QT combines with his GR as development and interpretation of quantum geometrodynamics such that the problem of time is resolved.

3 Developing the Interpretation of Barbour's QT

Barbour proceeds to develop his account of QT by drawing on the many worlds Everettian interpretation. He puts this interpretation in terms of his c-space points by using them to replace the Everettian branching worlds. The Everettian approach, however, is problematic on a number of grounds, and this chapter addresses its preferred basis problem in Machian terms. After presenting the Everettian setup, we examine the roles that the c-space points and wavefunction have in Barbour's Machian account. The heaps discussed in Ch3, rather than a structured c-space, are shown to play a prominent role in his QT. With the roles of his c-space points and wavefunction delineated, we finally turn to Barbour's reading of the time-independent Schrödinger equation and the manner in which he claims it is related to the time-dependent Schrödinger equation. With this QT account, we can turn to the manner in which he proposes to unify his 'timeless' GR and QT as a means of resolving the problem of time.

It is important to note here that most of what follows does not directly provide an account of our day-to-day experience. Barbour does not provide much by way of an interpretation of such experience for his QT directly, though, as is presented in the next chapter, he does go to some length to provide such an interpretation for his QG. So, although his QG account of personal experience may be at least partially attributed to his QT, I do not do so here because I am primarily concerned with analysing his QG.

3.1 Everettian Starting Point: An 'Internal' Approach

Barbour models his interpretation on that of Everett (1957). He wishes to utilize Everett's 'internal' "interpretative scheme," i.e., "deduce the measurement from the bare structure of the theory." Presumably, the 'bare structure of the theory' refers, at least partially, to the 'fundamental layers of theory', which were determined above (1994b, 2880). However, as Barbour does not go into detail about the meaning of 'internal', other than the preceding quote, this requires some unpacking.

Everett (1957) uses ‘external’ to refer to the observers in the von Neumann-Dirac collapse formulation of QT:

> We take the conventional or “external observation” formulation of quantum mechanics to be essentially the following: A physical system is completely described by a state function ψ, which is an element of a Hilbert space, and which furthermore gives information only to the extent of specifying the probabilities of the results of various observations which can be made *on* the system *by* external observers. (1957, 454)

Everett proceeds to elaborate on how this conventional formulation relies on external observers. Following von Neumann (1952, ChV,ChVI), he does so by stating two basic manners in which the state function can change according to this formulation. The first, termed ‘Process 1’, is the discontinuous change that is brought about by the observation of a quantity in which the state function will be changed to a particular eigenstate with a probability that is a function of the initial state function and the final, post-observation eigenstate. The second, termed ‘Process 2’, is the continuous, deterministic change of an isolated system with time according to a wave equation, e.g., that of Schrödinger. Clearly, Process 1 relies on observers in order to change the state function into an eigenstate.

One of the problematic implications of the von Neumann-Dirac collapse interpretation that Everett (1957, 455) notes is that it is unclear how this formulation is to be applied to a closed universe. Because there is no place to stand outside this system in order to observe it, Process 1 cannot be used to provide transitions from one state to another, and it is this process that determines the probabilities of the various possible outcomes of observation. In turn, Everett seeks to provide an interpretation that is applicable to a system that is not subject to an external observation, an interpretation that is internal to an isolated system. To do so, he posits that the pure wave mechanics of Process 2 is a complete theory. In effect, he can treat any system that has an external observer as part as a larger isolated system.

It is this sense of ‘internal’ that Barbour wishes to adopt from Everett, i.e., as an interpretation that does not rely on external observers. In view of Everett’s specific problem regarding the standard formulation’s inapplicability to a closed universe, Barbour’s motivation for choosing this route is relatively clear: Barbour considers his c-space points as fundamental. A c-space point is a configuration of all the stuff in the universe. Due to this focus on the universe as a whole, rather than focusing on parts of it, there is no place for an external observer. Thus, Barbour's approach requires a route that does not rely on external observers.

A final part of the Everettian setup that must be presented here is his proposed solution to the measurement problem. Though it is controversial exactly what the measurement problem is[173], Barbour does not present or address it in much detail. So, a brief sketch of it is sufficient for my expository purposes here. Assuming that the state of a system always evolves in accordance with the Schrödinger equation, a system's state should evolve continuously according to this equation; it should always be in Process 2. However, at least in the Copenhagen interpretation, Process 1 occurs as well: the wavefunction of a system with superposed states collapses into one of its eigenstates upon measurement. Thus, given that the system is supposed to evolve continuously in accordance with the Schrödinger equation, it is puzzling that the system's wavefunction collapses discontinuously into an eigenstate upon measurement. It is this incongruity that will serve as the measurement problem for the purposes of explicating Barbour's point later.[174]

Everett resolves the problem by rejecting Process 1: he denies that the wavefunction collapses upon measurement. Rather, at least according to Barbour's reading of Everett, such measurement, "tells us *where we are,* i.e., in which branch of the post-measurement wavefunction *we* are actualized" (1994b, 2880). Here, Barbour clearly seems to be adopting DeWitt and Graham's (1973) many-worlds version of the Everett interpretation; this version

---

[173] See Bachtold 2008 for the classification and discussion of several formulations of the measurement problem in the literature.

[174] Von Neumann (1952, Ch.VI) attempted to resolve this problem by accepting that the Schrödinger equation, though right in cases in which no measurement is made, does not describe what happens when a measurement is performed. In effect, he claimed that there are two types of dynamical evolution corresponding to the above two processes: When there is a measurement made on a system, its states evolve in accordance with Process 1 and not in accordance with the Schrödinger equation; and when there is no measurement being made on a system, its states evolve in accordance with the Schrödinger equation. See Albert (1994, Ch.5) for discussion.

is characterized by there existing, in addition to our own world, many other worlds.[175] To characterize these worlds, DeWitt (1970, 163) states that, "[a]ll are equally real, and yet each is unaware of the others. […] Each branch corresponds to a possible universe-as-we-actually-see-it." In this interpretation, there is a wavefunction for the entire universe, and the universe splits into branches after each quantum measurement made. For example, suppose a system containing an electron is in the superposed state of having spin-up and having spin-down. In the course of a measurement made on this system, the world with this system branches into two other worlds: one in which the electron is spin-up, and another in which the electron is spin-down. So, this version denies that the wavefunction collapses upon measurement and, instead, claims that such a measurement branches this world into two other worlds[176] as well as indicates that we, e.g., are in the world in which a particular electron is spin-up and not in the world in which the electron is spin-down.

However, this resolution of the measurement problem faces a number of problems, e.g., the preferred basis problem[177], the problem of recovering probabilities[178] and the problem of personal identity[179]. The latter two problems, which respectively and roughly are the problem of making sense of the probability of states in an arena where all of these states exist following a measurement and the problem of accounting for personal identity over time due the fact that the branching of a world entails that everything in the world, including

---

[175] This is distinguished from readings of Everett in which only a single world is involved, e.g., that of Zurek 2010 in which 'relative state' is defined in terms of decoherence of the environment. See Saunders (2010, 8-11) for a historically-oriented introduction to different interpretations of Everett. Following Barbour, I assume the many worlds interpretation of Everett because my concern here is the role of time in his account, rather than whether, perhaps, another version of the Everettian interpretation would work better for Barbour.

[176] How exactly these branches and worlds should be characterized is the subject of much debate. Vaidman (2010, 588) discusses a few definitions of 'world' and attempts to refine the concept of world given above by offering an alternative to the relatively standard view of branching that starts from a single world, splits at each quantum measurement and, effectively, evolves forward with time as a tree of worlds.

[177] For discussions of this problem, see Saunders 2010, in particular Wallace 2010.

[178] See Saunders and Wallace 2003 for discussion of this problem.

[179] See Saunders and Wallace 2008 for discussion of this problem.

agents, branches, are intertwined with one's experience. Due to this role of experience, these two problems are presented in detail and discussed following the exposition of Barbour's account of experience in §2.1.1 of the next chapter. But, as the preferred basis problem hinges less on the details of one's experience, I present this problem here and discuss its implications for Barbour in §3.2 of this chapter.

As Albert (1994, 113-4) presents it, the preferred basis problem arises because what worlds there are is dependent upon what separate terms there are in the universal wavefunction. But, what terms are in this wavefunction is dependent on what basis we choose to write the wavefunction down in. Because the quantum formalism itself does not pick out such a basis, some sort of principle has to be added to the formalism in order for there to be an objective matter of fact about which worlds there are at any given instant. But, it's not clear what this principle is.[180]

3.1.1 Methodological Similarities

Before moving on to key differences that Barbour highlights between his approach and that of Everett, I should elaborate on the manner in which Barbour's brief elucidation of his internal approach is likely related to the proceeding exposition of Everett. As stated above, Barbour goes towards explaining his internal approach by stating that it must "deduce the measurement from the bare structure of the theory" (1994b, 2880). Process 1 describes how a system changes when it is measured, while Process 2 describes how a system evolves when it is not being measured. Everett rejects Process 1 and proposes to regard the pure wave mechanics as a complete theory. He then describes his general approach to formulating an interpretation:

> The wave function is taken as the basic physical entity with *no a priori interpretation*. Interpretation only comes *after* an investigation of the logical structure of the theory. Here as always the theory itself sets the framework for its interpretation. For any interpretation it is necessary to put the mathematical model of the theory in correspondence with experience. For this purpose it is necessary to formulate abstract

[180] One popular solution to this problem is decoherence, which is outlined in §3.2 below and rejected by Barbour.

> models for observers that can be treated within the theory itself as physical systems, to consider isolated systems containing such model observers in interaction with other subsystems, to deduce changes that occur in an observer as a consequence of interaction with the surrounding subsystems, and to interpret the changes in the familiar language of experience. (1957, 455)

Accordingly, this approach starts with the wavefunction, rather than, e.g., measurement. As a means to gain an interpretation, abstract models for observers are considered given in 'the logical structure of theory', i.e., the Schrödinger equation and the role of the wavefunction in it. And, finally, the results of such enquiry are used to formulate an interpretation in terms of our experience. This formula-driven method may be seen as potentially motivated by Everett's internal approach, i.e., his rejection of Process 1 and acceptance of Process 2 only. The standard formulation's problematic amalgamation of experience in Process 1 with Process 2's wavefunction may be regarded as resulting from its treatment of experience, i.e., measurements, as on par with its treatment of the wavefunction. Because Everett finds that this pair has problematic implications, he endeavours to treat the wavefunction as more basic than observation, which is indicated in his methodology of starting with the wavefunction, assuming that the Schrödinger equation, qua providing a complete account of dynamics, is the basic mathematical structure of the theory and subsequently deriving an experiential interpretation from the Schrödinger equation and its wavefunction. In effect, within the context of Everett (1957), it seems that the 'bare structure of the theory' in Barbour's quote refers to the wavefunction and Schrödinger equation prior to interpretation and that 'measurement' refers to part of the experiential interpretation derived using Everett's methodology. Thus, Barbour's quote above and its connection to Everett's internal approach seem to indicate that he wishes to utilize Everett's internal route of rejecting Process 1 and accept the general methodology that results from his internal stance.

3.2 Machian Modifications to Everett

Despite wanting to adopt a parallel 'interpretive scheme', Barbour points out that Everett defined his universal wavefunction in terms of external time and internal frames. To adapt Everett's approach to fit his own approach, which lacks a fundamental external time and internal frames, Barbour proposes to make two changes.

First, Barbour must reject Everett's practice of considering many quantum systems coexisting in a single framework, i.e., the subsystems of a system (see §4 of 1957), with each subsystem having its own Hilbert space. Everett uses the interactions between the subsystems to construct a product Hilbert space that describes the larger system composed of a union of two subsystems. Barbour attacks this practice on two of its anti-Machian fronts. First, according to Barbour's Machian framework, position, for example, is defined relative to all of the other stuff of the universe. In effect, the Machian position cannot be defined, as Everett does, through the initial use of subsystems. Second, Barbour denies the existence of subsystems. He claims that though localized regions of some of the universe "look like instruments used to make quantum measurements" (1994b, 2880), these apparent subsystems are not really systems. This is supported by his recourse to CNP; he claims that splitting the universe, which is the only system, "does violence to the unity of the world" (1994b, 2880). Given that *all* the relative relations of the universe at an instant give the *complete* notion of the universe, it seems that we cannot legitimately divide the universe into subsystems. Because everything in a c-space point is defined in terms of its relations to everything else in that c-space point, we must consider the entire universe at an instant as a single system. Thus, because his Machian approach is incompatible with Everett's primary use of subsystems, the subsystem basis of Everett's interpretive scheme must be replaced with a basis on a single system.

Second, Barbour seeks to modify Everett's approach to the measurement problem. He accepts Everett's solution to the measurement problem to the effect that he denies that the wavefunction collapses with measurement and accepts that such measurements tell us 'where we are' in some sense. But, as Barbour's primary entities are c-space points, rather than Everettian branches, he rejects the Everettian claim that measurements tell us in which branch we are. Naturally, Barbour replaces these branches with c-space points: measurements tell us in which c-space point we are. This modification is further elucidated in the next section.

Moreover, as he adopts Everett's general solution to the measurement problem, he attempts to resolve its ensuing preferred basis problem. He tries to address the preferred basis problem by giving Machian reasons to reject the widespread solution to this problem, i.e., decoherence[181], and then gives some reason to believe that his c-space-point-based account dissolves the problem. Decoherence involves dividing systems into two subsystems with one being the environment. Schlosshauer and Fine (2004) present decoherence theory and the manner in which it resolves the problem as follows. Decoherence involves two steps. First, there is an interaction of a system with its environment and the resulting entanglement. Then, a formal restriction is imposed, namely a restriction to the observations of the system only, by which one ignores the unobserved part of the system. This setup is then used to resolve the preferred basis problem as follows. Consider a system entangled with its environment. A system and its observer or measuring apparatus cannot be fully separated from their surrounding environment. In turn, there are interactions between the surrounding environment and observer resulting in certain correlations such that initial correlations between the system and observer are disturbed. Such disturbances alter or destroy the measurement record. Such interaction with the environment is used to define the preferred basis: the basis that contains a reliable record of the system's state. In effect, the interactions between the system and environment depend on the small number of quantities with determinate values, e.g., position of medium-sized dry goods, that physical systems are observed to have.

However, Barbour (1994b, 2880) rejects this solution on the grounds of its presupposition of subsystems: decoherence presupposes that a system can be divided into two subsystems. Such division, to echo Barbour's rejection of Everett's subsystems, goes against his Machian approach in which the universe's system cannot be legitimately divided. Instead, he (1994b, 2880-1, 2882) (1999, 301) stipulates that the preferred basis problem may be solved by using his c-space points as the preferred basis. While he doesn't provide much by way of argument as to why or how exactly this would work, one could justify why c-space points are chosen via the results of his method for determining the fundamental components of QT given in §2.5 above. Recall that this resulted in c-space points as being the basic entities of QT given his Machian agenda of formulating a timeless, frameless theory. So,

[181] Zurek 2010 is a major proponent of this solution, and the above exposition leans on his version of decoherence. For different types of decoherence and discussion of it regarding time, see Saunders (1995, §3).

perhaps if such a Machian agenda is coherently incorporated with the quantum formalism, we at least have some reason for choosing c-space points as the basis.

Formally, however, it is not clear exactly how such a basis would work, e.g., how would standard quantum properties like spin be emergent from c-space? In passing, Barbour (1994b, 2880-1) suggests that particles with spin and internal degrees of freedom may be represented as the excitation of multicomponent fields. Yet, he has not developed this suggestion. And, as my purpose here is primarily to provide a metaphysical analysis of *time* as it appears in his view, rather than attempt to extend his formalism, I do not develop this suggestion here.

Nevertheless, he (1994b, 2882) does give some reason for believing that the reduction of such properties to position is possible *in principle*. He does so by making a quick reference to Bell. Bell (1988, 10, 34) makes the claim that many measurements reduce to measurements of position. He exemplifies this claim with spin: to measure the spin of a particle, the particle passes through a Stern-Gerlach magnet. One determines its spin by seeing whether the particle is deflected up or down. In effect, it seems as though spin in this context can be formulated in terms of position. So, if we can reduce such non-positional observables to relative positions between, e.g., lab equipment and particles, then it seems that, at least in principle, we can reduce such properties to the relative positions of stuff in a c-space point. And, if this reduction is possible for all non-positional observables, then there's some reason to believe that c-space points are a viable preferred basis.[182]

Thus, as the first step in developing his interpretation, Barbour advocates a many worlds Everettian setup with two modifications, namely a shift to a holistic perspective on the universe via regarding it as a single system, rather than regarding it as a composite made up of subsystems, and the emphasis on fundamental role of c-space points via their use to solve the preferred basis problem.

From this step, Barbour proceeds to develop his interpretation. In this interpretation of a timeless QT, Barbour does not provide much by way of an overarching, coherent account of our experience, though he does attempt do so for his QG as explicated in the next chapter.

---

[182] Additionally, see Esfeld 2004 for a treatment of QT in terms of relations, e.g., having the same spin as.

So, the remainder of this chapter mostly involves him extracting the temporal elements of QT with something of an Everettian framework in mind. In effect, his QT is approached mostly from an external perspective, i.e., one that considers c-space as a whole, rather than from an internal perspective, i.e., one that deals with our experience within c-space points. To develop this interpretation, he starts by explicating c-space points and the wavefunction. Though their roles seem interlinked, Barbour claims to distinguish these roles cleanly.

3.3 The Role of C-Space Points in Barbour's QT

Barbour delineates the role of his c-space points as follows. As quoted above in §3.1, he considers the measurements made in the Everettian picture to 'tell us where we are', i.e., in which world we are in. So, just as Everett regards measurements as telling us where we[183] are, Barbour regards observations as telling us where we are. However, rather than making recourse to branching worlds and given the fundamental status of c-space points assumed earlier, he posits that observations tell us in what c-space point we are. He (1994b, 2881) qualifies this by stating that these observations inform us "(in principle and imperfectly) in what" (1994b, 2881) c-space point we are in. Though this qualification in parentheses is made in passing, it is useful to elucidate it here as well as the likely reason for Barbour's replacement of 'measurements' with 'observations'.

Though Barbour does not provide much by way of explanation as to his slide from Everettian measurements to 'observations', this replacement is rather important for keeping the timelessness of his theory intact. A typical lab measurement process, as a process, takes place over time and is temporally ordered, e.g., an experiment is setup, started and results are then obtained. If this is applied to his c-space, then time may be smuggled in, e.g., c-space point(s) with the experimental setup could serve as the past to c-space point(s) in which the experiment is started, and c-space points with the experiments possible results could be

---

[183] Due the problem of personal identity for the Everettian interpretation, it is controversial who exactly this 'we' is, i.e., it is unclear how personal identity is to be account for in which a person branches into a number of subsequent individuals when a measurement is performed. I discuss this issue and its analogue for Barbour's QT in §2.1.1 in the next chapter as it hinges on his account of experience. Since I am here focusing largely on the external perspective of c-space, rather than the internal one, I, following Barbour, use 'we' without posing such issues of personal identity here.

deemed possible future c-space points.[184] In effect, Barbour needs to redefine 'measurement' in a timeless fashion or eliminate the possibility of measurements strictly speaking. In a discussion about time capsules, he (1994b, 2883) seems to opt for the latter: we do not measure, *we experience*, and what we experience is an indivisible whole. As the context of this comment deals more with the internal perspective of c-space, rather than the external one on which we are focusing on here, I return to this comment, unpack it and explore its ramifications for measurement in §2.2.1 of the next chapter. But, hopefully it provides some insight to the timeless reason that may back this slide from 'measurement' to 'observation'.

Regarding the imperfect qualification, this may refer to aspects of the external and internal perspectives of c-space points.

From the internal perspective, one might think that Barbour is referring to our, qua observers, limited domain of observations: our observations imperfectly inform us of our c-space point because our observations are limited to the properties in a very small part of the universe, e.g., the spin of a particular electron at a particular time. Such observations are potentially compatible with many other configurations of other stuff in the universe that we are not presently measuring. Thus, such a measurement, while ruling out that we are in some c-space points, e.g., those in which the electron is spin-down, is potentially compatible with several other c-space points. For this reason, one might conclude that such a measurement given the wavefunction *imperfectly* determines the c-space point we are occupying.

From the external perspective, the imperfect qualification may refer to the possibility of a c-space containing identical c-space points, i.e., points that have the same configuration of stuff. As we'll see below, Barbour holds that given certain solutions to the wavefunction of the universe, c-space can contain multiple copies of the same c-space point. So, even if we

[184] In view of Barbour's use of BMP in his classical dynamics, one may question whether it is possible for him to explain away this appearance of temporal succession by referring to a horizontally stacked c-space points. However, he cannot appeal to such dynamics at this stage because he is here attempting to explain away time as it appears in QT's dynamical principles alone. There is no reason to think that the two dynamics should be indicative of, e.g., sequences of configurations in QT. Instead there is only a frozen mist over the heap of possible c-space points.

observe all of the configurations of the universe at an instant from an external perspective, this may pick out a set of c-space points, rather than a specific point.

Making sense of the 'in principle' qualification in the context defining the roles of c-space points is a bit of a stretch. But, from the discussion of the imperfect qualification, it can be understood as follows. Either suppose that an external, God's eye view of the whole of the universe is possible, or that CNP holds for a c-space point in the sense that by observing part of it, you are observing all the configurations in the universe at an instant. Barring the possibility of there being identical c-space points, one would then be able to tell exactly in which c-space point one is in by what one is observing. So, either by taking an external perspective of the universe at an instant or by using the internal perspective with CNP, it is *in principle* possible to know which c-space point one is in.

Thus, in this fashion c-space points play a role similar to that of Everettian worlds, i.e., a c-space point is one of many configurations that we may occupy and observations (in principle and imperfectly) indicate in which c-space point we are.

3.4 The Role of the Wavefunction in Barbour's QT

The wavefunction's "sole role, as in Born's probability theory, is to say how likely the experiencing, or actualizing, of a given configuration is" (1994b, 2881). As in Everettian interpretations and due to Barbour's treatment of the universe as a single system, this wavefunction is the wavefunction of the universe.[185] By referencing the Born rule, according to which the probability of each outcome of a measurement is the squared amplitude of the outcome's corresponding term in the quantum state, Barbour is indicating that the wavefunction provides the probability that a certain configuration is 'experienced, or actualized'. While Barbour does not elaborate here as to what exactly the relation is between 'experiencing' and 'actualizing' or why he lists them separately here, it's useful to explicate this as a means of foreshadowing the rest of this chapter as well as to emphasis the timeless concept of *experiencing* he may have in mind.

---

[185] The use of a wavefunction that is applicable to the universe as a whole is pragmatically problematic, as Smolin 2001 points out, because a solution to the wavefunction of the universe would be extremely complicated and difficult to obtain.

As we'll see in the next section, Barbour distinguishes between the heap of actualities and the heap of possibilities, which are bunches of c-space points. Actualized heaps are those that actually exist, while the heap of possibilities includes the actualized heaps and c-space points that do not exist. Whether a c-space point is in the heap of actualities depends upon a solution to the universal wavefunction: if a certain configuration of the universe has a non-zero probability, then there are a number of copies of this configuration's c-space point that corresponds to the probability, i.e., the higher the probability of a certain c-space point, the higher number of actualized copies of that c-space point. So, it seems that Barbour is referring to such membership in the heap of actualized heaps with 'actualizing' above.

Regarding 'experienced', a natural reading of this term here is to indicate c-space points that *you* personally experience, as opposed to ones that, e.g., your doppelganger experiences. Barbour, however, could not accept this reading as it presupposes that you can be identified over time. Since there is fundamentally no time, you cannot be identified over time as a specific person, e.g., in $point_1$ as an infant, in $point_{378}$ as an adult, across c-space points.[186] Instead, 'experiencing' here must refer to some sort of experience that is limited to an instant. Barbour's notion of a time capsule, which is given below, will show to what his notion of instantaneous experience amounts. But, here I just want to emphasize that it does not necessarily import time into his account.

With this discussion, we can return to the quote. Where the sole role of the wavefunction is to provide the probability that a certain configuration is *actualized*, the

---

[186] A notion of personal identity that may work well with Barbour's timelessness is that of Hume according to which we are just bundles of perceptions: we are "are nothing but a bundle or collection of different perceptions, which succeed each other with an inconceivable rapidity, and are in a perpetual flux and movement" (Hume 1978, I.IV.VI). (See Campbell 2006 for a recent defence of a similar theory of personal identity.) Though Hume's account is supported by the changing of perceptions over time, it might be adapted to timeless c-space: at each c-space point, one is nothing but a configuration that corresponds to an instantaneous experience. Because one does not 'move' from one c-space point to the next, there is no temporal contiguity at all, just as there is no contiguity of perceptions, senses, faculties or soul according to Hume, that connects one's current experience with one's apparent past and future experiences. So, unlike Hume's temporally extended bundles, Barbour's bundles are confined to a single instant. Barbour's stance on personal identity is discussed further in Ch5 §2.1.1 below.

wavefunction serves to indicate the number of c-space points of that configuration that exist. Because it would seem that not all possible points are experienced, the experienced c-space points are likely a subset of the possible points. So, if a solution to the universal wavefunction only gives a non-zero probability to some configurations in which there is an experiencer(s), then the heap of actualized points would be the heap of experienced points. If not, then the experienced points would be a 'sub-heap' of the actualized points or would be merely in the heap of possibilities. Thus, the role of the wavefunction is to establish the probability of a configuration and, in effect, the number of actualized c-space points with that configuration. Whether the resulting heap of actualized points is identical to the heap of experienced points depends upon the solution to the universal wavefunction.

3.4.1 The Wavefunction and Heaps

He (1994c) spells out this role of the wavefunction more with his heap hypothesis. Before explicating this hypothesis, it is beneficial to explore Barbour's rationale for using 'heap'. Heaps are just c-space points that make up a c-space. One would suppose that Barbour uses this term in order to emphasize the lack of fundamental order among the points in c-space. Recall the upshot of the heap discussion in Ch3. Just as the things in a heap do not acquire different monadic properties and intra-relations in virtue of being in the heap, c-space points do not acquire different essential properties in virtue of being in a heap of c-space points.

In view of this implication of Barbour's use of 'heap' in describing c-space, let's turn to the task at hand, i.e., presenting the heap hypothesis and, ultimately, explicating the role of the wavefunction in more detail. The heap hypothesis (1994c, 409) states that physical theories simply provide rules to establish which configurations from the heap of possibilities go into the heap of actualities. The heap of possibilities is defined generally (1994c) as the heap of all possible configurations and, specifically for QG (1994b, 2881), as the heap of "all possible configurations of the universe which for closed-universe quantum gravity will be compact 3-geometries with matter fields defined on them." In other words, the heap of possibilities is the bunch of points resulting from considering all the different amounts and types of stuff in a universe and all the different configurations this stuff could be in. The heap of actualities is the heap of realized configurations, i.e., the c-space points that actually exist as specified by a solution to the universal wavefunction.

3.4.2 The Wavefuction and Heaps of the Schrödinger Equations

Barbour (1994b, 2881ff) (1994c, 409ff) (1999, 254ff) further delineates the role of the wavefunction via these heaps as follows. As the time-independent version of the Schrödinger equation ($\hat{H}\Psi = 0$) is timeless, Barbour uses this as the wavefunction of the universe in his QT. This equation determines the type and number of c-space point in the heap of actualities. Thus, it is necessary to provide some relevant background on the Schrödinger equation and Barbour's interpretation of it. To do so, I first present the formalism of these equations. Then, I provide what Barbour takes the status of these two equations to be in his version of QT as well as contrast Schrödinger's reading of them with that of Barbour.

3.4.2.1 The Formalism of the Time-Dependent and Time-Independent Schrödinger Equations

Before presenting Barbour's readings of these equations, some technical background is required to make clear the role of time and the wavefunction in these equations' formalism.

The time-dependent Schrödinger equation for a general quantum system, which describes the evolution over time of Ψ, is as follows:

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

In this equation, Ψ represents the wavefunction, which represents a state of a particle or system of particles. It is a function from a space that maps the possible states of the system into complex numbers.[187] The squared value of Ψ, i.e., $|\Psi|^2$, corresponds to the probability distribution. For example, in cases in which Ψ is a function of position and time, its square is equivalent to the chance of finding the subject at a specific time and position.

$i\hbar\frac{\partial}{\partial t}$ is the energy operator, which corresponds to the full energy of the system. The components of this term are as follows. i is an imaginary unit that allows the real number

---

[187] A complex number is a number consisting of real and imaginary parts. To visualize this mapping, picture a Cartesian coordinate system in which the x-axis represents the real numbers, while the y-axis referents the imaginary numbers. Now, pick a real number and an imaginary number. These serve as the coordinates for a complex number.

system to be extended to the complex number system. $\hbar$ is the reduced Planck constant, or the Dirac constant, which is equivalent to $\frac{h}{2\pi}$. h is the Planck constant, which is measured in cycles per second, as opposed $\hbar$'s unit of radians per second, and takes the value of the proportion between the energy and the quantum wavelength of a photon. $\frac{\partial}{\partial t}$ is a first derivative of time, which, in this context, is the rate of change of the wavefunction.

Finally, $\widehat{H}$ is the Hamiltonian operator. This operator corresponds to the total energy of the system and is usually expressed as the sum of operators that correspond to the kinetic and potential energies of the system, i.e., $\widehat{H} = T + V$, where $T = \frac{\hat{p}^2}{2m}$, in which p represents momentum, and $V$is usually a time-independent function of position $\boldsymbol{r}$, i.e., $V(\boldsymbol{r})$. The momentum operator $\hat{p}$ in this context is taken to be equivalent to: $-i\hbar\nabla$, where ∇ is a gradient operator. The gradient operator of a function is defined as a vector that points in the direction in which the function changes most rapidly and has a magnitude equal to the rate of change of the function in that direction. The substitution of this specific momentum operator gives us: $\widehat{H} = -\frac{\hbar^2\nabla^2}{2m} + V(\boldsymbol{r})$. ∇^2 is the Laplace operator that, for three dimensions, is shorthand for $\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ and gives the divergence of the gradient of a function on Euclidean space. So, the Hamiltonian here involves a space derivative. In sum, the term on the left-side of the time-dependent Schrödinger equation provides the total energy of the system, which involves a time derivative multiplied by the wavefunction, while the term on the right-side provides the sum of the kinetic and potential energy of the system multiplied by the wavefunction.

The time-independent Schrödinger equation (TISE) is:

$$\widehat{H}\Psi = 0$$

Given that, as stated above, $\widehat{H} = -\frac{\hbar^2\nabla^2}{2m} + V(\boldsymbol{r})$, then TISE for a single particle with potential energy V is:

$$\left[-\frac{\hbar^2\nabla^2}{2m} + V(\boldsymbol{r})\right]\Psi = 0.$$

This equation is clearly lacks any formal dependence on a time variable and, thus, provides a static probability distribution that is dependent upon spatial positions.

How does this relate to configuration space? As is well known[188], Schrödinger adopts a wave version of this equation, as opposed to de Broglie's version in which each particle is accompanied by a wave.[189] Usually, solutions to these are equations are represented in Hilbert space or phase space. However, as argued above, such spaces incorporate time. In effect, Barbour does not discuss these representations much in the development of his reading of the equations. So, I do not provide details of such representation here.[190] Instead, as we see in the next section, he makes recourse to Schrödinger's (1926) original formulation of his view in terms of a configuration space.[191]

3.4.2.2 Barbour's Reading of the Schrödinger Equations

According to the standard view of the relation between these equations, the time-dependent Schrödinger equation is fundamental, while TISE is derivative as a special case of the time-dependent version. Barbour (1999, 230-2), however, suggests that these equations are actually related in a different manner. He claims that TISE is actually fundamental, while the time-dependent version is merely an 'approximation' of TISE. While he does not provide a formal derivation of the time-dependent version from TISE[192], his claim is based explicitly on the reasoning that if one is working with some sort of time-dependent framework in mind, e.g., that of Newtonian mechanics, then a quantization will result in a QT in which time is a fundamental component. It is at least partially because of such temporal assumptions that the time-dependent Schrödinger equation is considered fundamental. On the other hand, if one

[188] See Moore 1992.

[189] See Jung 2009 for further discussion of de Broglie's view.

[190] See Amrein 2009 for details.

[191] Allori et al. (2011, 3) cite that he originally regarded his theory as describing a continuous distribution of matter spread out in physical space in accord with the wavefunction on a configuration space. For example, he (1926, 1050) treated a mass moving is a conservative field of forced by, "picturing the motion of a wholly arbitrary conservative system in its 'configuration-space' (q-space, not pq-space)." See Allori et al. 2011 for a recent attempt at taking Schrödinger's use of configuration space seriously.

[192] Interestingly, Schrödinger 1926 derived the time-dependent version from TISE. See Torretti (1999, 328) for further details and discussion.

starts with a Machian mechanics and proceeds to perform a quantization, then timelessness is crucial. In effect, Barbour's Machianism motivates his claim that TISE is fundamental, with the time-dependent version being a mere approximation of it.

To assist one in visualizing the difference between these two equations, Barbour (1999, 261) provides an analogy between mist over standard configuration space and the values of the wavefunction squared as well as the complex numbers involved in the time-dependent equation. However, before providing this pedagogical device, Schrödinger's configuration space involved requires some elaboration and comparison with Barbour's c-space.

Barbour (1999, 208ff) provides the following example of Schrödinger's assumed space in which he represents the time-dependent equation. Suppose there are only three particles in the universe. Consider each possible relative arrangement of the three particles; each arrangement can be expressed by the vertices of a triangle. Each of these possible arrangements corresponds to a single point in Barbour's c-space. In the absolute space presupposed by Schrödinger's configuration space, the configuration space has the three dimensions corresponding to the relative arrangements of the particles of Barbour's c-space, i.e., the lengths of each triangle's sides, as well as six additional dimensions. Three of these additional dimensions come from the location of the triangle's centre of mass in the absolute space. The remaining three are used to give the triangle's orientation relative to absolute space. In effect, Schrödinger's reading of his equation in this case utilizes a nine-dimensional configuration space in which each point of this space corresponds to a triangle's location in absolute space. And, generally, this space is generated by adding six dimensions, i.e., those corresponding to the system's centre of mass and orientation in absolute space, to the dimensions of any c-space. Following Barbour's (1999) term 'Q space', let's refer to all such configuration spaces, which contain both relative and absolute elements, as 'q-spaces'.

Schrödinger's wave mechanics is formulated on a suitable q-space and time, with the wavefunction defined on the q-space. The wavefunction provides, in principle, the maximally informative description of a quantum system at any instant *t*, i.e., the wavefunction provides predictions that can be made about the system. In principle, the wavefunction may have a different value at each point of q-space. As *t* changes, the wavefunction changes.

For example, consider the position of our three particles. The square of the relevant wavefunction of the system provides the probability of finding the system to be in the configuration specified by a certain q-space point at *t*, i.e., of finding the three particles in a particular configuration at *t*, after an appropriate measurement is made. In effect, Barbour's task here is to eliminate the time and absolute parts of the q-space in order to fulfil ONT.

Barbour (1999) introduces a means of visualizing the relation between q-space and the probability of the wavefunction as dictated by the versions of the Schrödinger equation. Though I do not intend to belabour Barbour's point by presenting such visualization, I find that it provides a pedagogical aid in presenting this relation as well as the manner in which Barbour claims to have eliminated time in the quantum context.

Barbour (1999, 230) likens the probability distribution of the wavefunction to a mist over static q-space. The intensity of the mist corresponds to how probable a q-space point is given that a certain measurement is made on the system; the more probable a q-space point is, the more intense the mist over this point is. The time-dependent equation, then, as providing the evolution of the wavefunction over time, is represented as a dynamic mist over a static q-space. As time passes, only the intensities across this mist change in accordance with the time-dependent Schrödinger equation. To see the manner in which q-space is time-dependent, contrast this visualization with that of the q-space of standard Newtonian mechanics. As time passes in the Newtonian framework, a single q-space point is picked out and actualized. Barbour (1999, 229) likens this case to one in which a single bright spot, which picks out a single q-space point at each instant, moves across q-space over time. So, while the Newtonian schema picks out a single q-space point for each instant of time that passes, the time-dependent equation provides the probability of whether certain q-space points are actualized given a certain measurement and dictates how this probability distribution changes for each instant of time that passes. In effect, both of these visualizations involve a static q-space on which a single spot or mist changes over time. However, unlike the Newtonian picture in which the light picks out a single series of q-space points with a temporal order, there is just a changing mist of varying intensities that is indicative of a c-space point's probability given a certain measurement is performed at *t* in time-dependent equation picture.

Let's extract the non-metaphorical upshot of these visualizations.

In the Newtonian case, there's a metaphorical moving light. Similarly, in the time-dependent Schrödinger case, there's a metaphorical changing mist. In the Newtonian case, the light is indicative of the temporal evolution of a system as dictated by certain equations; just as the light highlights a series of q-space points, such equations pick out a temporally ordered series of actualized q-space points. Additionally, there being a single light of one intensity may be indicative of the fact that if you plug the initial conditions into the relevant Newtonian equation, you can predict exactly which temporal sequence of q-space points would be actualized.

In the time-dependent Schrödinger equation case, the mist is also indicative of the temporal evolution of a system dictated by equations; the set of q-space points covered by the mist at t_1 and at t_2 pick out a temporally ordered set of c-space points that maybe actualized. Additionally, there being a widespread mist, which may cover several points at a time, of varying intensity at a time, indicates that the equation predicts that there is a set of q-space points with varying probabilistic values reflecting their likelihood to be actualized after a certain measurement.

There are two major differences between the metaphors. First, the light covers one q-space point at a *t*, while the mist potentially[193] has some value over the entire q-space at a *t*. Second, the light stays at the same intensity over time, while the mist may potentially have changes in intensity over time. So, though the time-dependent Schrödinger equation may be interpreted on a static q-space while not picking out a single series of instants, it involves a temporally evolving probability distribution that indicates the temporal evolution of the system and, thus, indicates the probability that the system may evolve at each *t*.

Barbour attempts to eliminate any such temporal evolution by adopting TISE. In contrast with the time-dependent Schrödinger equation's changing mist, TISE is associated with a static, 'frozen' mist over q-space; though the mist has different intensities over different q-space points, these intensities do not change over time.

[193] I use 'potentially' here to allow there to be cases in which the probability of a certain c-space point being actualized given a measurement at *t* is zero.

However, TISE, as presented above, has q-space, which presupposes an absolute space. In effect, Barbour must extract its components that rely on absolute space from its c-space in order to be in accord with ONT. To see in what fashion he must extract the absolute space components of q-space, it is necessary to identify what role this space plays in TISE.

Recall that TISE is: $\widehat{H}\Psi = 0$, where $\widehat{H} = T + V$, $T = \frac{\hat{p}^2}{2m}$, and $\hat{p} = -i\hbar\nabla$. By substitution: $[T + V]\Psi = \left[-\frac{\hbar^2\nabla^2}{2m} + V\right]\Psi = 0$. The second term in the brackets, i.e., potential energy V,does not seem dependent on time or absolute space. As Barbour (1999, 234) cites, any configuration of stuff has a potential energy associated with it as a function of the relative configurations of the bodies and their masses. Because this value is independent of a fixed background space as well as time, Barbour claims that he can assimilate it directly into his Machian QT.

The LaPlace operator involved in the first bracketed term, however, requires some modification. Standardly, the ∇^2 of the first term requires a fixed coordinate space on which to map its vectors. If this is put in terms of the q-space, ∇^2 must be a function of the dimensions dealing with absolute space: it represents changes with respect to distance in absolute space. Barbour (1999, 237) advocates replacing the means of calculating kinetic energy *T* using the operator with the best-matching procedure. Though he does not spell out the details of the replacement, he does give a sketch of how it would work. To calculate *T*, first measure gradients or 'curvatures' with respect to Machian distances created in c-space by the nonrelativistic BMP. Then add measured curvatures in as many mutually perpendicular directions as there are dimensions. This sum is *T*. As a metaphysical analysis is my primary concern, I do not attempt to further develop Barbour's formalism. Instead, I present this sketch qua sketch here to illustrate the manner in which he believes reference to a fixed background space may be eliminated.

But, I do need to address the appearance of BMP in this context. Given his interpretation of the equation as providing a static probability distribution in c-space, which, in this context, is the heap of possibilities, it is not clear that he can impose such connections between points by adding a BMP here without incorporating its sequential connections into his interpretation. Plus, because c-space is the heap of possibilities in this context, rather than a structured c-space like that of his GR, it seems that this use of BMP either requires an additional structured c-space, in addition to his heap of possibilities, or the heap of possibilities must be structured. Note, though, that we will encounter a similar issue regarding the nature of his heap of possibilities in the next chapter because in QG he assumes that the set of possible c-space points has a structure that serves to ‘funnel’ the wavefunction onto it. Nevertheless, because he mainly imports the above interpretation of the Schrödinger equation to the WDE, the details concerning the manner in which he can cash out the equation without reference to an absolute space do not impact his interpretation of QG. So, I set these issues aside and use his explicit interpretation.

Thus, Barbour claims to be able to extract the absolute space elements of Schrödinger’s c-space from the q-space version of TISE. And, because this equation is time-independent, Barbour’s QT, which features this equation as fundamental, lacks time. So, if the above arguments succeed in removing time and the use of a fixed background space and if they feature c-space points as fundamental, he has created at least a Machian QT formalism.

To sum up his Machian QT, Barbour’s account aims to resolve the problem of time by eliminating temporal elements in QT. With an eye towards such a solution, he attempts to formulate a Machian QT that, in accord with ONT and MP, uses only stuff and their instantaneous relative relations. Mirroring his classical accounts, c-space points are his QT’s fundamental components. In this context, however, this stuff seems to be that which we observe at the medium-sized dry goods level, e.g., the pointer on a measuring apparatus. And, again, he regards each c-space point as being all relative relations among all of the stuff in the universe at an instant. He initially develops his account along the lines of an Everettian many worlds interpretation in which the worlds are replaced by c-space points. Accordingly, the wavefunction does not collapse upon measurement. But, such measurements, claims Barbour, tell us in which c-space point ‘we’ are, and this c-space point is only one among many that ‘we’ may occupy.

He accepts TISE as Machian QT’s fundamental equation. It clearly lacks a fundamental time parameter and, thus, is in accord with MP2. He regards the squared value of its wavefunction to be indicative of a static probability distribution over the heap of possibilities. The heap of possibilities is the set of all possible c-space points. The higher the probability for a specific c-space point in this heap indicates the number of copies of this c-space point that there are in the heap of actualities.

In this interpretation, there seems to be no apparent sequential relation, spatial or temporal, among the c-space points. Rather, there are just more copies of certain c-space points than others given a solution to TISE. This complete lack of sequential connection among c-space points is clearly in accord with ONT and MP. However, unlike in Machian GR in which sequences could be built out of c-space points and effectively create histories, Barbour's QT offers no such histories. In effect, he, as we'll see in the next chapter, takes up the issue of our apparent experience of time. Because such experience indicates that there are such histories, he seeks to explain away such apparent connections among points. So, in view of the moves he makes to generate a timeless QT and its resulting complete lack of successive relations among c-space points, it seems that his task of eliminating time fundamentally has become more radical.

Let's now turn to the manner in which he integrates this Machian QT in his interpretation of the Wheeler-DeWitt equation such as to solve the problem of time.

Chapter 5: Piecing Together Barbour's Quantum Gravity

Now that we have seen Barbour's Machian rendition of QT's TISE and elucidated the manners in which it eliminates certain temporal features of the orthodox reading of the equation, we can proceed to explicate the manner in which Barbour puts together his Machian QT with his Machian GR in his favoured version of quantum gravity, while, in line with his (1994b, 2877) goals, keeping QT's and GR's 'deepest layers' intact and building a consistent interpretation of the resultant theory. Moreover, Barbour's preceding characterization of TISE will become important in his account of QG; as will be explained shortly, this characterization is used as motivation for his timeless approach to interpreting QG, i.e., it illustrates that a timeless QT is plausible and serves as a means of importing some features of his timeless interpretation of QT to QG.

To incorporate quantum mechanics, Barbour begins by adopting the Wheeler-DeWitt equation of canonical quantum gravity, which standardly, as stated in the previous chapter, is interpreted as being time-independent. Then, he puts it in terms of what he finds to be the fundamental feature of both GR and QT, namely c-space points. Additionally, as time is claimed to be a non-fundamental component of the two theories, he aims to provide an interpretation of the equation such that time plays no fundamental role.

As part of this interpretational endeavour, he seeks to explain away our association of the present with a temporal past, i.e., as the product of an ordered sequence of c-space points. For this purpose he introduces the notion of 'time capsules', notably in his (1994b) and (1999). These time capsules will be explained below.

Thus, this chapter is organized as follows. §1 explicates the manner in which Barbour eliminates time from QG from an external perspective: he constructs his Machian interpretation of quantum geometrodynamics in terms of a c-space version of the naïve Schrödinger interpretation of the WDE. Then in §2, time in QG is dealt with from an internal perspective: his account of the appearance of time in our day-to-day experience is provided, which follows this three step process that is provided in his (1994b). First, he introduces time capsules as a means of accounting for our experience of time because we are in a set of static c-space points that do not necessarily form a temporally ordered series. Second, in order to give some reason for thinking that there is some correspondence between the more probable c-space points as dictated by a solution to WDE and the c-space points that have time capsules, he provides Mott's explanation of alpha-particle behaviour. This is an example in which the heap of more likely c-space points is identified with the c-space points that contain time capsules. Third, he attempts to answer the question of whether the solutions to WDE are *'generically'* concentrated on c-space points with time capsules. §3 summarizes the resulting Middle Barbour account of QG.

1 The Wheeler-DeWitt Equation, Barbour's Interpretation and Their Relation with the Time-Independent Schrödinger Equation

As stated in the previous chapter, Barbour's favoured QG is canonical quantum gravity, quantum geometrodynamics in particular. Recall that this view requires that GR be put in Hamiltonian form and that this Hamiltonian be quantized. The equation that results from this process is the Wheeler-DeWitt equation (WDE) [194]. Here it is again for reference:

$$\widehat{\mathcal{H}}\Psi = \left(-16\pi G\hbar^2 G_{abcd}\frac{\delta^2}{\delta q_{ab}\delta q_{cd}} - \frac{\sqrt{q}}{16\pi G}R\right)\Psi = 0 \quad \text{(E4.8)}$$

To present his interpretation of the WDE, we first state what Barbour claims to be the relation between Machian geometrodynamics and the WDE. Then, some general information is provided as to Barbour's preferred interpretation of the WDE, namely the naïve Schrödinger interpretation. Finally, we present his version of the interpretation, which, as we will see, incorporates his reading of QT's Schrödinger equations in terms of c-space points.

1.1 Machian Geometrodynamics and the WDE

Though Barbour (1994a, 2861) does suggest a way of quantizing his nonrelativistic dynamics, he merely points out that the result resembles TISE and highlights the fact that it is timeless. Moreover, he offers no formal quantization of his relativistic dynamics in its

[194] See Rovelli (2008, 10) for the historical origin of the equation in brief.

entirety.[195] Instead, he states that we should consider the implications of a possible quantization of the BSW[196], which, in view of his (1994b) focus on providing an interpretation of the WDE and claim that we should expect such quantization to at least have the form of the WDE, is presupposed to be this equation throughout his attempt of providing an interpretation of QG. Additionally, even in his current work, e.g., (2011), he assumes that quantum gravity features the WDE. Thus, it seems that Barbour is attempting to unify GR, when in terms of his Machian BSW account, with his Machian QT such that they can provide a coherent interpretation of the apparently timeless WDE.

What interpretation does Barbour adopt for the Wheeler-Dewitt equation? In order to avoid violating ONT and effectively solve of the problem of time by taking a timeless approach, he begins with a timeless interpretation of WDE, namely the naïve Schrödinger interpretation, which is presented below. He puts this interpretation in terms of c-space points and, as explained in §2.2-2.3, supplements it with considerations from Mott.[197]

1.2 The Naïve Schrödinger Interpretation

---

[195] However, in some works, e.g., Barbour and Murchadha 1999, he does offer a means of remedying certain formal problems that arise in the quantization of the Hamiltonian. However, because we are here concerned with his interpretation of geometrodynamics and since his interpretation is directly in terms of the WDE itself, rather than in terms of the formal details of its quantization, such details are not presented or discussed here.

[196] See Wang for discussion of the quantization of the BSW.

[197] Unlike Kuchar 1992 and Isham 1992, 1993, Anderson (2011, 10-11) adds further options to the category of timeless interpretations of QG. So, rather than classifying him as an advocate of the naïve Schrödinger interpretation, Anderson classifies him under the option of 'Records Theory Scheme', i.e., those schemes in which records (i.e., some sort of instantaneous configuration) are considered as primary and where one seeks to construct a semblance of dynamics or history from the correlations between these records. This scheme is further subdivided into two types: (A) those in which the correlations are obtained by considering the fact that present events contain past memories, and (B) those in which the correlations are obtained by reinterpreting Mott's calculation of the manner in which alpha-particle tracks form in a cloud chamber. Barbour's approach is classified under the latter type. The classificatory issue of whether Barbour's approach falls under a development of the naïve Schrödinger interpretation or as a completely different solution of the third type does not impact my exposition above.

Barbour explicitly (1994c, 410) adopts the naïve Schrödinger interpretation of WDE as it is discussed in Kuchař (1992, 66-9).[198] This interpretation approaches the WDE by treating the wavefunction of the WDE in the same way as it is treated in standard QT. Recall that in standard QT, the square of the modulus of the wavefunction Ψ, i.e., $|\Psi|^2$, corresponds to the probability distribution. For example, in cases in which Ψ is a function of position and time, i.e., $\Psi(\mathrm{r}, \mathrm{t})$, its modulus squared is equivalent to the chance of finding the subject at a specific time and position. According to this interpretation, the square of the WDE's wavefunction is to be treated in the same fashion. Suppose we have a solution $\Psi(\mathrm{q}_{ab})$ of the WDE. Its square $|\Psi(\mathrm{q}_{ab})|^2$ is the probability density for finding a hypersurface with intrinsic geometry q_{ab}.

Unruh and Wald (1989), Kuchař (1992) and Isham (1992), raise some difficulties with this interpretation. However, many of them arise due to the roles of time in the standard interpretation of QT. For example, Unruh and Wald (1989, 40) state that the wavefunction on this interpretation provides the probability amplitude that an observer making a measurement at a certain parameter time *t* will find certain values. Yet, they object, such an interpretation must be rejected because the WDE's wavefunction is independent of time.

With this objection, it seems that Unruh and Wald are assuming a standard reading in which the time-dependent Schrödinger equation is fundamental and that QT requires a background time parameter. As Barbour's Machian QT seems to involve no such time parameter and regards TISE as basic, it seems that he can develop the naïve Schrödinger

---

[198] Though, as Kuchar notes, this interpretation was adopted by Hawking 1983, 1984 and originally termed the 'naive Schrödinger interpretation' by Unruh and Wald 1989. Unruh and Wald criticize it among other interpretations in order to elicit reasons for the lack of a satisfactory interpretation of the universe in canonical quantum gravity. It is interesting to note that Unruh and Wald (1989, 2598) state in their introduction that they are assuming that the term 'interpretation' refers to, "a description, in ordinary language, of what an observer would see or experience when the mathematical quantities used by the theory to describe the state of the system take on any of their allowed values." They further note that this implies that the Copenhagen and Everett interpretations of QT are equivalent because they both "give the same rules for what an observer 'sees'."

For more discussion of this interpretation, see Isham (1992, 90), Anderson (2011, 9ff). For less technical discussion, see Butterfield and Isham (1999, 153) and Kuchar (1999, 187).

equation in a fashion that bypasses at least this worry. However, as my purpose is to evaluate the role that time plays in Barbour's theory, I do not evaluate whether the problems raised by these authors apply to Barbour's resulting interpretation here. Rather, I mention these issues to emphasize the importance of Barbour's Machian QT, notably his timeless, frameless rendering of the Schrödinger equation, in generating his QG. Now, let's see how he uses the naïve Schrödinger interpretation with his Machian reading of the Schrödinger equation in order to provide a c-space-point-based account of QG.

1.3 Barbour's Rendition of the Naïve Schrödinger Interpretation

In Barbour's c-space rendition of this interpretation, the Wheeler-DeWitt equation puts a probability density on each configuration in the heap of possibilities. Generally speaking, this probability density indicates that some c-space points have more copies in the heap of actualities than others.

In accord with the naïve Schrödinger interpretation's strategy of imposing the treatment of Schrödinger equation's wavefunction with that of the WDE, Barbour makes use of the frozen mists over the c-space of the Schrödinger equation. He (1999, 247, 260) characterizes WDE's wavefunction in terms of mist: the square of it corresponds to a static mist across superspace, i.e., the space of all possible Riemannian 3-geometries (Barbour FXQi, 4),[199] that has a density in proportion to the probability of the c-space points. Recall from Ch3 that in the context of his relativistic dynamics, Barbour refers to the points of superspace as 'c-space points'. There, superspace just is a c-space: it is a metric of Riemannian 3-geometries that is obtained by quotienting out the diffeomorphisms of the space of the Riemannian 3-geometries.[200] In effect, the static mist is denser over c-space

---

[199] Note that Current Barbour replaces superspace with conformal superspace, i.e., a space in which each point has a conformal geometry and is represented by the equivalence class of metrics related by position-dependent scale transformations. This plays a large role in Current Barbour's attempt to relativize shape. But, as we are using only Middle Barbour as a model to which to apply ACA, we do not discuss this alternative here.

[200] As we'll see in Barbour's speculations regarding the implications of Mott's problem, he claims that this space has a stratified manifold, which is a collection of manifolds of different dimensions that is structured by these dimensions. Barbour's choice of stratified manifold and proposed uses of it are explained in detail below. Since such a manifold is not integrated in Barbour's discussions of his QG until after this problem and because

points that are more probable, and this density is given by the value of the wavefunction resulting from a solution to WDE.

Additionally, just as in his reading of the Schrödinger equation in which the higher probability of a c-space point in the heap of possibilities indicates that there is more copies of such a c-space point in the heap of actualities, the more probable a 3-geometry of superspace is, the more copies of that c-space point is in the heap of actualities. This is supported by the following quote:

> A solution to [WDE] puts a value of Ψ and, with it, the Schrödinger density Ψ*Ψ on each configuration in the heap of possibilities. Let us then suppose that whoever or whatever creates the world puts a corresponding number of identical copies of the configuration into the heap of actualities. (1994c, 410)

In effect, if a c-space point is assigned a positive value by $|\Psi|^2$, then it is in the heap of actualities. Moreover, the WDE dictates the numbers of copies of a particular c-space point that appear in the heap of actualities. A solution to WDE makes certain c-space points probable than others. The probability of a c-space point is to be understood as indicative of how many copies of the point is in the heap of actualities: the more probability a certain c-space point is assigned, the higher the number of copies of that c-space point in the heap of actualities.

It is important to note here that a heap of actualities is not clearly stackable for two reasons. First, given the manner in which Barbour interprets the WDE thus far, it seems that there is no reason for the probable c-space points to correspond to a set of best-matching c-space points. However, we'll see at the end of this chapter that he may be able to make

---

it is not clearly consistent with ONT and his pre-Mott discussions, I do not present it until §2.3 below and analyse its consistency with his overall project in Ch6. Moreover, as Anderson (2004, 10) notes, the quotienting out the diffeomorphisms makes superspace much more complicated than Barbour's three-point illustration of c-space because superspace requires much more strata than his simple three-particle illustration, which is reflective of a Machian Newtonian c-space. Nevertheless, Anderson claims that it is a useful model by which to consider c-space. And, what really matters for my analysis is that Barbour proposes any such manifold with strata, rather than specific types of strata. So, we only focus on the model stratified c-space as presented by Barbour and bracket off such technicalities regarding the additional strata of superspace.

recourse to the interaction of the wavefunction with the stratified c-space. But, this suggestion is highly speculative. Second, even supposing that these probable c-space points are best-matching, such a stack likely contains copies of certain c-space points. How can we determine which particular copy of a c-space point belongs in a certain stack? Given PSR, there appears to be no reason to include one copy rather than another in a certain stack. And, given ONT, any relation between such points must be reducible to the stuff and relative relations of the c-space points. Other than a best-matching relation, which, as presented in his classical dynamics, presupposes that a given best-matching set has no copies, it does not seem that Barbour has any other means of generating a succession of c-space points. So, the heap of actualities must indeed be a heap. Thus, given his characterization of the WDE and his principles, the c-space points in the heap of actualities are disconnected from others even in terms of spatial relations; each instantaneous configuration of the universe that exists has no successive relation to the others.

In order to attempt to illustrate in more detail the possible outcomes of using this interpretation as well as sketching out some possible formalism involved, he (1994b, 2881) assumes that we have a solution Ψ of the Wheeler-DeWitt equation and further assumes that Ψ is for a quantum system that has a finite number of degrees of freedom in order to bracket off the issue of renormalization that arises in systems of infinitely many dimensions and indefinite kinetic energy.[201] With only such finite quantities in play, Barbour supposes that it is possible to divide superspace into infinitesimal hypercubes of equal side length by using the kinetic metric. The value of Ψ is then taken in each hypercube, and $|\Psi|^2$ is calculated for each cube. Finally, for each hypercube, a number of identical copies of a representative configuration of the hypercube is put into the heap of actualities. This number is to be proportional to $|\Psi|^2$ of the hypercube.

Barbour does not give much else by detailed explanation here or elsewhere that explicates exactly how this is connected to WDE, e.g., 'kinetic metric' may correspond to its

[201] Though Barbour's (1994b, 2881) motivations for such bracketing here, i.e., "trying to understand the appearance of time from timelessness," are understandable, he does not address this issue directly elsewhere. Additionally, Smolin 2001 criticizes precisely the impracticality of implementing his view in a universe like ours in which such infinite quantities are likely to come into play.

extrinsic curvature analogue in WDE, or precisely how this setup works, e.g., how exactly the hypercubes of superspace correspond to a point in c-space. But, presumably, he is using the hypercubes as a means of mathematically splitting up superspace in order to specify the probability assigned to each c-space point.

Thus far I have made the difference between the heap of possibilities and the heap of actualities in terms of existence. Yet in Barbour's account, it is not made explicit whether the number of heaps is merely representative of the probability of us being in a certain c-space point or, rather than being only metaphorical, the heap of actualities, which contains multiple copies of certain points, actually exists. For example, in the 1994c quote above, Barbour indicates that the heap of actualities comes into existence when the universe is created. Though this *prima facie* seems to indicate that such c-space points exist by being created in the initial creation of the universe, it may also indicate that each possible configuration of the universe was assigned a certain probability at the moment of the universe's creation. As this issue is closely related to the Everettian interpretation's problem of probabilities and because, as we shall see, this issue is intertwined with one's experience, I need to present Barbour's account of experience before addressing it. So, I discuss and resolve the issue in §2.1.1 below following Barbour's account of experience.

2 Explaining Away the Appearance of Time

Given that Barbour aims to eliminate or reduce any temporal connections between c-space points, he is obligated to provide an account of our temporal experiences. His 1994b proposes a three step process for explaining away such apparent temporal relations. Thus, this section is organized into three main subsections. First, his notion of time capsules is presented and clarified. It is with these special configurations that he aims to explain away our apparent memories and perception of motion. After discussing these time capsules, I return to the Everettian problems of probability, measurement and personal identity, and address them along Barbouric lines. Second, the Mott problem is presented. Barbour regards Mott's solution to this problem as motivation for the claim that the probability distribution of the WDE is higher on c-space points with time capsules. Third, we look at the manner in which Barbour proposes that Mott's solution can be generalised to his Machian QG.

2.1 Time Capsules

Because the static c-space points are ontologically basic in Barbour's picture, he needs some account in which our experience of time is merely ostensible. The first stage in this account is the introduction of time capsules. As these time capsules play a central role in the manner in which Barbour attempts to explain away our experience of time, this stage is key in indicating to which temporal concepts Barbour's use of 'experience of time' refers. Thus, it is also key to our later application of ACA to his theory. Note that the content of this section does not make much reference to the existent literature on the experience of time because my main aim here is to tease out the temporal concepts as they appear in Barbour's own narrative. However, the analysis of these concepts in Ch6 puts Barbour's concepts dealing with temporal experience in the context of such literature.

Barbour (1994b, 2884) provides the following "general"(2883) definition of 'time capsule'.

> By a time capsule I mean *a static configuration of part or all the universe containing structures which suggest they are mutually consistent records of processes that took place in a past in accordance with certain laws*.

Intuitively, this notion of a time capsule seems to be exemplified by the artefacts we encounter daily. For example, a series of footprints in freshly fallen snow 'suggest that they are mutually consistent records of processes that took place in a past in accordance with certain laws'.[202] The footprints suggest that they are a set of *mutually consistent records* because each footprint, e.g., is a footprint of the same size, roughly 6in away from another footprint and alternates with an opposite footprint. So, each footprint seems to be a record of some event, and these records seem to be consistent given their relative locations. Further, these records seem to be records of *processes that took place in a past*, i.e., as individual processes they each seem to be a record of a shoe making an imprint at a particular location in an apparent past, and as a set of processes they seem to be records of someone walking in the snow in an apparent past. Thus, 'processes' above refers to a temporally ordered

[202] Barbour (1994b, 2885-6) provides a few other examples of time capsules: the apparent evidence of our evolutionary history as found in rocks, plants and animals; the apparent rotation of planets inferred from their oblateness.

sequence of events. Finally, these records are indicative of a process that *took place in accordance with certain laws*[203]: the apparently past process of someone walking appears to have taken place in accordance with laws governing gravity and human physiology, e.g., there is no five foot gap in the series of footprints that suggests the person levitated and the size and distance between the footprints are consistent with them being from a human of a certain height walking at a certain speed rather than a yeti.

It is with these time capsules that Barbour attempts to explain away any sense of temporal extension associated with experienced configurations in a c-space point that appears to be the result of a temporally ordered sequence of events. Thus, with artefacts that appear to be the result of a past process, such as the set of footprints above, Barbour claims that only the present c-space point in which these configurations appear actually exists and that one did not necessarily experience any of the configurations in the apparent past process. Rather, it is due to the presence of these time capsules, which suggest that there was a past temporally ordered sequence of events, e.g., someone who walked through the snow, that we erroneously come to believe that there was a past ordered set of c-space points the led to the presently experienced c-space point. Thus, one is just interpreting the present configuration as being the result of a past process due to the presence of a time capsule, but no such sequence of c-space points led up to the c-space point that one is experiencing.

Thus far, we have been considering a case in which we see a static configuration and interpret it as being the result of a past process. How are these time capsules supposed to work for experiences of apparently dynamical configurations, e.g., seeing motion? How do they even work for the apparent process of seeing something and making inferences about it, e.g., even in the footprint case it seems that there is a process involved by which one sees the object in which photons are reflected from the imprints, arrive at one's eye, are interpreted by

[203] Barbour does not indicate here exactly what he means by 'laws' here, but some options are in the offing: *the* laws of nature; possible sets of laws of nature; or laws associated with some sort of folk theory that arises from one experiencing certain events being followed by certain other events often. While I am non-committal here as to which option is more plausible given Barbour's account, these options will be elaborated upon and evaluated later as to their consistency with his methodology for arriving at the laws of nature.

the brain, and one seems to make an inference from this data to the conclusion that someone recently walked by.

Recall that experiencing on Barbour's account is confined to that of a single c-space point. And, given ONT, he can only appeal to objects and their relations in a single c-space point in order to explain away temporally extended experience. So, to answer these questions, he (1994b, 2883) appeals to a specific type of a time capsule: brain configurations. This passage is presented in the context of distinguishing his stance from that in which "direct experience," i.e., present sensory experience, I presume, is 'correlated'/'coded' with the positions and motions of atoms in our brain.

> An alternative is that our direct experience, including that of seeing motion, is correlated with only *configuration* in our brains: the correlate of the conscious instant is part of a point of configuration space, not phase space. Our seeing motion at some instant is correlated with a *single* configuration of our brain that contains, so to speak, *several* stills of a movie that we are aware of at once and interpret as motion. Such a brain configuration is a *time capsule*.

Our experience of the process of motion, e.g., our experience of a temporally ordered sequence of events that we interpret as motion, is explained by there being neural time capsules. A neural time capsule is a configuration of one's brain in a particular instant, i.e., it is part of the configuration making up a particular c-space point, that somehow 'encodes' an apparent experience of a temporally ordered sequence of events. Barbour suggests that these neural time capsules do so by 'containing' "several stills of a movie that we are aware of at once and interpret as motion," i.e., one's brain configuration in a particular c-space corresponds, in some way[204], with a set of configurations of which we are aware concurrently and that are interpreted as the process of motion.[205] However, he (1999, 267) notes that there

---

[204] As I discuss shortly, Barbour takes his claim that the brain at an instant contains several stills that are interpreted as temporally ordered to be a primitive that, perhaps, arises from CNP, or some sort of well-known fact.

[205] The viability of his use of time capsules to explain away our usual temporal experience, which seems to be extended well beyond what is encodable in the configurations of a single c-space point, is discussed in Ch6.

are also c-space points that do not contain such neural time capsules, e.g., some of the stills are missing, some of the stills "are jumbled up in the wrong order."

This jumble quote may strike one as odd because the second long quotation implies that we, somehow, interpret these stills as having a certain order. In effect, it's our interpretation of the stills that imposes temporal order on them, rather than the stills themselves being presented in some sort of order. The jumble quote, on the other hand, suggests that these stills are given to us in a certain order, i.e., a temporal sequence. In effect, on this reading Barbour may be accused of sneaking in temporal order via such neural time capsules that contain sequences of temporally ordered stills.

However, at least *prima facie*, this threat of sneaking in temporal order via neural time capsules is benign; Barbour can make recourse to the following two-fold reply.

First, the stills 'encoded' in neural time capsules are indeed given in an order. However, this is a fundamentally spatial order, which may be something akin to best-matching, rather than a fundamentally temporal order. Moreover, this reply can be used as a means of identifying where we get our concept of temporal order: it is from these given spatially ordered stills that we create our empty notion of temporal order.[206]

Second, shortly we will see how Barbour uses the WDE to make c-space points with time capsules more probable. But for our present purposes, it merely needs to be noted that Barbour wants his theory to make such c-space points much more probable so that our apparent experience of temporally ordered events can be explained by his account. In turn, the higher likelihood of c-space points containing such neural time capsules, rather than sneaking in temporal order, is used to explain where we get our concept of temporal order. Because we are much more likely to experience c-space points in which we have neural time capsules and since such neural time capsules are interpreted by us as temporally ordered sequences with duration, we seem to experience temporally ordered sequences of events. At

---

[206] This will be developed and discussed further in Ch6 via some models of the structure of the specious present. There, I argue that the retentionist model, rather than the cinematic and extensional models, fits best with Barbour claims about our experience of time. And, I also spell out another and more radical option that involves a mental/physical property dualism.

the god's eye view of c-space, however, one does not necessarily experience c-space points in the order implied by the stills encoded in neural time capsules. Rather, Barbour (1999, 300; 1994b, 2883) seems to accept that, at least barring some sort of spatial ordering, that one may 'jump around' wildly from one c-space point to the next.[207] So, while at the experiential level there is apparent temporal order, the series of c-space points that one actually experiences does not necessarily follow the order of stills given by a particular neural time capsule: one does not necessarily experience the c-space point with the configuration of the apparently previous still 'prior' to experiencing the c-space point in which one's neural time capsule 'encodes' this still.

Further, while Barbour does seem to realize this in discussion about the role and ontological status of histories, which I provide below, and elsewhere[208] that given that his account is fundamentally timeless and that this account, at least at this stage, deals with heaps of c-space points, we cannot legitimately speak of our experience of c-space points as potentially 'jumping around' or even ask the question of what is the actual temporal order of c-space points that we experience. Strictly speaking, there is no such order to or succession with our experience of c-space points. So, this talk of 'jumping around' is just to emphasise that there is no fundamental link among c-space points that directly corresponds to a temporal sequence. However, we can legitimately speak of some spatial order of c-space points, e.g., that imposed by best-matching, assuming that such spatial order is not derived from our temporal experience. This interplay between spatial and temporal order plus whether Barbour must use the latter to generate his laws and best-matching will be discussed in Ch6. But, for the purposes of this portion of the exposition, the upshot of this discussion is: at least in the context of his exposition of time capsules and their function in his interpretation of QG,

---

[207] He seems to accept this in the context of using Bell's 1981 discussion of Everett's many worlds interpretation. This discussion is used to setup Barbour's (1999, 302ff) development of his Many-Instants picture.

[208] In (1994b, 2883), he states, "However, we can never step out of the present instant, we can never know if any other instant is actually experienced […]. For we shall never know whether other possible instants, including what we take to be our own past, are actual or whether the present instant is unique."

the temporal order that neural time capsules impose does not entail that there is temporal order at a fundamental level.

Now that the timeless nature of these time capsules has been clarified, a more concrete rendition of the neural time capsule example is in order. Suppose that an apple appears to have, say, rolled off a table apparently in accordance with certain laws. Imagine seeing the apple in the c-space point in which the apple just appears to be going off the end of the table. At that instant one would say that the apple, prior to this particular c-space point, had a certain continuous trajectory and speed before reaching the end of the table. This apparently past trajectory is the process encoded by the time capsule; it is some sort of law-abiding temporally ordered series of configurations that, Barbour claims, is somehow encoded in one's instantaneous brain configuration. Furthermore, as Barbour explains and as my apparent overuse of 'apparent' above indicates, such temporal evolution does not actually occur. Rather, certain c-space points are or contain time capsules, which are those configurations that somehow encode the appearance of a past set of temporally ordered configurations. Thus, our experience of time is merely the result of us interpreting such time capsules in terms of a temporally ordered set of configurations.

At c-space points that one usually experiences, why does one usually seem to have a brain configuration that corresponds to a certain set of configurations, i.e., is a time capsule, and how does one, while at a particular c-space point, interpret these configurations such that they seem indicative of a temporally ordered past? His answer to the former question is provided shortly in the following two sections. To foreshadow the following sections, note that he answers the first question by claiming that the wavefunction, as governed by the WDE, makes those c-space points containing brain configurations with time capsules much more probable than those c-space points that lack such brain configurations. He (1999, 255, 266) answers the second question by claiming that such interpretation is primitive or is some sort of "well known fact."[209]

---

[209] In Ch6 I develop a few options for such interpretation of our perception of time that fit with Barbour's claims and accounts. These are the retentionist model, in which one is presented with a number of simultaneous retentions in an instant though one interprets them as having a duration, and a psycho-physical dualism, in which certain epiphenomenal mental properties supervene on one's brain configuration at an instant.

Barbour's general Machian project makes clear his rationale for positing such time capsules on two related fronts. First, c-space points are basic in his ontology, with motion being derivative from such static configurations. Thus, he must provide an account fundamentally in terms of c-space points only, rather than in terms of a combination of objects' relative positions and their motion.

Second, each c-space point is supposed to be a static snapshot of all the objects in the universe. As such, these c-spaces points have no temporal extension. Additionally, they have no emergent sequential order due to the fact that the heap of actualities can contain more than one copy of a given c-space point. So, he must explain away the appearance of a temporally extended present as well as the appearance of a particular past.

In effect, Barbour claims that any apparent motion, memories, the past and presently perceived objects that are indicative of a past, are encoded in a single instantaneous configuration. Whether this account of experience, the consequence from his principles that his heap of actualities is not stackable and our day-to-day temporal experience are reconcilable is discussed in Ch6.

Let's now turn to addressing issues associated with his Everettian-based account.

2.1.1 Formulating and Addressing Problems of the Everettian Interpretation in the Time Capsule Context

With this account of our experience of time in place, we are now in a position to present responses on behalf of Barbour to the other main problems of the many-worlds version of the Everettian interpretation mentioned in the preceding chapter, i.e., the problem of probability and the problem of personal identity. Plus, we can address the issue of measurement raised in §3.3 of the previous chapter.

2.1.1.1 The Problem of Probability

In the many-worlds version of the Everettian interpretation, a problem of making sense of probability arises. This is due to all possible outcomes of a quantum measurement existing following the measurement. For example, suppose someone sets up an experiment that can result in a measurement of spin-up or spin-down. According to this Everettian interpretation, upon measurement this world branches into a world in which spin-up is measured and a world in which spin-down is measured. In effect, it seems that the probability of each outcome is 1. According to the Schrödinger equation, however, the probability of each state is 1/2. Saunders (1998, 374) diagnoses this result in terms of the apparent inapplicability of the concept of probability in this context. He claims that the concept of probability seems only applicable to cases in which a single possibility out of a range of possibilities is realized so as to exclude all the other possibilities. Because all of such possibilities are realized for quantum measurements, this concept seems inapplicable to the Everettian account. So, the general question arises: How are we to make sense of quantum probability in this Everettian interpretation?

Although Barbour bases his account partially on that of the Everettian, it seems as though this problem runs much deeper for Barbour. Given ONT, all he has are the stuff and relations of each c-space point. Unlike an Everettian view in which branches come into existence when a measurement is made, Barbour cannot have a single c-space point or a certain range of them coming into existence at a time as this requires at least some background time parameter. This parameter would be in violation of ONT. Nor can he, unlike a static block version of the Everettian picture[210], have a static but temporally ordered series of c-space points. In this case, a temporal concept, i.e., temporal order, appears in violation of ONT. So, there must exist either a single set comprised of each possible c-space point, i.e., those in the heap of possibilities, or all the points in the heap of actualities, which includes copies of certain c-space points corresponding to the probability distribution calculated from a solution to the WDE. Above the problem is claimed to arise on the Everettian picture due to all possible outcomes of a quantum measurement existing following measurement. In Barbour's picture, we have neither a set range of possible outcomes existing following a quantum measurement nor the temporal order implied by the term 'following'. Rather, we just have either the entire heap of possibilities or the entire heap of actualities existing, with certain types of c-space points allegedly more probable than others. This view effectively is very far removed from being able to employ Saunders' concept of probability, which is only applicable to cases in which a single possibility out of a range of

[210] See Saunders 1995, 1998 for a discussion of framing the Everettian interpretation in this way that focuses on modifying the time-flow laden tenses often used to speak about branching and the like.

possibilities is realized so as to exclude all the other possibilities, because all possibilities exist and there is no sense of being realized at a time. So, how can sense be made of Barbour's use of 'probability'? [211]

Since c-space points are supposed to be the basic thing in his QG, let's try to make sense of his use of 'probability' in some manner using c-space points. We'll proceed by ascertaining whether some of the standard accounts of probability can be used in this context. As we'll see below, standard interpretations of probability on the metaphysical market attempt to explain something along the lines of Saunders' time-dependent concept of probability. However, because Barbour's use of this term must be removed from the usual

---

[211] Because the problem of probability that Barbour faces is so removed from the problem as it appears in the Everettian interpretation as well as the time-laden concept of probability presupposed, it does not seem that the main Everettian resolutions to this problem can be used by Barbour. For example, a prominent line of response to this problem is the Deutsch-Wallace decision-theoretic approach. According to this approach, one can generate quantum probability distributions through a combination of a non-probabilistic theory and some axioms of classical decision theory, e.g., the axiom of additivity according to which an agent is indifferent between receiving two separate payoffs and receiving a single payoff of an amount equivalent to the sum of the separate payoffs. However, Wallace (2003, 437) argues that such decision theory seems only "reasonable for small-scale betting". In effect, this seems only a reasonable account for determining the quantum probability for a single branching. It is not clear how such decision theory may be applied to the entire heap of possibilities. Plus, because this decision theory is usually cast in temporal terms, e.g., one puts values on receiving a specific range of future payoffs or, more generally, is concerned about future consequences, it would have to be recast non-temporally to be employed by Barbour. For discussion of this approach, see Albert 2010.

Another main line response is to claim that probabilities are to be cast entirely in terms the observer's uncertainty about something, e.g., Vaidman's 1998 immediate post-branching location, and, in effect, are merely epistemic. It seems that Barbour can appeal to time capsules in order to recover such uncertainty. Moreover, such epistemic uncertainty seems to presuppose that there exists a temporal sequence of c-space points, e.g., the uncertainty of which c-space point we *will* experience *next*. However, there are no c-space points in a temporal sequence, whether an ordered sequence or a sequence that is not ordered and jumps around. So, unless one's experiences correspond to an existing sequence of c-space points, which violates ONT by appealing to some basic temporal relation among points, it does not seem that this appeal to uncertainty can be employed to make sense of Barbour's use of 'probability' that refers to the number of copies of a c-space point in the heap of actualities corresponding with the wavefunction's squared modulus given a solution to the WDE.

time-laden concept of probability, these interpretations must be modified. I attempt to do so below with the frequency and propensity interpretations of probability.

One route is to have the heap of actualities exist. Recall that the degree of probability of a configuration corresponds to the number of c-space points in the heap of actualities. Let's try to read this claim in terms of a frequency interpretation of probability[212], i.e., the frequentist probability of some event of type *x* occurring is the number of occurrences of *x* in a set divided by the total of set members. As this frequentist probability is time-laden due to it being in terms of the occurrence of an event, let's eliminate this component: the probability of some event of type *x* is the number of occurrences of *x* in a set divided by the total of set members. This just amounts to statistical probability, but it seems to be assimilated into the Barbour picture easily: the probability of a configuration of the universe *c* is the number of occurrences of *c* in the heap of actualities divided by the total number c-space points in this heap. Thus, using this form of probability in conjunction with the existence of the heap of actualities, Barbour can account for probability without temporal concepts by correlating the higher probability of a c-space point with a higher number of existent copies of the c-space point: the more copies of a certain c-space point there is, the more probable that type of c-space point.

Furthermore, when cast in this fashion, 'probability' just seems here to be a static ratio of the number of a certain type of c-space points in a heap to the total number of c-space points. Because the 'probability' merely gives this ratio and doesn't provide any information about, e.g., the tendency of something to occur, it lacks the modal aspect that usually characterizes probability.

The other route is to suppose that only the heap of possibilities exits. If only the heap of possibilities exists, then how are we to understand probability without violating ONT? We cannot make recourse to statistical probability as above because the heap of possibilities contains only one copy of each possible c-space point. Because only one copy of each c-space point is there to be counted, each c-space point would have the same probability.

[212] See Papineau 2010 for a discussion of frequentism as well as propensity theory in the context of the Everettian interpretation. Also, for general discussion of frequentism, see Salmon 1977.

One option is to equate the higher probability of a c-space point with us experiencing the c-space point more often. By referencing our experience, it seems that we have to have some way of counting the number of times a c-space point is experienced. In a timeless c-space of possibilities, it is not clear how this would be done: given ONT, all the c-space points are simply given as being experienced where the c-space point has an experiencer.

An alternative option is to drop the experiencer and equate the higher probability of a c-space point with the fact that it occurs more often. However, this 'occurring more often' seems to presuppose that there are a number of times in which the universe is in a certain configuration. This, again, is in violation of ONT. To make sense of this, we have to assume that the universe adopts the configurations of certain c-space points, with some c-space points being adopted more often than others. However, this picture seems to presuppose some temporal concepts: it seems to assume that the universe traces some path through c-space to effectively create a set of 'realized' c-space points that may be deemed its temporal history. If only the heap of possibilities exist and the universe, in accord with ONT, does not trace some path through c-space to effectively create a set of 'realized' c-space points that may be deemed its temporal history, then there exists only the c-space points of the heap of possibilities to be counted. As there is only one copy of each c-space point, each corresponds to the same probability.

However, this second option might be modified by recourse to propensity theory[213] which would allow for a timeless account of probability that does not require, e.g., the universe to trace out paths in the heap of actualities. Usually in propensity theory, a probability is understood as a propensity, i.e., a physical property or disposition, of a certain physical situation to yield an outcome of a certain kind. As the yielding of a certain outcome seems to assume that there is a temporal sequence of events, we have to choose something thing that may be 'yielded' non-temporally. So, let's take 'certain physical situation' to refer to the heap of possibilities and replace 'to yield an outcome of a certain kind' with 'to be indicative of which possible c-space points and the number of copies of these c-space points are in the heap of actualities'. As we are assuming that only the heap of possibilities exists, the heap of actualities may be thought of as a mathematical tool or metaphor here. So, the

[213] For discussions of propensity theory generally, see Benlap 2007. See Eagle 2004 for criticism.

propensity account in this context claims that the probability of a c-space point is the propensity of the heap of possibilities to be indicative of the number of copies of that c-space point in the heap of actualities. To visualize how this may work, let's make recourse to the mist analogy: like the frozen mist of different intensities across the heap of possibilities, the heap of possibilities has a propensity field that assigns certain c-space points a propensity with some propensities being of a higher weight than others.

Suppose that we can make sense of propensity fields and that this account is not circular, i.e., the *probability* of a c-space point is the propensity of the heap of possibilities to be indicative of the number of copies of that c-space point in the heap of actualities and this number correlates to the *probability* of a c-space point that arises from a solution to the WDE. This setup, however, does not offer much of an explanation of probability. Rather it is precisely this issue, i.e., what does it mean to say that there are more copies of a certain configuration in the heap of actualities, that needs to be analysed.[214] Additionally, even if there is a more explanatorily viable propensity formulation of his account, Barbour will still have difficulty assimilating these propensities qua physical properties or dispositions. Given ONT, propensities must be reducible to stuff and their relations. It seems that Barbour may be able to derive the *values* for the weights of such propensities from his c-space points and the WDE. However, the existence of propensities *simpliciter* seems to be part of accepting the propensity theory. As, by definition, such propensities exist, Barbour cannot accept this account without violating ONT.

So, as it is difficult to make sense of probability in Barbour's account using an existent heap of possibilities alone such that ONT is satisfied, it seems that statistical probability combined with an existing heap of actualities is the only viable option of those considered above.

Moreover, in view of this discussion, we can return to the question raised at the end of §1.3: Are the number of heaps merely representative of the probability of us being in a certain c-space point or, rather than being only metaphorical, does the heap of actualities,

[214] See Hitchcock 2002 for general objections to propensity theory along this line that propensities do not really offer an explanation of probability.

which contains multiple copies of certain points, actually exist? Because it does not seem possible for Barbour to hold that only the heap of possibilities exists without importing temporal concepts and irreducible properties into his account of probability and, thus, violate ONT, it appears that he must claim that the heap of actualities exists and that the WDE's 'probability' is just a ratio indicating the number of existing copies of a particular c-space point.

2.1.1.2 The Problem of Personal Identity

A specific problem of personal identity arises in the many-worlds Everettian interpretation. At each branching, a world splits into a number of different worlds. This implies that an observer at a branching world can have a successor in each of the branched worlds. Because each successor can claim spatiotemporal contiguity with the observer, how can it be determined which successor is the same person as the observer?[215]

This problem cuts even deeper for Barbour. He has no basic spatiotemporal contiguity connecting c-space points. There is no time linking them or an order of the c-space points. Instead, the heap of actualities just exists statically. So, as there's no time, it does not seem as though Barbour could accept a notion of personal identity that, as usually conceived, is across time. Could we have a spatial link by appealing to some sort of best-matching among the points, e.g., the c-space point in which you seem to be in now is best-matched with the c-space point in which you are reading the next sentence? Such a spatial link does not seem possible. Because there can be multiple copies of a single configuration of the universe, both the configurations involved in the best-matching procedure may each correspond to a number of distinct c-space points. In effect, even with best-matching, no specific c-space point may be picked out as the spatially next point. And, no specific point may be picked out as the spatially prior point. In effect, one only seems able, by Barbour's

[215] This can be considered a case of fission, and such cases are widely discussed generally in philosophical personal identity literature, e.g., Parfit's 1971 example of an organism that literally undergoes fission, cases in which one's brain is removed, divided and successfully transplanted into two different bodies. See Saunders and Wallace 2008 for a good discussion of Parfit's fission case generally as well as evaluation within the Everettian context.

account[216], to identify the point one is experiencing.[217] Assuming that there are multiple copies of such points in the heap of actualities, there are no unique spatial links between the point one is experiencing and another c-space point. So, it seems as though Barbour has to deny that there is some trans-c-space point notion of personal identity that relies on unique spatial or temporal contiguity.[218]

2.1.1.3 The Issue of Measurement

In §3.3 of the previous chapter, the issue was raised as to how Barbour deals with measurement. As was mentioned there, because typical lab measurements are processes and, thus, usually involve a temporally ordered succession of events, Barbour needs to either create a timeless concept of measurement or eliminate this concept strictly speaking. I made reference to a quote that suggests Barbour opts for the latter with the promise that I would provide a fuller discussion of it here. Here is the quote in context:

> I merely wish to connect the 'internal' and 'external' interpretations of a timeless universal wavefunction. In the latter, we suppose a divine mathematician who actualizes (by random selection) one configuration of the universe and can then examine it in its entirety. In the former, it is as if we are inside part of that [c-space point] and have direct awareness of that part as an experienced instant [or c-space point?]. The [c-space point] is actualized for us; we are powerless to bring it into being. However, experiencing it, we are effectively in the same position as the divine mathematician except that we can only see part of the configuration. The nature of

[216] He (1994b, 2883) also seems to make this claim directly: By analogy with Descartes's *Cogito ergo sum*, we know that the present instant is actualized. However, because we can never step out of the present instant, we can never know if any other instant is actually experienced.

[217] However, in view of (what appears to be) our day-to-day experience, which seems to be extended far beyond the present instant, it seems that we are capable of experiencing much more than a single c-space point. I return to and discuss this issue in Ch6.

[218] There is some precedence for such an account. Lockwood 1996 develops a many minds version of the Everttian interpretation in which there is no transtemporal identity of minds. See Loewer 1996 and Papineau 1996 for criticism.

> what we see must be of the same kind, for otherwise experience would never give any reliable information about the conjectured external world. Incidentally, I believe that the division of quantum mechanics is alleged to make between the measurer and the measured, or the observer and the observed is non-existent. When the moment of truth is there (in each and every actualized [c-space point]), we do not measure, *we experience*, and what we experience is an indivisible whole. (1994b, 2883)

Before moving to a discussion of this passage and measurement, I want to note that I have replaced ‘instant’ above with ‘c-space point’. Though he equates the two, it is not entirely clear whether the second occurrence of ‘instant’ above should be equated to ‘c-space point’ as it could be in reference to our experience in what we perceive to be an instant, i.e., it might refer to some version of the specious present. However, as my aim in this chapter is just to explicate his account, I am going to bracket off this possible equivocation here. But, I will return to this issue in the next chapter.

With his claims that ‘we do not measure, we experience, and what we experience is an indivisible whole’, it seems that, strictly speaking, measurement is not possible. Instead, he claims, we experience an indivisible whole. Preceding these claims, he compares a divine mathematician who is examining externally a single c-space point with our experience of part of the c-space point internally. Unlike the mathematician, we are ‘powerless to bring this c-space point into being’. However, he claims that what we see must be the same as what the divine mathematician sees in some sense.

There seems to be two senses in which these experiences are the same in view of the above passage. First, with the claim, “The nature of what we see must be of the same kind, for otherwise experience would never give any reliable information about the conjectured external world,” it seems that Barbour is making a correlation between what we experience and what stuff and relations are actually in the world. What we experience in an instant must be in at least indicative of what the divine mathematician sees, which presumably is the c-space point's stuff and arrangement. So, both we and the mathematician must 'see' at least some of the configurations of stuff in the c-space point that is being experienced.[219]

Second, both we and the mathematician experience 'an indivisible whole'. Unpacking this experience of 'an indivisible whole' shed some light on his position on measurement. Though it may be made in the context of standard QT, where a distinction is drawn between the measurer and measured due to the collapse of the wavefunction when a system is measured, it implies much broader claims about the general stance Barbour must take on all measurement. It is these broader claims that I am interested in here since he has already rejected collapse for other reasons.

A time capsule in a particular instant suggests that we do make measurements. For example, we read the pointer of a device and we seem to remember putting an experiment involving that device into action. But, such time capsules are really just part of a c-space point, e.g., the neural time capsule corresponding to stills of our memories of starting an experiment. So, we do not actually make such measurements. Instead, we are just experiencing a single c-space point's configurations, e.g., the position of a device's pointer, the memories corresponding to configurations of our neurons. In effect, there is no distinction between a measurer and measuree: both are just stuff in a c-space point in a relation R. As long as R is nothing over and above the relative relations of stuff in a particular c-space point, then a measurement process and any substantial division between a measurer and measuree are reducible to the stuff and relations. Assuming that we cannot divide c-space points into, e.g., subsystems, via stuff and their relations alone and because a possible measurer/measure division is reducible to stuff and relations, this supposed division

[219] This point warrants a brief note on Barbour's realism, i.e., realism (roughly, a view that holds that there is an external world that causes our perceptions) in the literature on perception that serves as the foil for idealism (roughly, a view according to which ideas are the direct objects of perception and denies that there are mind-independent material objects), is required for clarification. In this quote as well as throughout his writings on time capsules, Barbour seems to presuppose that the configurations to which our brain states correspond somehow with actual world. While he does not specify his opinions on various types of realism, he (1999, 255), in giving one of the aims of his cosmological account, does state that his theory is realist in the sense that it is non-solipsistic, claims that other sentient beings exist and uses the structures of "external, objectively existing real" things to explain the structure of experience in a "perceptual instant."

gives us no means to divide c-space points. In effect, rather than a measurer/measuree division implying that there are subdivisions in a c-space point, we must, strictly speaking, experience a c-space point as ‘an indivisible whole’.

With the above example, we have seen how a process involved in a generic lab experiment can be made reducible the stuff and relations of a single c-space point. Such a measurement involves a process and, in effect, is a temporally extended activity. How can Barbour deal with a measurement that does not involve such a process? Consider the case in which this you experience this configuration in a c-space point: the edge of a ruler is placed on a piece of wood, and the piece of wood extends from the end of the ruler to the mark that reads ‘1cm’. It seems that if this case is presented to you, you are measuring that the piece of wood is 1cm wide. Any background knowledge needed, e.g., how to read a ruler, could be part of your neural configuration in this c-space point. In effect, this measurement also seems to be reducible to the stuff in a c-space point and their relations. Thus, even in the case of measurement that does not involve much of a process, Barbour can claim that, strictly, there is no measurement; there are only stuff and relations.

So, in line with ONT and given his account of time capsules, it seems that Barbour can deny that there is measurement qua result of a process and qua simple reading of a measuring apparatus.

Now that we have addressed those Everettian problems dealing with experience, let’s return to the second stage in Barbour’s three-stage means of explaining away the appearance of time.

2.2 The Mott Problem: Motivation for the Probability Density Being Higher on C-Space Points with Time Capsules

In the process of answering our previous question, i.e., Why does one usually seem to have a brain configuration that is a time capsule?, and in order to provide some account of histories, Barbour makes recourse to Mott’s (1929) and Heisenberg’s (1930) explanation of why alpha particles form straight lines in cloud chambers. This brings us to the second stage of Barbour’s account of our experience of time. In this stage he provides the above case as an example that shows that wavefunctions satisfying timeless equations *can* be concentrated on time capsules and that the appearance of a classical history can result from such a setup.

In the final stage, he returns to the WDE and provides some rationale for the generic concentration of its solutions on time capsules. Further, note that Barbour (1999, 307) claims that much of the inferences he makes below are speculative. So, though the following may not have the same rigor as the preceding, it does provide a means of explaining away time that has some sort of precedent.

The phenomenon that Mott and Heisenberg attempted to explain is as follows. To observe alpha particles, one can use a Wilson cloud chamber. Alpha particles are observable there via their interactions with atoms: such particles dislodge atoms’ electrons and, thereby ionize the neutral atoms rendering them positively charged. This excess positive charge causes vapour condensation around them and, thus, makes alpha particle tracks visible.

Suppose one uses a radium (Ra) atom as a source of alpha particles in the cloud chamber. According to Gamow’s 1928 theory of alpha decay, one would expect an alpha particle that is emitted from the Ra atom to have a spherical wavefunction and, thus, cause random atoms throughout the cloud chamber to be ionized. However, this effect does not occur. Instead, a linear track from the Ra atom is observed.

Mott offers an explanation of this behaviour by appealing to a configuration space and a TISE. He (1929, 80) does so by first assuming that the nuclei of the atoms in the cloud chamber are effectively at rest during the formation of a track. Nuclei are treated as effectively at rest, while alpha particles are governed by TISE. A configuration in which there is a nucleus without neighbouring electrons is interpreted as an excited nucleus. The conclusion that Mott attempts to come to is that the probability distribution of a solution to TISE is concentrated on configuration space points in which there are nuclei without electrons aligned.

He reaches this conclusion by, as Barbour (1999, 310) describes it, “a kind of book keeping record about how the process would unfold in time.” He starts by making some assumptions: there are outgoing spherical waves that radiate from the Ra atom, and only outgoing waves from the Ra atom can be used**.** He (1929, 80) makes this latter assumption “[t]o obtain a consistent theory of the straight tracks.” After stating these assumptions, he considers a case in which there are only two hydrogen atoms, which are in line along a mathematical radii from the Ra atom, in the chamber. He (1929, 81) formulates a TISE to describe this system, and proceeds to solve it by making only configurations in which there are linear paths of excited alphas particles probable via focusing the probability distribution on these two cases and generalizing them. In the first case, the atom nearest the Ra atom is excited, and the scattered waved of the alpha particle is concentrated in a narrow beam pointing away from the Ra atom. In the second case, both atoms are excited, and the scattered wave is concentrated in a narrow beam that is emanating from the outermost atom and pointing away from the Ra atom. Thus, Mott performs ‘bookkeeping’ in order to solve the problem: he reaches the desired solution by, so to speak, tallying up the probabilities of those tracks that correspond with the observed tracks and making the probabilities associated with all other configurations null.

As a result of this procedure, the probability distribution that Mott obtained is concentrated on configuration space points that contain electronless nuclei. As these static points seem to indicate that there was a prior history leading up to the configuration, e.g., a series of alpha particles was emitted from the Ra atom and ionized atoms in a certain linear track, Barbour claims that such points are examples of time capsules. Further, because the resulting solution to TISE, which, like the WDE, involves no time parameter, has a probability distribution that is concentrated on configurations with time capsules, he speculates that the same might be true for a solution to the WDE.

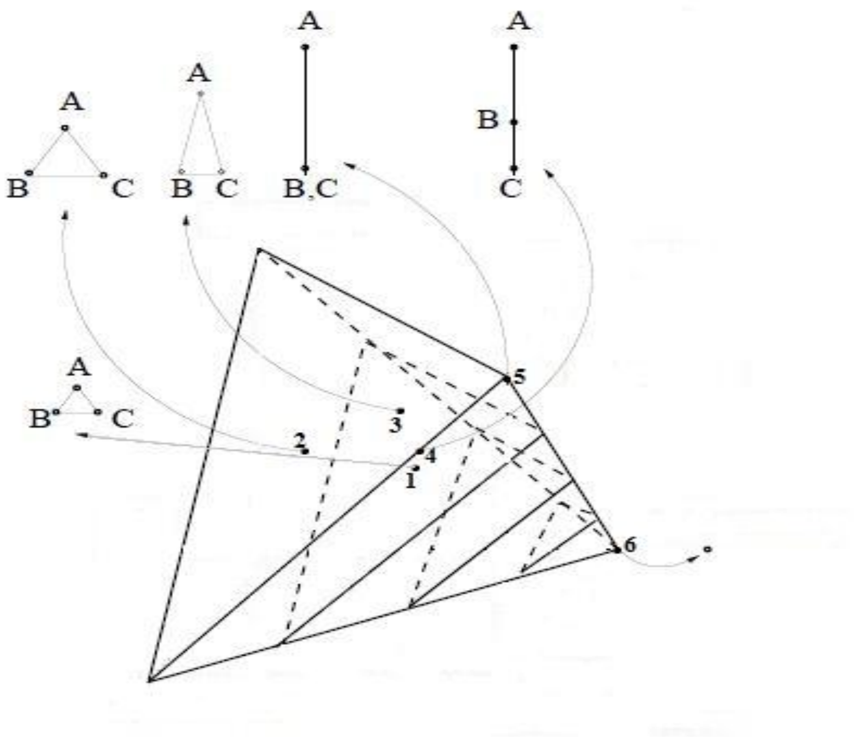
He admits that this speculation is based on rather shaky foundations, e.g., Mott’s solution is not actually derived given the ‘bookkeeping’ approach, it is semiclassical as interaction between the alpha particle and nuclei are omitted from the calculation and, as Barbour claims, Mott made an assumption about the direction of time, which is presented in the next section, in order to get his results to match the experienced linear paths. Nevertheless, he proceeds to make some further speculations as to how some of the assumptions used in Mott’s solution could be applied to c-space and the WDE. Such speculations form the next and final stage of Barbour’s attempt to explain our temporal experience.

2.3 The Relation between Solutions to the WDE and Time Capsules

There are two assumptions made by Mott for which Barbour (1994b, 2891ff) attempts to find analogues in his QG.

First, the Ra atom is assumed to play a distinguished role and has a definite position. The Ra atom functions as an origin from which the outgoing waves are emitted. Because it is from this setup that Mott generates his TISE that favours time capsules, Barbour attempts to put his c-space in a form in which there's an analogue of the distinguished Ra atom. He claims that his c-space has a stratified manifold. Such a manifold is a collection of manifolds, where each manifold has a different dimension; roughly speaking, an *n*-dimensional stratified manifold is built by decomposing an *n*-dimensional manifold into disjoint smooth manifolds. Each of these decomposed manifolds are of h dimensions, where h is a real number and $0 \leq h \leq n$.[220]

Anderson (2004, 6) provides this very clear illustration of the stratified manifold that Barbour associates with a case in which there are only three point particles in the universe that are in Euclidean space. I have modified this figure, removing some details not relevant here.



[220] For further details on stratified manifolds in the context of geometrodynamics, see Fischer 1986 and Giulini 2009.

This space has an origin labelled by point 6, and it extends to the left to infinity. To distinguish the particles in configurations, they are labelled with ‘A’, ‘B’ and ‘C’. The volume inside the boundary represents all possible 3-d configurations of the particles, e.g., those configurations that correspond to points 1, 2 and 3. Points on the triangular faces, e.g., point 4 representing a configuration with three particles on a straight line, are 2-d, and points on the vertexes, e.g., 5 representing a configuration where two particles coincide, are 1-d. The origin at point 6 is the point where all three particles coincide and is 0-d. Though he admits that this picture would be much more complicated for cases in which a higher number of dimensions are required, Barbour (1994b, 2892) claims that it shows the most characteristic features of stratified c-space.[221]

He (1994b, 2893) speculates that the origin of this manifold can function somehow like Mott’s distinguished Ra atom. With the above stratification, c-space is asymmetrical and, in effect, features the origin as a distinguished point.

Note that in order to avoid a violation of ONT, this asymmetry must arise due to the c-space points. This claim can be supported by the manner in which the stratified manifold is built. It is the dimensions associated with the configurations of particular c-space points that determine how the manifold is decomposed. Plus, the space is organized in terms of congruence and symmetry of the c-space points. If you draw a ray from the origin to the left within the boundaries, the series of c-space points on that line is related in terms of being congruent to the other points on that ray. Additionally, if you take a slice of it, the point in the centre of the slice represents the most symmetric configuration, i.e., is an equilateral triangle, and the symmetry of configurations represented by the points decreases as one moves out from the centre.[222] Because these relations of congruence and symmetry can be cashed out in terms of the relative spatial relations of the c-space points, this structure does

---

[221] See note200 above for other complications with the stratified superspace needed in his QG. However, this model will be sufficient for our discussion and analysis of its role in Barbour’s account as, he quite rightly states, it highlights the features characteristic of a stratified c-space.

[222] See Fischer 1969 for an introduction to stratified superspace.

not violate ONT. So, it seems that it is the particular 3-geometries of the c-space points that give rise to this structure; this structure may be constructed from the relative relations in the c-space points. Thus, Barbour's claim that the c-space points give rise to the asymmetry seems vindicated. Moreover, as based on the stuff and relations of c-space points, it seems *prima facie* that ONT is satisfied. However, note that we examine in more detail whether such a structure actually does violate ONT in the next chapter. But, for the present expository purposes, let's assume that ONT is upheld in this case.

Second, it is assumed that outgoing waves are to be used consistently in obtaining Mott's result. If Mott had, e.g., chosen an incoming wave at any stage, a linear path would not result. So, Barbour (1994b, 2894) claims that this assumption is required in order for there to be the "sharply focused time capsules" that are created in the Mott solution. In effect, the sole use of outgoing waves was to obtain the resulting focus on configurations containing time capsules. This suggests that Mott imposed an arrow of time onto the case, and he did so regularly: he only applied outgoing waves in order to get the favoured c-space points to contain the apparent histories that are usually experienced.

Barbour suggests that we believe there to be an arrow of time because it is encoded in time capsules, e.g., one only seems to experience an arrow of time because the configuration of one's neurons indicates that one experienced some previous c-space points but has no experience of c-space points that would follow it. In turn, he attempts to mirror Mott's imposition of an arrow of time by proposing a manner in which the stratified c-space may concentrate the probability distribution on c-space points with arrow-suggesting time capsules. He reasons as follows. Stratified c-space is asymmetrical. It is due to this asymmetry that "the wavefunction is 'funnelled' onto time capsules" (1999, 308). Though how exactly this funnelling occurs in static c-space is not developed, he notes that, despite the lack of such development, the analogues of Mott's assumptions in a stratified c-space at least indicate the manner in which a higher probability distribution on time capsules requires neither time nor a special initial condition. If these speculations can be developed, then a stratified c-space is all that is required.

Furthermore, he (1994b, 2894) tries to mimic the regularity of Mott's choice by suggesting that the origin "sitting as it does at the centre of a hierarchical system of frontiers, is likely to impose strong regularity conditions on Ψ." He hopes that the structure of the stratified manifold forces perturbations outward and away from the origin in a regular fashion such that the resulting probability distribution is regularly on points with arrow-suggestive time capsules. But, other than this hope, this is the extent to which he develops a means of accounting for the regularity of our experiencing an arrow of time.

Though this final stage has been very speculative and remains largely undeveloped by Middle Barbour[223], I present them here in order to illustrate the fashion in which Barbour envisions the topological structure of all possible c-space points to function. As is discussed in the next chapter, it is unclear whether a structured heap of possibilities can play these roles without violating ONT or conflicting with other components of his theory.

To sum up, his Machian QG aims to solve the problem of time in a manner that is in accord with ONT and MP: he provides an interpretation in which there are no fundamental temporal features. Thus, the apparent lack of a time parameter in the WDE, which is supposed to describe evolution, is not a problem at all because it is not the case that it describes an evolving system. Instead, on his interpretation it seems that the WDE indicates which c-space points make up the heap of actualities, which just exists statically in its entirety.

---

[223] Anderson 2009, though, suggests some means of developing this account by, e.g., combining Barbour's QG with a semiclassical approach. Additionally, Barbour's 2011 website states that he and Anderson are in the process of developing such an account; however, he does not offer details about it. Moreover, Halliwell 2000 offers a formal development of Barbour's suggestion of using Mott's solution in this context. However, Halliwell's development largely mirrors that of Mott's bookkeeping approach. As such, it does not make use of the topography of Barbour's possible c-space but, instead, assumes that there are histories and that the probability distribution is concentrated only on such histories. So, Halliwell's approach starts by assuming that there are such histories, rather than providing some means of deriving them from the possible c-space's topology; it does not offer much insight into the manner in which such histories may emerge of possible c-space. Nevertheless, given that Barbour speculates that the structure of this space does the work in 'funnelling' probability distributions and does not have an explicit account of exactly how histories may emerge from this structure, our discussion in Ch6 will explore the general question of whether possible c-space can be used as a means of determining emergent histories by examining whether such use is compatible with Barbour's other ontological and metaphysics commitments.

In turn, he provides an interpretation of the WDE that mirrors his interpretation of TISE. Again, c-space points are the fundamental components of his interpretation. However, here, instead of being in terms of only medium-sized dry goods and their relative relations, c-space points are supposed to be 3-geometries. Moreover, he makes recourse to GR's structured c-space consisting of the set of all possible 3-geometries, rather than QT's heap of possibilities, and a heap of actualities such that the square of a solution to the WDE is the probability density for finding certain 3-geometries. This density is likened to a mist that has different intensities over the structured possible c-space. Like that of TISE, this density indicates the number of copies of a particular c-space point that there is in the heap of actualities. In order to fulfil ONT, it was argued that the heap of actualities must exist and that the distribution given merely amounts to a static ratio that reflects that number of copies of a particular 3-geometry in the heap of actualities.

Moreover, the heap of actualities does not have any particular successive relations among the 3-geometries in it. Instead, the heap of actualized 3-geometries just statically exists with no sequential connections. Due to the lack of such connections, Barbour attempts to explain our apparent experience of duration and motion as well as the fact that our apparent memories and present experience of artefacts, e.g., footprints in the snow, are indicative of there being a certain past series of c-space points. To accomplish this, he uses time capsules, which are certain configurations of a c-space point that indicate an apparent past process occurred in accordance with certain laws. These time capsules can be in the form of perceived artefacts as well as neural configurations. Such instantaneous neural configurations, Barbour claims, encode 'six or seven' static stills that are given in an order. In accord with ONT, this order, rather than being indicative of a fundamental temporal succession, can be regarded as an ordering in terms of relative spatial relations along the lines of that involved in best-matching. It is from our interpretation of these stills that we seem to experience a duration, rather than an instantaneous c-space point, and motion. Additionally, he claims that such interpretation is also the origin of our concepts of temporal order and the arrow of time. However, this setup and lack of connection among c-space points appears to entail a very restricted account of personal identity: there seems to be no trans-c-space-point notion of personal identity in the offing.

Nevertheless, given that ‘we’ ‘usually’ experience time capsules, Barbour feels obliged to provide some explanation in terms of indicating why the WDE’s probability density may be higher on c-space points with time capsules. Making parallels with Mott’s solution, he speculatively reasons that the wavefunction is somehow ‘funnelled’ onto c-space points with time capsules because of the asymmetrical structured set of all possible c-space points. However, though the construction of this space seems to be in accord with MP, the use of this supposedly representational space for this purpose may be in violation of ONT.

Now that we have all the components of Barbour’s account and have attempted to present them as parts of a single Machian network by highlighting and drawing out the primacy of his relationist principles in his GR, QT and QG in Chapters 2-5, let’s turn to applying the remaining stages of ACA to this network.

Chapter 6: The Application of ACA to Barbour's Account

With Barbour's accounts of GR, QT and QG at hand, we have completed ACA's initial requirement of spelling out the theories involved. Additionally, in the process we treated them as parts of a single Machian network by highlighting the manner in which his Machian principles are or can be fulfilled in each of the accounts. Thus, we have treated them as part of a single network in accord with ACA. However, as noted in Ch1's presentation of ACA, even though we have treated the accounts as components of a single network, such components may initially lack connections among each other. Yet, at least metaphysical connections may be developed over the course of subsequent analysis of the network. Let's turn to such analysis and, thus, the application of ACA's other steps.

Because this chapter is organized in terms of the steps of ACA proposed in Ch1, it is worthwhile summarizing all of its steps here and relating them to the content of this and previous chapters.

According to ACA, we first obtain the theories that we are considering. For folk theories, this is accomplished by using experiential and nonexperiential, i.e., *a priori*, intuitions about possible cases to construct a folk theory by means of armchair analysis. For scientific theories, this is accomplished by reference to the theory's interpretation, which is often largely given.

Further, if more than one theory is being analysed, ACA dictates that they are to be treated as a single network. The previous chapters have served to treat Barbour's GR, QT and QG as parts of a single Machian network by utilizing his principles as the overarching criteria for their development. Furthermore, over the course of presenting and discussing Barbour's treatment of our experience of time in Ch5, a partial Machian folk theory of time emerged. I describe it as 'partial' because our, following Barbour's, focus in Ch5 was on reconciling some features of our temporal experience with his Machian QG interpretation, rather than on giving a comprehensive account of our experience of time. In turn, I develop his folk QG account in the next section so that we may better explore the role of time in it and its compatibility with *time* in other parts of the network. Additionally, it does not seem to be evident that Barbour is aware of the impact of his QG and ONT on personal identity. In effect, the resulting features of his Machian folk time need to be integrated. We turn to such integration in this chapter by applying the remaining stages of ACA to *time* in his entire Machian network that resulted from the discussion in Chapters 2-5. So, in this chapter we begin with the following stage of ACA.

The next stage in ACA is the determination of what role *time* plays in the network. To do so, first initially identify *time* by appealing to what appears to be the temporal roles in the network. In this preliminary identification of *time,* use the structure of the propositions made in the theories and/or the role that temporal variables play.

In order to avoid the problem of naïve realism, we proceed to determine whether components of the role clash, are redundant or are irrelevant, with each other as well as with other concepts in the theory. If the role exhibits no such conflicts, incoherency or redundancy, then we accept this role and identify it with *time*. On the other hand, if the role exhibits such conflicts, incoherency or redundancy, then we must 'engage in metaphysics'. Recall from Ch1 that Jackson characterized such metaphysics' aim as the creation of a list of what there is that is coherent, complete and parsimonious. If the concept is completely redundant, then one can eliminate it from such a list relatively easily. However, barring this result, 'engaging in metaphysics' involves either the construction of a coherent, relevant and non-redundant *time* or the reduction of its role to those played by other elements in the network. Further note that in Ch1, other than stating that it may possibly involve re-examining metaphysical assumptions and roles of other concepts in the theory, the exact nature of this engaging in metaphysics was left rather vague. But, it is intended that such engagement can at least be exemplified in the application of these latter steps of ACA to Barbour's network in this chapter.

With our Machian network at hand, let's proceed to apply the remaining steps of ACA. First, we must determine what role *time* plays in this network. To do so, we first initially identify it by appealing to its apparent role in propositions made in the network and the role of temporal variables. This is accomplished in §1. In §2, four main clashes are identified among the roles that *time* plays in the parts of the network. Then in §3, I 'engage in metaphysics' in order to resolve two of these clashes. These particular two clashes are selected due to their central role in Barbour's account of QG and, thus, that feature in his solution of the problem of time. Additionally, in the next chapter's general discussion concerning ACA, I address the possible schematization of 'engaging in metaphysics' as well as its scope in view of my attempt of resolving the two clashes. Finally, in §4 I sum up the ramifications of our application of ACA to Barbour's accounts and present the most promising ways of resolving these issues. While this chapter focuses largely on the application of ACA to Barbour's accounts, I discuss the applicability and extension of ACA to non-Barbouric accounts in the final chapter.

1 The Initial Identification of *Time* in Barbour's Network

Recall in Ch1 that I assumed that a concept can be complex. A complex concept is composed of sets of features, and these features are themselves concepts. Upon the examination of the Machian network, *time* in this network is such a complex concept: it can be broken down into four main subconcepts. In effect, I have identified four main temporal roles that *time* plays in this network: the infinitesimal instant role, the static existence role, the arbitrary parameter role of the time variable and the derivate temporally ordered succession role. Before explaining what these roles are, I, following Jackson's above suggestion to create a list, present a table that specifies what plays each of these temporal roles in all parts of the Machian network. In addition to illustrating the manner in which each part of the network exhibits these roles, this table serves the purpose of making salient conflicts, incoherencies and redundancies, of these roles across the network.

	Nonrelativistic Machian Dynamics	Machian GR	Machian QT	Machian QG	Machian Folk Theory (assuming QG)
Infinitesimal Instant Role	C-space points: instantaneous configurations of particles in the universe.	C-space points: instantaneous 3-geometries of the universe.	C-space points: instantaneous configurations of all medium-sized dry goods of the universe.	C-space points: instantaneous 3-geometries of the universe.	Time capsules: instantaneous configurations that are indicative of there being past processes.
Static Existence Role	Best-matching c-space points that are a solution to the BMP.	Best-matching c-space points from a solution to the BSW and the best-matching c-space points of all foliations of the constructed space.	The points in the heap of actualities, which are indicated by a squared solution to TISE.	The points in the heap of actualities, which are indicated by a squared solution to the WDE.	You at a c-space point, despite the appearance of motion, duration and a specious present with length.
Arbitrary Parameter Role of the Time Variable	A single monotonically increasing parameter that is applied to horizontally stacked best-matching c-space points such that each c-space point is assigned a single value.	In BSW: indicates instantaneous ‘velocity’ of a 3-geometry. In proper time: monotonically increasing parameter that is assigned to each set of equilocal points; each one does not necessarily register the same value.	None.	None.	N/A
Derivate Temporally Ordered Succession Role	The values of the time parameter associated with the c-space points of a horizontal stack, which is ordered and successive in virtue of relative spatial relations.	The values of a local time parameter associated with the equilocal points of a horizontal stack, which is ordered and successive in virtue of relative relations.	No such role is recovered: there are no ordering or successive relations among c-space points generated by a solution to TISE.	No such role is recovered: there are no ordering or successive relations among c-space points generated by a solution to the WDE.	There is no such role: experience indicative of the role is only apparent via six neurally encoded ordered ‘stills’. Plus, ‘identity over time’ is restricted to one c-space pt.

In order to explain the table, I explain each general role and make comments where necessary about the manner in which GR, QT and QG play the role. Discussion of the manner in which the thing that plays a role in one column conflicts with that of another is provided in §2. In contrast, §1.1 only serves to present the table and, thus, identify the surface roles of *time* across the network.

However, in order to provide a fuller exposition of the folk column, it is also required that I spell out this section a bit more in §1.2. Because I was more concerned in earlier chapters with presenting Barbour's physical theories and pounding them into a single network that fulfils ONT and MP, I did not there develop Barbour's folk account much. So, before pointing out conflicts in the table in the next section, I develop his folk account by providing a few options for his account of our experience of time that are drawn from some categories presented by Dainton. Note, however, in the remainder of §1 I only discuss options for Barbour's account of our experience of motion at a single instant. In §2 and §3, in which I point out a conflict that arises due to his QG's lack of histories and our apparent experience, which seems to have a temporal extension much longer than that corresponding to 6-7 stills encoded in our instantaneous brain configuration at a single c-space point, I examine the plausibility of extending these options to the case in which our apparent lifetimes' worth of experiences are limited to a single instant.

So, in the remainder of §1, I first turn to commenting on each row of the table with respect to the non-folk columns. Then, I present some options for specific claims in the folk column.

1.1 The Roles and GR, QT and QG

The first role presented on the table is the infinitesimal instant role. This role arises from Barbour's characterization of c-space points as instantaneous 'snap shots' or 'instants' of the universe. It seems that such snap shots must have only infinitesimal temporal length in the sense that they are presented as, e.g., hyperslices.[224] Furthermore, because these c-space

[224] However, one may argue that at least in QG, these 'instants' must be of Planck length because the canonical quantization procedure involves quantizing the 3-metric. In effect, these 'instantaneous' 3-metrics actually have a length of around 10^{-43} seconds. But, because Barbour does not make this suggestion and since this length is much too small to have an impact on our day-to-day experience, I follow Barbour in regarding these instants as

points play an ontologically basic role in his account, it seems that he accepts that *time* can refer to the temporal extension, even though infinitesimal, of these c-space points. Additionally, given his commitment to c-space points as only having such infinitesimal temporal extension, it appears that a time capsule must also only have infinitesimal temporal extension. We'll return to discussing whether this depiction of time capsules is problematic for Barbour's folk theory in the next main section.

The second role is that of static existence. If something plays the role of static existence, then all of it co-exists and it does not undergo temporal becoming. To elucidate this role, consider a comparison with B-theory and A-theory. According to A-theory, there is an objective temporal becoming. B-theory, on the other hand, involves a denial of this claim. In effect, an example of a B-theory model is a 4-d block universe that exists in its entirety without involving temporal becoming. Because it does not undergo temporal becoming and all co-exists, the B-theorist's block universe provides an example of something that may play the role of static existence. So, static existence amounts to all of something or some group of things co-existing without there being any objective temporal becoming or passage. However, I must highlight that the block universe is merely an example of something that may play this role. The A-theory/B-theory debate usually presupposes that there is an ordered sequence at some level, e.g., the events of a statically existing block are sequentially ordered within the block. Since it seems that Barbour's heaps of actualities exist in a static fashion, i.e., the points in the heap co-exist and do not undergo temporal becoming, yet they lack a sequential order, I have formulated the static existence role such that it clearly does not entail or presuppose that the parts of a thing playing that role are in an ordered sequence.[225]

---

infinitesimal; whether they have a Planck length does not impact my discussion regarding our experience of time.

[225] There are some explicit definitions very similar to the content of the static existence role made in the context of the presentism debate, e.g., Hestevold and Carter's 2002 'static time', Zimmerman's 1996 ontological characterization of this debate. However, I have not made use of these definitions above because they, in addition to presupposing that there is a temporal sequence of events, involve claims about the manner in which objects exist over time as well as claims about the 'realness' of objects that do not presently exist, i.e., presentism can be formulated as holding claim that only present objects exist and are real and all non-present objects are unreal in some sense. Thus, I am using the above definition rather than similar definitions that appear in the presentism literature because I do not want to build these further presuppositions into the role or

In addition to the block universe's sequential order not being entailed by the static existence role, a feature of the manner in which the block universe's slices co-exist is also not entailed by the static existence role. It is usually presupposed by block universe advocates that such slices co-exist such that they do not overlap, i.e., there are not multiple time-slices superimposed at a particular slice of the block. However, as I delineate the static existence role, the role does not prohibit the overlapping of the components of something playing the role; the static existence role is silent as to whether there can be such relations among these components. The upshot of this discussion for something that plays the static existence role is that any components of such a thing must all exist statically, i.e., there is no objective temporal becoming, its components do not necessarily come in a sequential order and its components are not precluded from overlapping in some sense. Thus, the essential feature of the static existence role is its static nature, rather than it involving any sort of ordering or exclusivity relations.

Additionally, note that I have included 'you at a particular c-space point' as something that plays the static existence role under the Folk Theory column. Because, as was discussed in the previous chapter, it seems that personal identity for Barbour does not extend beyond a single c-space point, the you at a particular point must completely exist within that point. Moreover, because a c-space point itself is static and instantaneous, it does not seem that there can be any fundamental temporal becoming that occurs in a point. Thus, the you in a point statically exists: all of you co-exists in a c-space point and cannot undergo temporal becoming. However, note that this classification of 'you at a particular c-space point' as something with static existence relies on the claims that no history(s) is recoverable in QG and that personal identity is restricted to a single c-space point. In §3 below I discuss whether such claims are modifiable in QG and, thus, whether this classification is required.

The third role on the table is the arbitrary parameter role of the time variable. This comes from our surface reading of the equations. In order to be thorough, I have included the time parameter that appears in the relativistic BSW as well as the arbitrary time parameters that Barbour creates in the process of vertical stacking: the global monotonically increasing

make some sort of contrast with the contentious sense of 'unreal' that enters into the debate. See Dorato 2006a and 2006b for recent discussion of possible senses for 'real' as well as the role of 'existence' in this debate.

time parameter assigned to a nonrelativistic horizontal stack as well as the local time parameter assigned to local lapses in GR have been included. Moreover, TISE and WDE do not have an explicit time parameter and since Barbour does not attempt to recover one, they are listed as having nothing that plays this role.

The final role listed is that of the derivative temporally ordered succession. Because Barbour must fulfil ONT, all ordered successions must be, at base, in terms of stuff and their relative instantaneous spatial relations. However, in the cases of nonrelativistic dynamics and GR, Barbour offers what can be considered a means of recovering a temporally ordered succession from the spatially ordered successions generated by best-matching. In these cases, an ordered sequence in virtue of spatial relations is obtained via a horizontal stacking of the c-space points. Then, an arbitrary time parameter is assigned to all, i.e., to each c-space point in the nonrelativistic stack, or part, i.e., to each path among equilocal manifold points, of the stack. In effect, we can recover something that looks like a temporally ordered succession. However, *time* in this sense is only derivative from the spatially ordered sequences created by best-matching. Thus, there is this derivative temporally ordered succession role in his nonrelativistic dynamics and GR that is played by an arbitrary parameter assigned to horizontal stacks.

In QT and QG as presented in Chapters 4-5, however, there is nothing that plays this role.[226] Their respective equations only indicate that there exist a certain number of copies of a particular c-space point. As discussed in the previous chapter, it, in effect, does not seem as though TISE allows us to stack the heaps in an ordered succession in virtue of instantaneous relative spatial relations alone; such heaps have copies and, given PSR, we cannot choose which copy of a c-space point to put in a particular stack because there is no reason to choose including that copy rather than another. Without such a stack, it does not seem that we can obtain a derivative temporally ordered succession that is in accord with ONT. In effect, this

[226] Though I've largely argued that this claim seems to follow from his principles and interpretation of the WDE, for evidence of Barbour's explicit support of this claim, see, e.g., his (1999, 302) in which he sums up his view, though using metaphors, and thus asserts that there is no 'thread' connecting points of possible c-space. Moreover, whether a history or histories are recoverable at some level in QG given ONT is discussed in §3 below.

subconcept cannot have a referent in QT and QG: only heaps of c-space points exist, and there are no relations among the c-space points. Compare this lack of referent with the manner in which this role is played in GR. In GR, one can regard this subconcept as having a referent, namely the successive order that is generated by best-matching. Though, note that such a referent does not violate ONT. Here the derivative temporally ordered succession just refers to an ordered succession that is generated from stuff and their relative relations alone.

We can further stipulate that there is not intended to be a referent for *derivative temporally ordered succession* in the context of QG. This is due to the fact that Barbour feels the need to provide a means of explaining the origin of this concept. Recall that he does so via speculating that the asymmetrical structure of the space of the set of possible c-space points 'funnels' the wavefunction onto points that contain time capsules. In effect, he is using this asymmetry to explain the appearance of *derivative temporally ordered succession*, rather than attempting to reduce it to spatially derived relations among c-space points.

However, one may object to this depiction of this concept in QG. One may claim that Barbour does in fact have a referent for *derivative temporally ordered succession*: the relative configurations within a c-space that are time capsules. In a time capsule, there are certain static relative relations among stuff such that there seems to be a temporally ordered succession. For example, recall Barbour's explanation of our apparent motion. In that case, a configuration in our brain corresponds to six or seven ordered stills such that there appears to be a temporally ordered succession. However, this succession can be said to be derivative from the instantaneous configuration of our brain. In effect and contra the table's Folk Theory diagnosis of this role, time capsules can be regarded as the referent for *derivative temporally ordered succession*.

I reply to this objection on the grounds that it conflates *derivative temporally ordered succession* with the appearance of *derivative temporally ordered succession*. In GR, there is a set of stackable c-space points from which there is a spatial ordered succession. In this context *time* can refer to this spatial ordered succession. Yet, in a c-space point there is only a bunch of stuff and their instantaneous relative relations. I accept that time capsules are part of this set of instantaneous relative relations, but such time capsules merely give rise to the appearance of a temporally ordered succession. This apparent temporally ordered succession, e.g., a set of footprints indicative a person walking there in the past, the movement of an apple rolling off a table, does not correspond to there actually being a certain set of past events or to a series of events that seems to be contained in a specious present. Instead, in terms of the example, there is only the apple near the edge of the table and a perceiver with a certain brain configuration in the c-space point. In effect, the apparent *derivative temporally ordered succession* of the trajectory of the apple does not have a series of spatial ordered successive c-space points that serves as its reference. Rather, the time capsule serves as a means of eliminating a reference, i.e., there being a certain spatially ordered succession, that would correspond to such an apparent *derivative temporally ordered succession*.

Thus, there is not intended to be a referent for *derivative temporally ordered succession* in the context of QG. In the next section, we'll discuss the manner in which QG's lack of such a referent conflicts with the referent that QT has for this concept.

1.2 Options for QG's Folk Theory

In Ch5, Barbour gave an account of our experience such that he was able to explain away the appearance of motion and of there being a prior sequence of events given certain configurations in a single c-space point. Recall that to do so, he claimed that there are instantaneous configurations that contain certain structures that appear to indicate that there was a past, e.g., footprints in the snow, as well as instantaneous neural structures that 'encode' one's apparent experience of certain processes with a temporal duration, e.g., the motion of a bird in flight. Such configurations were termed 'time capsules'. Regarding the case of motion, Barbour claims that our seeing a bird in flight can be explained in terms of six or seven static stills that are encoded in our neural configuration at an instant. In effect, he offers some means of explaining the appearance of a specious present, i.e., the experiential or phenomenological present which seems to span a temporal interval[227], given that we are limited to a single brain configuration at a single c-space point. However, he offers no account of why we seem to experience a single and apparently linear sequence of events that extends well beyond what is contained in six or seven stills. As I point out in the next section, because histories do not seem to be recoverable, it seems that he must offer some explanation of our linear and temporal experience that appears to extend beyond a single specious present. Though I discuss some means by which Barbour may offer such an explanation in §3, I here focus only on presenting options by which his account of the specious present may be cashed out. In effect, I here elaborate on some options for developing a folk theory that incorporates Barbour's explicit claims about our experience of time, which is summarized by the first role on the table and the first statement of the fourth role under the folk column.

Barbour's account of our experience of the specious present requires that there only exist the stuff and relations in a single instantaneous c-space point. And, given ONT, no fundamental temporal relations can be introduced. There are two views in the literature that may meet these requirements. The first of these, retentionism, seems to be in line with ONT and the use of an instantaneous configuration from which one may generate the appearance of time without introducing fundamental temporal relations. The second option, a psycho-physical dualism, however, involves a dualism between physical and mental properties. If the stuff of ONT does not preclude mental properties, then Barbour can make recourse to it. We'll assume for the sake of discussion that ONT alone does not rule out the existence of such properties, though note that this may be contentious given Barbour's claim that such

[227] It may be helpful to follow Dainton's 2010 echoing of William James and contrast the specious present, which seems to have a brief duration such as to accommodate the change and persistence apparent in our immediate experience, e.g., the motion of an apple plummeting off the edge of a table, with what he terms 'the strict or mathematical present', which can be exemplified by one of Barbour's instantaneous c-space points. As is well known, James develops this notion of the specious present, but it is contentious as to how exactly it should be interpreted: for discussion see Grush 2008, Le Poidevin 2007, 2009, Dainton 2011. Nevertheless, the above characterization of it should be sufficient for our purposes of developing and examining Barbour's account of it.

stuff is ‘perceived variety’. I next present each of these views and highlight the manner in which they lack fundamental temporal relations.

1.2.1 Option 1: The Retentional Model

The retentional model[228] of the specious present seems to fit with Barbour’s account of our experience at a c-space point. In the retentional model, a specious present is not actually extended over time. Instead, it involves some momentary states of consciousness that only appear to be spread over time. In terms of Barbour’s suggestion, these ‘momentary states of consciousness’ may be put in terms of, e.g., the six or seven snapshots or stills that are encoded in our instantaneous brain configuration. In effect, the Barbouric retentional model posits that the motion that one seems to see in a particular c-space point is merely apparent and is a product of six or seven snapshots encoded in one’s brain. These snapshots occur simultaneously at that c-space point and, thus, only seem to be successive.[229] Given this characterization, the retentional model seems to be in line with ONT. No fundamental temporal relations have been introduced: the encoded snapshots all exist simultaneously and, in effect, do not require there to be a temporal interval corresponding to the apparent duration of the specious present. Moreover, the model is only fundamentally in terms of the stuff and instantaneous relative relations: it provides an account of the specious present given the configurations in a single c-space point using Barbour’s suggestion that one’s experience motion of in a c-space point corresponds to six or seven stills encoded by an instantaneous neural configuration.

Contrast this model with the two other main models of the specious present[230]: the cinematic model[231] and the extensional model[232]. According to the cinematic model, the

---

[228] For support of the retentional model see Broad 1938, Grush 2005, and for criticism see Dainton 2000, 2003.

[229] However, as Dainton (2011, 395) points out, the retentionist must provide some means of addressing this issue of how such a set of simultaneously occurring states is experienced as successive rather than as simultaneous. I consider such a mechanism at the end of this subsection and examine whether it may be used in the Machian QG context.

[230] These categories and the manner in which I have defined them above are delineated by Dainton 2010, 2011.

[231] For discussion of the cinematic model, see Le Poidevin 2007.

momentary experienced contents are momentary and static, e.g., one's immediate experience of an apple ¾ off the edge of a table in a c-space point consists of only the single snapshot of the apple in this position. In effect, one's momentary experience contains no perceived motion. In contrast, the retentionist model claims that the content of one's momentary experience does have a perceived temporal extension and, in effect, there can be apparent motion. This contrast highlights the relation of apparent motion with a single instant in the retentional model as well as the content that is included in one's experience in an instant, i.e., one experiences a number of stills, rather than only one. Now, consider the extensional model. According to the extensional model, the specious present is actually temporally extended. So, unlike the retentional model in which the contents of a specious present all occur simultaneously, the extensional model posits that the contents of a specious present actually occur over time.

In view of these key characteristic differences among these models, neither of these latter two models can be used on Barbour's account due to the lack of there being a derivative temporally ordered succession in QG and his ensuing characterization of one's experience of motion at a c-space point in terms of one experiencing six or seven stills encoded in one's instantaneous neural configuration. Barbour, in effect, requires a view in which, unlike the cinematic model, there is apparent motion at a moment that can be put in terms of there being six or seven snapshots experienced at the instant, and, unlike the extensional model, does not presuppose that there is a temporal, ordered sequence of events.

Because the cinematic model presumes that one experiences a single, static, punctuate event at each moment, it rules out the possibility of having an experience of, e.g., motion via one experiencing a number of snapshots, if one can only experience a single snapshot. Thus, Barbour cannot make use of this model in order to explain our apparent experience of motion at a single c-space point: Barbour requires that we experience a series of snapshots at an instant, while the cinematic model claims that one only experience a single snapshot.[233]

---

[232] For advocates of the extensional model see Dainton 2000, 2003, and for criticism see Gallagher 2003.

[233] However, it may be possible to use some form of the cinematic model even in the case in which there is no linear sequence of c-space points, provided that we ignore Barbour's claim that we seem to experience motion due to six or seven stills that are neurally encoded at a single c-space point. For example, Koch 2004 argues that

Moreover, the extensional model's extensional specious present, which has actual temporal extension, is usually depicted as being extended over many actual instants. Barbour, however, must explain our apparent experience of motion at a single c-space point using only the configurations in that point because there are not necessarily linear sequential histories in QG: 'you'- assuming, as Barbour does, that there can be some sort of personal identity over time that is not limited to an instant- 'were' not necessarily in the c-space points that correspond to the sequence of configurations that you seem to experience, e.g., those in which someone was recently walking through the snow or those in which an apple neared the edge of a table. So, because his account of the specious present must be limited to a single c-space point and must neither introduce any fundamental temporal relations nor presuppose that there are sequential, linear histories, it does not seem that he can use the extensional model either.

Before moving onto the second option for cashing out Barbour's claims about our experience of time, it is necessary to present the retentional model in more detail and to mention a dominant mechanism that retentionists use in order to address the issue of how a set of simultaneously occurring states is experienced as successive rather than as simultaneous. The purpose of this is to evaluate its plausibility in the context of Machian QG.

Dainton (2010) characterizes the basics of the relational model as follows. According to this model, the specious present consists of a momentary phase of perceptual experience and a sequence of retentions of recent experiences. These retentions are a type of past-directed mental representations that are automatically and involuntarily triggered after each momentary phase of experiencing. The retentions and perceptual experience all exist simultaneously and are co-conscious.

---

our experience of a single snapshot, though motionless strictly speaking, can suggest motion, e.g., a static snapshot of an apple ¾ off the edge of a table has motion 'painted onto' the snapshot. Yet, because I here aim to provide options for Barbour's explicit claims about our temporal experience, e.g., it is the result of six or seven neutrally encoded stills at a c-space point, as well as keep this discussion relatively manageable by only examining in detail the options that reflect such claims, I bracket off such developments of this option.

This setup can easily be assimilated into Barbour's picture. Consider a single c-space point in which you seem to be experiencing the motion of an apple falling off a table. The retentionist's momentary phase of perceptual experience can be exemplified in this case by the content of a perceived snapshot in which the apple just fell of the table. The set of retentions are the snapshots, six or seven, of the apple on its way to the edge of the table. Because all of the snapshots are encoded in an instantaneous brain configuration, are all experienced simultaneously and have no significant temporal duration, no irreducible temporal relations are tacked onto the c-space point. Moreover, note that though Dainton's characterization presupposes that there was a past, e.g., the retentions are said to be a sequence of recent experiences, which conflicts with QG's lack of commitment to such a past linear sequence of events, this characterization can be easily modified. On Barbour's account, all of these snapshots are encoded in a single instantaneous neural configuration. So, the entire retentionist structure should be regarded as being given to one in a particular instant and, thus, not necessarily dependent upon there being an actual past that one has experienced.

Given that we, strictly speaking, experience all of these snapshots simultaneously, how, then, do we seem to experience successions that appear to have some duration? In terms of Barbouric retentionism, why do we seem to experience a series of snapshots, rather than have an odd instantaneous experience of seven superimposed snapshots? According to Dainton (2011, 400-1), the dominant mechanism that retentionists use to explain the appearance of such succession is a notion of presence. Unlike memories, retentions are regarded as having a greater presence. All retentions have presence, but they may have it to different degrees. In effect, one of the retentions in a single specious present appears to be, e.g., fully present, while another of its retentions appears to be slightly-in-the-past. It is because of these different degrees of presence of the components of a retentional specious present that the simultaneous contents of an instantaneous specious present appear to have a sequence and seem to be temporally extended. Thus, the retentionist may claim that their specious present, though actually an instantaneous set of retentions, appears to one as having a temporally extended succession.[234]

Can Barbour incorporate this mechanism without importing fundamental temporal relations? It seems that he may do so as follows. One's instantaneous brain state could also somehow encode a different degree of presentness for each snapshot perhaps in terms of the manner in which one experiences the snapshot. Though I am admittedly leaving to exactly what this presentness amounts vague, as long as presentness can come in degrees and is something encoded by an instantaneous neural configuration, it seems to be in accord with Barbour's claims about temporal experience.

Further, to avoid a notion of presentness that imports some fundamental temporal relation, the variation of this degree could be a function of the best-matching-like stacking of the snapshots encoded by a neural time capsule. Recall that Barbour claims that these snapshots are given in a certain order. In effect, we can regard it as part of a neural time capsule's definition that such given order involves a sequential range of temporal modes that corresponds to the best-matching-like order of the snapshots as follows: in a neural time capsule, a snapshot's degree of presentness corresponds to its appearance in a sort of horizontal stack of such snapshots. In a similar fashion to the nonrelativistic best-matching of c-space points, it seems that a set of snap shots can be ordered in virtue of their relative spatial relations such as to appear to form a horizontal stack. Thus, the location of a snapshot in this stack can be regarded as indicating the degree of presentness that it is assigned. In effect, we do not need to make reference to or introduce a fundamental temporal order in the characterization of time capsules when Barbour's experiential claims are put in terms of the retentional model: ONT can be upheld because presentness need not be some fundamental temporal property. Moreover, because these simultaneous snapshots are given to us by the

[234] While this mechanism is certainly not without its critics, I here want to focus on whether this mechanism can be incorporated in Barbour's account, rather than contribute to this general debate directly. For a comprehensive overview of this mechanism, criticisms of it and alternative mechanisms, see Dainton 2000, 2003, 2010. Additionally, for defence of retentionism and a development of it that incorporates neurophysiological features, see Grush 2005, 2007, 2008.

neural configuration in a single c-space point, no actual history corresponding to this set of snapshots is required.

Thus, the retentional model and the above mechanism seem to offer a means of developing Barbour's claims about our experience in the context of Machian QG.

1.2.2 Option 2: Psycho-Physical Dualism

Though this option might already strike one as unpalatable due to its commitment to irreducible nonphysical mental properties[235], it is worth exploring for two reasons. First, it can be developed along Barbouric lines, provided that ONT does not rule it out by limiting our ontology to stuff with physical properties, such as to offer a partial reply to Dainton's criticism of it. Second, as we'll see below, it may offer some means of dealing with a conflict that arises in the case in which one is completely confined to a single c-space point yet one seems to have temporal experiences that extend far beyond the content of a single specious present. Though this view is extended below to deal with this issue, I here only present the view for a single specious present generally, cast it in terms of Barbour's account such that it does not introduce fundamental temporal relations and then reply to Dainton's criticisms of this view.

In the context of presenting some options by which the block theorist, who assumes that time does not actually pass, may explain our immediate experience of temporal becoming, Dainton (2011, 288-9) discusses a dualistic option that may also be used by Barbour provided that the mere existence of mental properties does not violate ONT. This option aims to offer an account of why one seems to move through time along a block universe by claiming that the mental properties are 'housed in' an additional temporal dimension. Such an additional temporal dimension is required in order to make sense of the claim that Dainton dubs 'Exclusion': Our experiences are dynamic in a way the Block universe isn't, but our experiences are not part of the Block universe. Dainton attributes it to a suggestion made by Weyl, points out that it is a radical position and quickly rejects it after considering a few objections to it. So, he gives the following sketch of it, which should be sufficient for our purposes. The additional temporal dimension, i.e., meta-time, is along the

[235] See Chalmers 1996 and Jackson 1982 for prominent defences of property dualism.

set of one’s conscious states. However, assuming that the block constitutes the entirety of the physical universe, these conscious states must be nonphysical. Thus, this account presupposes dualism, but it may be cashed out in terms of that between physical properties and mental properties, e.g., being in a particular conscious state. In effect, meta-time is along a series of conscious states and is supposed to somehow offer an explanation of our experience of temporal becoming if in a block universe.

Dainton (2011, 389), however, rejects this psycho-physical dualism as a means for the block theorist to explain our experience of becoming because of the nature of its meta-time, i.e., the additional temporal dimension that he describes as ‘housing’ the nonphysical entities. He poses the question: What sort of time is the proposed meta-time? He argues that if this meta-time parallels that of the block universe, i.e., it is non-dynamic and involves no objective becoming, then the meta-time offers no explanatory gain: it does not explain our experience of temporal becoming. So, he claims, to do this explanatory work, this meta-time must be some sort of dynamic temporal dimension that involves objective becoming. However, he rightly points out that a block theorist would not accept this sort of meta-time.

This criticism seems reasonable if such a dualism is appended to a block universe. Yet, if this dualism is developed for Barbour’s folk theory, it can provide some explanatory power in the context of QG. To support this claim, I first develop it for Barbour’s folk theory. Then, I return to Dainton’s critique of its role in the block universe and see the extent to which a Barbouric psycho-physical dualism can overcome this objection.

To generate a Barbouric version of this account, let’s attempt to add irreducible mental properties such that the rest of his QG account is left largely unchanged. With this aim in mind, it seems that the mental properties must supervene upon an instantaneous brain configuration. Thus, in accord with Barbour’s somewhat vague claims about our temporal experience in terms of being ‘encoded’ somehow in our brain states, we can establish a relation between an instantaneous neural configuration and the ‘encoded’ snapshots, where the latter are in terms of mental properties.

Plus, given our aim of preserving Barbour's dynamics as they are, these mental properties are best regarded as purely epiphenomenal[236]: they do not have any causal influence on other mental properties or on physical properties, but merely arise from a certain instantaneous neural configuration. My reasoning behind this claim is as follows. If mental properties do not have any causal influence on physical stuff, then Barbour can seem to maintain his focus on giving an account of dynamics in terms of the relative instantaneous relations among stuff, where 'stuff' refers to only physical properties, e.g., point particles, or mathematical entities, e.g., manifold points. So, he does not need to add some 'dynamics' of nonphysical properties in his account because they do not bear causal relations to each other or such stuff. Moreover, one may argue that because he requires some explanation of our apparently temporally extended experience, he can make use of epiphenomenal mental properties that supervene upon an instantaneous brain configuration. So, by introducing such properties, he may provide an explanation of our apparently temporally extended experience; however, he does not have to integrate them into the rest of his dynamics.

Furthermore, one way of cashing out these mental properties is in terms of Barbour's suggestion that the appearance of motion corresponds to six or seven snapshots. Perhaps the following set of mental properties supervenes on a particular instantaneous neural state: perceptually experiencing snapshot_1, perceptually experiencing snapshot_2,…, perceptually experiencing snapshot_7. To ensure that a mental property does not have temporal extension, we may further suppose that each such mental state is instantaneous and has no duration strictly speaking.

We do not want to introduce some sort of irreducible meta-time among this set of mental properties, however, because ONT would be violated. Instead, our meta-time must be reducible to instantaneous relative relations among stuff. To do so, we can use the spirit of the best-matching procedure as follows. A set of mental properties can be regarded as something like a horizontal stack: it has a sequence that is ordered in terms of relative instantaneous relations among the content of the snapshots. With this sketch, no fundamental temporal relation is introduced among the mental properties that supervene upon an instantaneous neural configuration. Instead, it may be regarded as derivative from an

[236] See Jackson 1982, 1986 for support, and see, e.g., Nagasawa 2009 for criticism of epiphenomenalism.

ordering of the set of supervening mental properties that is in virtue of the relative relations of the stuff in the corresponding snapshots, much like the manner in which horizontally stacked c-spaced points provides a derivative temporal order in nonrelativistic dynamics. Though this application of something akin to horizontal stacking to nonphysical properties may strike one as ghastly, I should emphasise here that such potentially nonspatial properties need not actually form horizontal stacks. Rather, what is essential is that such properties may have some sort of experienced ordering, but this ordering is fundamentally in virtue of the relative spatial relations among their content, rather than a fundamental irreducible temporal relation. Moreover, because Barbour claims that such snapshots are given to us as ordered in time capsules, note that we are not required to do any active 'stacking' of these snapshots. Instead, we just experience them. Such a lack of active stacking is in accord with the above claim that mental properties are purely epiphenomenal.

With this sketch of Barbouric psycho-physical dualism, let's return to Dainton's criticism above. I grant that, if such a reducible meta-time is appended to Barbour's instantaneous neural configurations, it does not offer a means of accounting for our experience of temporal becoming without itself involving objective becoming. The addition of such an irreducible temporal property would be in violation of ONT. However, as presented above, this meta-time can be developed in line with ONT: meta-time is derivative from instantaneous relative relations among the contents of snaphots. Thus, as derivative from apparent spatial relations, it does not introduce some irreducible temporal relation and, thus, does not violate ONT in this sense.

Additionally, meta-time can do some explanatory work in the context of QG. Because there is only a possibly non-stackable heap of c-space points according to QG, there is no derivative time that arises as in, e.g., GR, via horizontal stacks of c-space points. Compare this with Dainton's depiction of the block theorist. If the block theorist's meta-time is static and involves no becoming, it seems to be the same as the time of the block itself. Thus, the meta-time is redundant and effectively offers no additional explanatory power. In contrast, the QG heap picture lacks derivative time, i.e., that from a stack of c-space points. In effect, meta-time in this context at least offers some explanation of our apparent temporally extended experience at a c-space point in the heap. So, at least in the context of

QG, we can answer Dainton's question regarding what sort of time meta-time is such that ONT is upheld and that this meta-time is not explanatorily redundant.

Thus, psycho-physical dualism may offer another option for Barbour's folk theory provided that the existence of mental properties isn't ruled out by ONT and that stacking analogues can be articulated in terms of such properties. Plus, in order to have some explanatory power that does not violate ONT, it seems that these properties must be completely epiphenomenal, supervene upon instantaneous neural configurations and may exhibit reducible temporal relations. So, this option comes with some cumbersome and contentious metaphysical baggage, but it appears to provide a coherent option that is free from irreducible temporal relations and preserves his interpretation of WDE.

Now that we have our initial identification of the role of *time* in the Machian network as well as some development of the folk part of the Machian network via two ways of cashing out Barbour's comments regarding our apparently temporally extended experience at an instant, we can move to the next stage in ACA in which we identify conflicts across the network.

2 The Conflicts, Incoherencies and Redundancies of the Temporal Roles

ACA dictates that after the initial identification of the temporal roles in a network, we proceed to identify clashes in the roles across the table. Recall from Ch1 that the reason for this move is to be able to identify *time* in a fashion that does not saddle us with naïve realism from a mere surface reading of a theory. So, from the above identification of *time* in the Machian network, we must proceed to examine these preliminary roles, identify clashes among them and attempt to resolve them in the context of this network.

There are four clashes in the table that I highlight here, the latter two of which will be discussed in the next section in which I 'engage in metaphysics' in an attempt to resolve them.

2.1 Clash 1: *Time* in GR and Nonrelativistic Dynamics

Note that there is a clash between what plays the arbitrary parameter roles in nonrelativistic dynamics and GR. In the nonrelativistic column, *time* is depicted as being a single parameter that is applied to an entire stack such that each c-space point in the stack is assigned a single value. Yet, *time* as the role of GR's proper time is regarded as being a multitude of parameters. Each is assigned to a different set of equilocal points, rather than entire c-space points. Moreover, the parameters will not necessarily have the same increments because the 'strut length' or local lapses to which they are assigned are a function of the particular geometry. Thus, it seems that there is a conflict between what plays the parameter role of the time variable in the respective dynamics. However, this clash is to be expected given the different roles of *time* in GR and nonrelativistic dynamics as it is standardly depicted, which was discussed in Ch3. Moreover, as my focus here is to examine the manner in which Barbour resolves the problem of time in QG, I am bracketing off this clash and do not attempt to resolve it below. Additionally, I henceforth do not refer to the nonrelativistic column given this focus.

2.2 Clash 2: Infinitesimal Instants and Experience

Let's examine the infinitesimal instant role row. The things that play the infinitesimal instant role in each of his non-folk accounts appear to have no apparent conflicts. Because he put QT's c-space points in terms of relations among medium-sized dry goods, e.g., the relation of a pointer on a measuring device allows such relations to be assimilated into the QG c-space points of 3-geometries relatively easily. To do so, we can add matter fields, which would be indicative of such classical relations, to Barbour's pure 3-geometries. Pooley (2001) presents the manner in which such fields could be assimilated into an account such as Barbour's in a fashion that does not violate MP. Such a field, he claims, can be characterized in terms of the relative dispositions of the field intensities, e.g., by the infinite number of facts about the relative distances and angles between particular values of a scalar field. So, at least *prima facie,* it seems that relative relations of the field can serve as a means of cashing out the content of QT c-space points in terms of 3-geometries such that MP is not violated. Yet, I do not intend here to present exactly the manner in which this proposal may be developed because I want to focus on the issue that the role of the infinitesimal instant for the Folk Theory column.

Given the depiction of c-space points in GR and QG as only having such infinitesimal temporal extension, it seems that a time capsule must also only have infinitesimal temporal extension. Plus, a time capsule, a part or all of a single QG c-space point, has no horizontal stack in QG. As presented above and as was presumed in the presentation of folk options, QG's c-space points are not necessarily stackable. Thus, given the manner in which c-space points feature in QG's infinitesimal instant role and QG's lack of a derivative temporally ordered succession role, it seems that time capsules must also have infinitesimal temporal length yet not necessarily have other c-space points 'preceding' it in a stack. Assuming that such infinitesimal temporal length is compatible with the actual instantaneous nature of time capsules discussed in the folk options above, then this resulting characterization of c-space points does not clearly present a clash. By referring to his neural time capsules, Barbour can claim that the configurations in our brain in this infinitesimal instant correspond to those in which one is actually recognizing the content of the snapshot. In effect, this content is, so to speak, given to one at an infinitesimal instant.

However, this resulting characterization of time capsules has a potentially unpalatable implication. It seems that, e.g., having a perceptual experience of something, is a temporally extended causal process: it takes time for signals produced in one's eye to reach one's brain and for one's brain to process such signals and produce the appropriate perceptual experience. In making reference to psychophysical data, Dainton (2010) states that this process can take from 60ms to 500ms. However, given the implications of the chart for time capsules, a time capsule is of infinitesimal temporal length. No such temporally extended process can take place within a time capsule. Moreover, because there is not some stack of c-space points leading up to a particular c-space point with a certain time capsule, one cannot assert that the causal process is a product of prior time capsules. Instead, one can only make recourse to the instantaneous relative spatial relations among the stuff in a single c-space point. In effect, it seems that Barbour may maintain that one's experiential perception is correlated with a particular instantaneous brain configuration; however, there need not be a correlation between the contents of the perception and any other configurations in the c-space point.

Thus, it seems that a time capsule may consist of only a certain neural configuration, and there need not be any non-neural configuration in the c-space point that corresponds to the encoded snapshots. However, Barbour assumes throughout his presentation of time capsules that our mental snapshots also correspond somehow to non-neural configurations in the present c-space point. For example, he (1999) presupposes that our perception of a kingfisher in flight corresponds to something in the c-space point, e.g., a kingfisher, part of a matter field that gives rise to us seeing a kingfisher in flight. So, if Barbour's neural time capsules are intended to correspond to some non-neural configuration in a c-space point, then there seems to be a clash as his explicit definition of a time capsule in conjunction with the implications of QG's roles for time capsules does not entail that all time capsules have such correspondence.

However, there are a few resolutions to this clash.

One option is to posit that Barbour's discussion of time capsules, which is only in terms of them having some correspondence with a c-space point's non-neural configurations, is not intended to rule out the possibility of time capsules that lack such correspondence. Thus, a c-space point in which there is only a certain neural configuration and a set of encoded snapshots is also considered a time capsule.

Another option is to append a further condition to the time capsule definition to rule out such cases as time capsules. Here is a possible condition: the experienced content of a time capsule represents a configuration that is actually part of the c-space point, e.g., footprints in the snow, or something that would be in a best-matching set of c-space points. For an example of the latter, consider your experience of an apple falling off the table. Suppose that in this c-space point the apple is actually on the floor. Your encoded snapshots are not directly correlated with this configuration; however, if there were a best-matching set of c-space points leading up to this c-space point, then each of those c-space points has a configuration that corresponds to the content of the seven experienced stills encoded in your neural configuration at this particular c-space point.

I do not here develop these options, explore their metaphysical implications or compare them in the context of Barbour's QG. Yet, it is important to note that which option is chosen has implications for his interpretation of the WDE. This is due to his use of time capsules in QG. Recall that the probability distribution resulting from the WDE is claimed to be concentrated on time capsules with the aim of giving some reason as to why we usually experience such time capsules.

Additionally, this clash highlights the problematic nature of Barbour's time capsules. Given the other commitments of his QG, we must be wary of making standard presuppositions about there being a temporally extended linear sequence of c-space points in which there are causal links across c-space points. Barbour's discussion about time capsules seems to presuppose that there are such causal links across c-space points, e.g., he assumes that the non-neural configurations somehow give rise to our neutrally encoded snapshots and dubs these 'neural time capsules'. However, because a c-space point in QG is infinitesimal and does not have a derivative sequential ordering, it cannot be assumed there are such perceptual processes that causally lead up to one's current set of experienced snapshots. Thus, his notion of time capsules is in need of further refinement because, as this second clash illustrates, it may presuppose that there are causal connections across c-space points. Further, though I am not going to address this clash below, it is hoped that the two options above, though in need of development, at least give sketches as to how time capsules may be redefined such that this definition does not presuppose that there is a temporally extended linear sequence of c-space points.[237]

Let's next turn to the third and fourth clashes. Unlike the previous clashes, I focus on resolving these two clashes in the next section because of their centrality to his interpretation of QG.

2.3 Clash 3: The Timeless Problem of Time

The third clash occurs in the Derivative Temporally Ordered Succession row. GR's dynamics does allow one to horizontally stack c-space points and, thus, obtain a derivative temporally ordered succession in virtue of this stack. However, as explained in the presentation of the table above, by extracting the background structure from QT and carrying this over to his interpretation of QG's WDE, it does not seem that Barbour can reconstruct horizontal stacks and, thus, vertical stacks in QG. Instead, he is left with a mere heap of c-space points that does not appear stackable. I am going to term this clash 'the timeless

[237] Also note that my use of psycho-physical dualism as a means to cash out his folk theory may also be suspect: epiphenomenalism usually involves there being a causal link from physical to mental properties. But, if this rather mysterious causal link to nonphysical properties does not require a temporal interval, then it is not problematic. Otherwise, we may have to turn to parallelism, which denies all causal interaction between physical and mental properties, instead of epiphenomenalism. In turn, I'm bracketing off this possible issue, while regarding either route as involving another cumbersome piece of metaphysical luggage that goes along with the dualism option.

problem of time', or 'T-POT'. It arises because he tries to resolve the standard problem of time by eliminating any fundamental temporal ordering among and background structures associated with QG's and QT's c-space points. However, he maintains that there are horizontal and vertical stacks in GR. Given that the WDE is a quantization of GR's 3-metrics, one may expect that GR's stacks are recoverable. Yet, his heap interpretation of the WDE makes it difficult to recover GR's stacks and, in effect, a derivative temporally ordered succession of c-space points. Thus, he is faced with T-POT: because Machian GR posits that there is *derivative temporally ordered succession*, but Machian QG lacks such a role, how can horizontal stacks be generated in Machian QG? I explore Machian means of resolving this clash in the next section and, thus, discuss whether two general manners of resolving T-POT can be formulated such as to uphold ONT: the generation of some sort of ordered succession among c-space points in QG and the elimination of GR's stacks.

2.4 Clash 4: Extended Experience and QG

Finally, the fourth clash also occurs in the Derivative Temporally Ordered Succession row, but it is between Machian QG and Folk Theory. In QG, there are not necessarily linear sequences of c-space points. Instead, there is just a heap of c-space points, some of which have copies. Barbour has given an account of the specious present at one of these points, which can be developed, as done above, in terms of the retentional model or in terms of a psycho-physical dualism. However, because our experience seems to extend well beyond that of a single specious present and involves what appears to be a relatively sequential, ordered set of events, Barbour needs to reconcile such experience with his account of QG as well as its implication for personal identity as being limited to a single c-space point, as argued in Ch5. So, this clash arises primarily because of the incomplete nature of Barbour's folk theory. The folk column is silent about our apparently far extending experience; however, claims made about our experience in the Folk Theory and the implications of QG clash with such apparent experience. I examine means of resolving this clash in the next section by further developing retentionism and psycho-physical dualism. Further note that because this clash and the third clash are in the same row, options for resolving them depend on each other, e.g., if ordered sequences are able to be recovered in QG, then it seems that our well extended experience may be along such a history. Since, Barbour's dynamics is more fundamental than his folk theory, I discuss means of resolving T-POT first. Then, I examine options for resolving this fourth clash in view of T-POT options.

Now that we have identified some of the major clashes in the table, ACA dictates that we attempt to resolve such clashes by ‘engaging in metaphysics’. Because the first clash identified deals with a relatively standard difference between the role *time* plays in nonrelativistic mechanics and GR and since my focus is on the coherency among GR, QT and QG, I do not discuss it further below. Additionally, I bracket off the second clash between the infinitesimal, non-sequential instants of QG and the characterization of time capsules that seems to presuppose that there are causal processes. Though the options given to resolve this clash are admittedly incomplete, they at least provide some suggestions as to the manner in which this clash may be resolved. In effect, I focus in the next section on the third and fourth clashes due to their central roles in his unification of GR and QT and interpretation of QG.

3 Engaging in Metaphysics

With the clashes identified, ACA dictates that we next attempt to resolve these clashes by ‘engaging in metaphysics’. This is because the role that time plays in the network exhibits conflicts, incoherency or redundancy. Recall that if the concept is completely redundant, then one can eliminate it relatively easily. However, barring this result, ‘engaging in metaphysics’ involves either the construction of a coherent, relevant and non-redundant *time* or the reduction of its role to those played by other elements in the network. Additionally, recall that other than stating that it may possibly involve re-examining metaphysical assumptions and roles of other concepts in the theory, the exact nature of this engaging in metaphysics was left rather vague. This section, in effect, provides an example of how such ‘engaging in metaphysics’ may be done.

Because this is primarily a metaphysical enquiry in which we focus on conceptual clean-up and development, rather than one that seeks out possible mathematical mechanisms by which the resulting options may be presented, I aim to provide Barbour with some options such that he has a largely coherent and non-redundant set of metaphysical and ontological commitments. Yet, I do not attempt to develop these options formally. Whether this focus on conceptual clean-up and development imposes an undue limitation on metaphysical engagement in this context is discussed in Ch7. Moreover, because ONT and MP are basic to his network, I assume that these metaphysical principles cannot be amended over the course of this analysis.

Further, because his Folk Theory depends upon his QG, I begin by presenting possible resolutions to what I have identified above as the timeless problem of time. With the resulting options for this clash at hand, I turn towards examining whether his folk theory can be made coherent in view of each option for resolving T-POT. In Ch7, I discuss my ‘engaging in metaphysics’ in view of the manner in which I addressed these clashes: though it seems that this practice would be difficult to schematize, I offer some suggestions regarding its scope and limitations.

3.1 Resolving the Timeless Problem of Time

Recall that T-POT involves a clash between GR, which Barbour claims has c-space points that can be horizontally stacked, and QG, which is just a heap of c-space points that cannot generate such stacks. So, we first turn to the issue of how stacks may be generated in QG. After assessing the options for this route, we will turn to the route in which we resolve T-POT by eliminating the need of incorporating GR-ish stacks in QG.

Let’s begin by considering Barbour’s explicit suggestion, which is presented at the end of Ch5, as to the manner in which the heap of actualities is determined by the wavefunction in the arena of the stratified possible c-space. Recall that he conjectures that the wavefunction is ‘funnelled’ onto the c-space points with time capsules because of the structure of possible c-space. And, he likens the probabilities of the squared wavefunction to a static mist of varying intensities across c-space.

Can this setup be used to indicate sequential stacks of c-space points such that ONT is not violated? If the wavefunction is ‘funnelled’ along, e.g., sets of hyperbolic curves, each of which has an end around, perhaps, the origin of a possible c-space and are ‘directed’ towards the other end, then the static funnelling of the wavefunction may be regarded as being indicative of sequences of c-space points.[238] Assuming that this conjecture is possible, we

[238] This mirrors a suggestion made by Hartle and Hawking 1983. They propose that the WDE is a hyperbolic equation on superspace. However, they assume that superspace has the signature (-,+,+,+,+,+) and choose a timelike direction in which to draw such curves. Barbour, given ONT and his arguments against such arbitrarily

must determine what is doing the work in picking out such sequences and, thus, assess whether this mechanism is in accord with ONT.

This setup has three main components: the wavefunction of the WDE, stratified possible space, which has a structure, and the heap of actual c-space points. The probabilities that the mist represents can be regarded as a product of the wavefunction. As argued in Ch5 in the context of making sense of Barbour's interpretation of the probability distribution, only the heap of actualities exists. If those arguments hold, then possible c-space is, perhaps, best regarded as merely a mathematical tool for determining the number of particular c-space points that there are in the heap of actualities. Moreover, as was suggested in Ch5, we will assume that the stratified possible c-space may be derivative from a single actual c-space point and, thus, this space is not in violation of ONT.

Is the wavefunction compatible with ONT? If Barbour is a realist about the wavefunction[239], i.e., he holds that at least the wavefunction along with its configuration space features in his fundamental ontology, then he is committed to the existence of certain entities, i.e., the wavefunction and the stratified possible c-space in which it resides. This option offers a literal reading of his suggestion, i.e., the wavefunction is an entity actually spread out over possible c-space. However, on this view, the wavefunction is a fundamental ontological entity that, in effect, is not reducible to the relative relations of stuff. Plus, given my argument in Ch5 for the conclusion that the heap of actualities must exist, we would be committed to the existence of not only the heap of actualities but also the possible c-space. Though we're assuming such space is reducible to stuff and their relative relations, this picture involves a huge ontology. But, bracketing off the resulting c-space point proliferation and its denial of Ch5's conclusion that only the heap of actualities exists, the commitment to the existence of the wavefunction as an entity that is not reducible to stuff and their relations clearly violates ONT. In effect, the wavefunction as some sort of entity spread across c-space

---

chosen timelike directions, which we encountered in Ch4, cannot use such a chosen direction. Instead, as suggested above, the topology of possible c-space must 'guide' the probability distribution along such curves.

[239] For defence of wavefunction realism in the context of standard QT, see Lewis 2004 and Albert 1996. For criticism, see Monton 2002, 2006, and Maudlin 2007

and ‘guided’ by possible c-space’s structure cannot do the work in picking out sequences of c-space points in Machian QG.

Thus, Barbour cannot accept wavefunction realism as characterized above. However, note that he does claim that the wavefunction is ‘guided’ somehow through possible c-space via its structure. We should enquire as to whether there is a less literal reading of this claim that upholds ONT. One alternative that seems compatible with ONT is to consider the wavefunction to be, following, e.g., Monton (2006), merely a useful mathematical tool for, in the case of QG, calculating the probability that indicates whether a specific number of copies of a certain c-space point is in the heap of actualities. If this is the case, however, then it seems that, rather than the wavefunction or its mist, the structure of possible c-space is what indicates the probability distribution. Rather than ‘guide’ some entity or mist, this structure itself is what indicates the number and types of c-space points in the heap of actualities.

Given the central role of the structure of possible c-space on this route, it is necessary to examine whether we should continue to hold our assumption that this c-space can be structured without violating ONT. In view of the presentation of stratified manifolds in Ch5, it seems that at least the contents of each of its submanifolds may be determined without violating ONT, i.e., considering the manners in which one may change an actual c-space point can generate the set of possible c-space points. Barbour suggests that the points in each submanifold are arranged in terms of the relative congruence, symmetry and volume of each c-space point. If such relations can be obtained through some sort of best-matching procedure among possible points, then the organization of the points on each submanifold does not clearly violate ONT. But, Barbour arranges his example of a stratified manifold as having three flat sides with a certain volume. Other than simplicity perhaps, it is unclear why the submanifolds do not, e.g., curve. In effect, it seems that he has merely chosen a certain topology for the submanifolds that is not clearly dictated by stuff and their relative instantaneous relations. Moreover, a different topology for the same submanifolds could result in, e.g., a conical possible c-space. In effect, the topology of the submanifolds and the shape in which they are stratified violate ONT: these features of stratified c-space do not seem to be derivative from stuff and their relative relations alone. Thus, it does not appear that Barbour may use stratified possible c-space in his Machian QG.

But, let's grant that Barbour may find a Machian means of stratifying possible c-space. Moreover, let's continue to assume that the structure of c-space may effectively concentrate the probability distribution along hyperbolic curves in c-space. If c-space's structure is what does the work in indicating the number of c-space points in the heap of actualities, then, because this space has a single structure, it must only offer a single solution to the WDE. In effect, for a given stratified c-space, there is only one heap of actualities. This implication does not seem to conflict with Barbour's QG generally. Additionally, he (1999, 302) explicitly admits that the WDE may have one or many solutions. So, this implication is in accord with at least Barbour's claims about the WDE.

Now that we have some means of generating ordered sequences of c-space points via hyperbolas there, granting that the stratification of c-space can be Machianized, we can turn to resolving T-POT. Can these sequences be used to stack the heap of actualities and, thus, go towards recovering GR's horizontal stacks? No: as long as a particular possible c-space point along a hyperbola in possible c-space has a probability indicating that there is more than one copy of it in the heap of actualities, then, given PSR, one of the points cannot be put into the stack rather than the other.

Moreover, it is likely that certain regions of c-space, rather than just a number of relatively isolated parabolas, are assigned a higher probability. This is because of Barbour's claim that the probability distribution will be concentrated on c-space points with time capsules. Since such points would likely be clustered together in a c-space that is arranged in terms of congruency and symmetry of stuff in its points, it is difficult to see how a single path could be traced through the region. So, we may have to forgo the hyperbola assumption in this c-space as well. In effect, it seems that, even in the case in which the WDE is indicative of hyperbolas through c-space via the space's structure, it is not clear that these hyperbolas offer a means of stacking the actual c-space points such as to recover GR's horizontal stacks.

Though this suggestion does not seem to resolve T-POT in a Machian framework, there may be another means of recovering GR's horizontal stacks. Begin by stipulating that along with a probable c-space point, its best-matching set of c-space points is also in the heap of actualities.

One way of accomplishing this is merely to assume that there is such a set of each copy of a probable c-space point. The BSW could be used to determine this set given a specific probable c-space point.

However, this setup does not offer a means of stacking because there will again be copies in the actual heap. Nevertheless, one may reply that a particular set stacks in virtue of the fact that these particular c-space points are obtained through the specific application of the BSW to the probable c-space point. There are two problems with this reply. First, it assumes that the BSW is what determines which points are in the actual heap. However, in this context in which actual c-space points are primary, one may claim that the actual heap simply exists, and the BSW is a mere calculational aid for finding out what c-space points are in the heap of actualities. But, if one does not hold this role for the BSW, then this reply is still problematic for a second reason: this reply presupposes that there is some sort of irreducible particular relation among c-space points that arises only in virtue of the application of the BSW. It must be irreducible because there is nothing in a particular c-space point that would indicate that it must be best-matched with a certain copy of a c-space point. Rather, it just indicates that a specific type of c-space point must follow it in a stack. Thus, a stack cannot be constructed without violating ONT by positing an irreducible relation among particular c-space points.

There is a second setup that one may associate with the stipulation. Take a particular probable c-space point, and assume that it is part of a best-matching stack that is completely foliated. This stack constitutes the heap of actualities: each c-space point in the heap is indicated by the solution to the WDE in the manner in which Barbour interprets it. In effect, the resulting probability distribution indicates the number and types of c-space points in the stack. On the assumption that this heap contains all the c-space points in a completely foliated stack, then the stack can be regarded as indicating where each of the points in the heap of actualities may fit in. But, it doesn't specify exactly where each one fits, e.g., where a particular copy fits. Thus, we can obtain a stack such that each c-space point in the heap of actualities has a place in it.

However, this setup does not specify exactly where each c-space point fits. Is this lack of specification problematic? It does seem to be a metaphysical, rather than just an epistemological, issue: the relative relations of a c-space point do not indicate which stack such a point should be in. Nevertheless, this setup at least allows us to recover the general structure of GR stack. Yet, to do so, it assumes that there is such a stack initially. But, other than perhaps the fact that the WDE is supposed to be a quantization of GR, there is no reason to assume that there is such a stack. The task here is to recover stacks given Machian QG, rather than to simply assume that there are such stacks in QG. So, though this setup may offer some means of recovering GR's stack, it may be regarded as question begging.

This discussion brings us to the second means of resolving T-POT: claim that such stacks are eliminable in GR. The c-space points of GR are merely heaps and are not actually stacked. However, this would be a radical interpretation of GR. Moreover, Barbour gives an account of its foliated space by making reference to a horizontal stack of c-space points that is completely foliated and, in turn, is committed to there being the c-space points associated with all possible foliations of this space. So, to determine the points in GR's heap, one would need to stack a best-matching set that is a solution to the BSW and then foliate it. However, this poses no inconsistency in this stackless GR. Such a stack can have the same role as that of stratified possible c-space in that it only offers a means of calculating what points there are in the actual heap. Such a stack does not actually exist.

To sum up this section, T-POT may be resolved in principle by either by reconstructing stacks in QG or by eliminating stacks in GR. The latter approach, though radical, seems to provide a coherent Machian GR. The former approach, in contrast, is difficult to formulate without violating ONT. We went through two main attempts of developing this approach. First, we considered Barbour's suggestion of using the structure of stratified possible c-space as a means of indicating stacks. However, it seems that a particular stratification of c-space violates ONT due to the fact that its topologies and shape do not appear to be derivative from stuff and their relative relations alone. Moreover, even assuming that the probability distribution is concentrated on hyperbolas in this setup, such a hyperbolic curve does not necessarily indicate the manner in which actual points are stacked due to the possibility that a point along it may have copy in the actual heap. Second, we considered the possibility that a probable c-space point indicates that, in addition to that point, the heap of actualities also contains either its accompanying best-matching set or all the points in a completely foliated stack in which it appears. But, the former option does not allow stacks without violating ONT by introducing some irreducible relation among particular c-space points. And, the latter option, though recovering GR's stack to some extent, may be regarded as question begging by assuming from the outset that there are such stacks.

So, though the viability of the former approach to T-POT is questionable, I consider in the next section the implications of both of these general approaches in the context of developing an account of our experience, which appears to have quite a long duration and seems largely sequential.

3.2 T-POT's Approaches and Extended Experience

In this section I consider whether Barbour's folk theory can be developed such that it can account for our experience that seems to extend well beyond a specious present.[240] To do so, I attempt to develop it for each of the general approaches in the previous section. However, note that I do not attempt to develop an account of the phenomenal passage of time that we seem to experience. This is due to the fact that this issue is not unique to Barbour's accounts since it also arises for, e.g., the block theorist. Instead, I focus on coherently

---

[240] Note that I am assuming here that we need some account for at least segments in which our streams of consciousness appear continuous. To delineate my aim here, it may be helpful to refer to three main positions Dainton 2010 delineates regarding the continuity of experience. According to the Discontinuity Thesis, although consciousness is commonly described as continuous, this is incorrect because our consciousness is highly disjointed. According to the Modest Continuity Thesis, our streams of consciousness are continuous, which involve freedom from gaps and/or a significant degree of moment-to-moment qualitative similarity. According to the Strong Continuity Thesis, the stream of consciousness involves the relationships proposed by the Modest Thesis as well as there being an experiential connection among the successive brief phases of our typical streams of consciousness. I do not here attempt to provide an account of the Strong Thesis. And, it is difficult to see how one may hold the Discontinuity Thesis in the context of the stackless solution to T-POT. Because, even if our typical 'streams' of consciousness may be very gappy, it seems that there is some linearity of our experience presupposed, e.g., such gaps are not of the type in which a physician in his Canadian office suddenly finds himself to be the captain of a banana boat in South America. So, though I do not have the space to do so here, one may make the case that the plausibility of the Discontinuity Thesis relies on there being some sort of linearity of actual events in the world. Moreover, though the Discontinuity Thesis may be an option for the stacked route, in which there is such linearity, I here aim to show how the Modest Continuity Thesis may be accommodated such that at least segments of continuous experience in a stacked Machian QG context are explained.

extending the specious present alternatives given by the folk options such that they may explain one's apparently linear and largely sequentially ordered experience. Unlike block theory generally and even the branching worlds of an Everettian interpretation, Barbour's QG does not assume that there is some sort of linear sequence(s) of events in the world. So, the prospect of accounting for experience that reflects such linearity needs to be discussed here.

Let's start with the first general approach in which linear stacks that are sequentially ordered are recoverable. Assuming that such stacks are not superimposed[241], then it seems that one may identify oneself along a particular stack and account for one's apparently extended experience in relatively standard ways.

For the retentional model, we can append some means with which it accounts for such experience provided that it is in accord with ONT. Following Dainton's (2000) (2010) (2011) account of one of Broad's proposals, one's extended experience is made up of a dense succession of instantaneous specious presents. As presented in our development of the retentional model for Barbour's claims about experience, a specious present on this model arises from a simultaneous set of snapshots that are encoded in a single neural configuration. These snapshots, though, do not seem to be simultaneous because each is assigned a different degree of presentness. In effect, for a linear sequence of c-space points in which one has a series of neural time capsules, each neural time capsule encodes six or seven snapshots. It is this set of neural time capsules and their associated snapshots that accounts for our

---

[241] In places, Barbour suggests this possibility. For example, he 1994b claims that, assuming that there are such superpositions of stacks, this may result in one experiencing Thursday without there being a Wednesday. Presumably, he posits parts of such stacks may somehow annihilate some of the c-space points in the stacks. However, I only offer options for the extremes of there being linear sequential stacks and there being no such stacks recoverable. Nevertheless, this possibility may be accounted for via one or a combination of the above options. For example, if one accepts the claim that personal identity is limited to a single c-space point, then one may adopt the latter option for this case and perhaps claim one's experiential contents at, e.g., at a superposed set of c-space points, are also superposed in a manner parallel to that of Lockwood's 1996 picture in which the minds at each instant in an Everettian interpretation are superposed without there being trans-temporal identity. On the other hand, if one denies this claim, then one may, e.g., use some form of the stack-friendly retentional model in which retentions are superposed. Since this model has all of its retentions simultaneously co-existing at an instant, does not seem incompatible in principle with there being gaps in a stack.

experience that seems to last longer than a single specious present; one effectively is experiencing a series of retentional specious presents.

To exemplify how this may work, suppose that there are two best-matched c-space points in which it appears that a millipede is crawling under a rock. At the first c-space point, where one sees the millipede in its entirety moving right next to the rock, i.e., no parts of it is under the rock, one has a neural time capsule that encodes six snapshots. The most-present of these snapshots is the one in which the millipede is right next to the rock. The slightly-less-than-present snapshot is one in which the millipede is slightly left of the rock. The even-less-than present snapshot is one in which the millipede is a bit more left of the rock, and so forth for the other three snapshots' contexts and temporal modes.

At the next best-matching c-space point, one sees the millipede moving under the rock. Again, assume that one's neural time capsule encodes six snapshots. Here, one's neural time capsule encodes a most-present snapshot in which the millipede is partially under the rock. The slightly-less-than-present snapshot is one in which the millipede is right next to the rock. The even-less-than present snapshot is one in which the millipede is slightly left of the rock, and so forth for the other three snapshots.

Thus, by considering a series of retentional specious presents that correspond to the snapshots encoded by a set of best-matching c-space points, it seems that the retentional model offers some means of cashing out our apparently largely linear and extended experience for the case in which QG has stacks. Moreover, because we have not introduced anything more than the Barbouric retentional account of the specious present and since such an account was earlier argued to be in accord with ONT, this option does not violate ONT.

The dualism option in the context of this approach, however, becomes a victim of a horn of Dainton's dilemma for the block universe and psycho-physical dualism. Because such a static, linear sequence of c-space points is essentially a block universe, his dilemma applies to this approach. And, due to our bracketing off the issue of explaining our experience of the passage of time, with which Dainton is concerned in his presentation of the dilemma, it needs to be recast in terms of explanatory power generally. In effect, on this approach, there would be a derivative meta-time from a series of mental properties that has some sort of best-matching-like ordering. But, there would also be a derivative time of the horizontal stack of c-space points. In effect, one can argue that the meta-time of the psycho-physical properties is the same sort of time as that of the vertical stack of the sequence of c-space points: both sorts of time are derivative from a best-matching horizontal stack of some sort. In effect, the meta-time lacks additional explanatory power and, thus, appears to be redundant.

So, in view of the redundancy of dualism's meta-time in this case, it seems that the retentional model offers the more viable account of experience in the case in which linear, non-superimposed stacks are recovered in QG.

Let's now turn to the approach to T-POT in which stacks are not recoverable. One general option for explaining our apparently linear and sequential extended experience on this approach is to claim that it only seems that we have such a temporally extended experience.

Given what this claim entails on a stackless QG, it does not seem that there are any other options that may be developed. To see why this is so, consider a comparison with the block universe and stackless QG. In stackless QG, 'you' would be statically co-existing in all the c-space points in which there is a 'you'. So, in the static co-existing respect, this picture parallels the block universe. However, the block theorist could point to some spatiotemporal worm and claim that, strictly speaking, all of you co-exists there and this worm corresponds somehow to your temporally extended experience. In a block universe it is generally presupposed that 'you' are spread across a single linear sequence. Yet, in stackless QG, there is not necessarily such a linear sequence. Instead, there may be multiple exact copies of 'you' in the c-space points in the heap of actualities as well as many c-space points in which, e.g., 'you' are in a slightly different configuration from the one you seem to be experiencing. In turn, with the static co-existence of multiple copies of 'you' and variations on a single c-space point that 'you' seem to experience, one cannot make reference to a single linear sequence in which 'you' appears and claim that there is a linear sequence that corresponds to your linear experience.

Thus, without any stacks to which our apparently linear experience corresponds, it seems that we must claim that our temporally extended experience is only apparent. Due to QG's lack of stacks, let's attempt to develop the option that our apparently linear, extended experience must somehow be contained within a single c-space point. Other than, perhaps claiming that one actually co-exists in all the c-space points in which one appears, which does not seem to offer any explanation of why one seems to have a largely linear, sequential set of experiences, this appears to be the only viable option in stackless QG. Can either of the folk options be developed such as to incorporate this apparently single viable option for explaining our apparent linear and extended experience? If so, such an account may have the added bonus of making the notion of personal identity that is restricted to a single c-space point more palatable.

It seems that a general means of developing this option is to extended Barbour's account of the specious present to 'the specious lifetime', i.e., one's experience of one's apparent lifetime as a largely linear and sequential set of experiences.

Recall that for a QG with recoverable stacks, we made use of the specious presents that correspond to the six or seven snapshots encoded in a best-matching set of c-space points. However, on the stackless QG route, there are no such best-matching sets to utilize. So, instead of being extended over a set of c-space points, the specious lifetime must be restricted to a single c-space point.

One may believe that we can do so simply by allowing a specious present to correspond to an entire lifetime's worth of snapshots, rather than just six or seven. However, given that there would be a huge number of snapshots encoded in a single neural configuration, this puts strain on the claim that such snapshots are given by one instantaneous neural configuration. But, even allowing that this may occur, recall that all of these snapshots are actually simultaneous. It is the ascription of different degrees of presentness to the snapshots that make the specious present appear to have an extended, sequential ordering. The degree of presentness that a snapshot is assigned was assumed to be a function of the place of the snapshot in a horizontal snapshot 'stack' given that the snapshots can be best-matched in virtue of their content.

Though this setup may seem feasible for providing an account of, e.g., motion that one seems to experience at a particular instant, it gives a somewhat contentious account of, e.g., the motion of the horses involved in an entire horse race that one seems to experience. Because all of the snapshots are given fixed modes in virtue of their place in the snapshot stack, the snapshot of Workforce rounding the final corner at Epsom Downs in 2010 has a certain fixed mode, e.g., not-at-all-present. However, when you seemed to be watching the race back in 2010, Workforce's rounding the corner had the temporal mode of most-present. And, when one seemed to see Workforce crossing the finish line, the snapshot at which Workforce was at the final corner had the temporal mode of slightly-less-present. So, it seems that, though temporal modes were introduced in order to provide an account of the specious present, such modes need to change in order to account for a specious lifetime. In the retentional account of the specious present, a single, fixed temporal mode is assigned to each snapshot in it. However, if we claim that these modes can change, then it does not seem that they can be assigned merely by the location of a snapshot in the stack. Additionally, it is unclear what exactly may be added to the stack that does not presuppose fundamental temporal relations. So, pending the addition of something to the stack to account for changes in temporal modes such that it does not violate ONT, it does not seem that the retentional model can provide an account of a specious lifetime that is limited to a single c-space point.

Nevertheless, one may object to the preceding worry for the retentional model in this context on grounds that it presupposes that there is some sort of temporal becoming that one experiences. If we deny that there is such actually becoming, then we can certainly extend the retentional model of the specious present to the specious lifetime. It was incorrect to state above that one did in fact experience snapshot of Workforce at the final corner as most-present. In effect, one's apparent sequential experience of an apple falling off of a table is essentially of the same kind of experience of watching an entire horse race. The main difference is one of the lengths of the apparent durations.

In principle this seems to be a cogent response. Because the temporal modes assigned to c-space points are offered as a means of explaining our experience of the snapshots as a linear sequence with duration, rather than all at once, it does not seem that temporal modes must necessarily change to account for the horse example. And, because I do not aim here to give an account of our experience of the passage of time, it seems that I should concede this point. So, though somewhat counterintuitive, the retentional specious present may be used to provide an account of such apparent motion.

Yet, even if this point is conceded, there is another general reason for denying that temporal modes must be static: not all of one's experienced snapshots can be placed neatly into a single horizontal stack in virtue of their contents' apparent relative relations alone. To support this claim, I first illustrate the manner in which a single horizontal snapshot stack is not clearly able to be generated. Then, I consider a further case in which this lack of a single horizontal stack is problematic if static temporal modes are assigned.

The above example involves an idealized situation in which you did not, for a moment, look away from the race. If one, say, glances down at a newspaper to examine the odds for the race, then this apparent experience must also correspond to a set of snapshots in the stack. However, given that stacks are ordered in virtue of the relative relations of the content of them alone, it seems that there must be at least two stacks: one corresponding to your newspaper reading and another corresponding to your watching the horse race. But, it is not clear that the newspaper-reading stack can be inserted into the watching-horse-race stack such as to reflect the order in which you seem to experience them. Further, because temporal modes are assigned in virtue of the manner in which they are stacked, it is not clear that the temporal modes can be assigned such as to account for the order of your experience at the track. Though this case highlights a problem with Barbouric retentionalism's reliance on snapshot stacks as a means of assigning temporal modes, it does not highlight the problem of using static temporal modes. To support this latter problem, we must turn to another variation on the case.

Assume that you seem to recall watching that race in the past. In effect, it seems that by here using it as an example, its temporal mode has changed due to you recalling it now. This, of course, also puts strain on the claim that retentions are distinguished from memories. But, assuming that we can provide an account of memories in terms of a very large stack of retentions only, which we must do because we are restricted to using a retentional model to provide an account of the specious lifetime given a single c-space point only, it seems that temporal modes must change in order give an account of our experience. To see the reason for this claim, suppose that temporal modes are static. Perhaps one may attempt to account for this case on the Barbouric retentional model by proposing that your apparent memory of the horse race which has been recalled by the example is actually part of the stack too: in addition to the not-present-at-all series of snapshots associated with the race, there is a series of snapshots later in the stack that, though resembling the content of the horse race, have a different temporal mode affixed to them that reflects their memory status. Clearly, to make sense of memories on this model, we must extend our repertoire of temporal modes to include a mode indicative of what seems to be a memory. Regardless, though, this proposal seems to use a series of retentional-ish snapshots that are each assigned a static temporal mode.

Nevertheless, this alternative is problematic given that temporal modes are assigned in virtue of their 'position' in the best-matching stack of snapshots. In the sense that there appears to be at least two best-matching stacks corresponding to one's experienced snapshots, rather than a single one, our reading of this example and recalling the race resembles the case in which one is reading a newspaper and watching the race. The major difference between these two cases on this proposal is only the different type of temporal modes, i.e., one associated with a standard retention and one associated with some sort of memory retention, assigned to the watching-the-horse-race stack. So, just as in the case in which you are watching the horse race, it is not clear exactly how the two stacks should be combined such as to reflect your experience, which is interspersed with reading these examples and recalling the race. And, thus, it is not clear exactly which particular temporal mode, which is a function of a snapshot's position in a horizontal stack, should be assigned to each snapshot.

Thus, barring the possibility that a sort of best-matching among 'memory' snapshots and 'perceived' snapshots may be developed, a possibility for which I do not have space to develop and discuss here, it appears that a change in temporal mode of a series of snapshots elsewhere in the stack is required as a means of offering an account of recollections. However, as argued above, there is no clear means of incorporating such change without violating ONT.

In effect, a Barbouric retentional model of the specious lifetime seems to either violate ONT by involving some sort of irreducible change of a snapshot's temporal mode or require much metaphysical development, e.g., some sort of best-matching catered to apparent sequences of snapshots that must, in accord with ONT, be only in term of the relative relations among the stuff in the content of snapshots. Let's now turn to the other folk option and evaluate whether it offers a more viable account.

Psycho-physical dualism can account for the specious lifetime by claiming that a single neural time capsule corresponds to a lifetime's worth of snapshots, and these snapshots are given by a large number of epiphenomenal mental properties, e.g., perceptually experiencing a particular snapshot.

To account for the specious present, our Barbouric psycho-physical dualism involved a meta-time along the mental properties. In that context, this meta-time is derivative from an ordering relation among the contents of the snapshots, parallel to that of best-matching, which is in virtue of the relative relations among the stuff in such contents alone. Thus, such meta-time does not violate ONT.

If this setup is applied to a lifetime experiences, then there is a large sequence of mental properties corresponding to a particular neural configuration. Such an account of the specious lifetime does offer an advantage over the retentionalist account: no temporal modes are required. However, the resulting meta-time across these mental properties violates ONT. Using the same argument for the retentionalist's lack of a single horizontal stack, it does not seem we can sequentially order the content of such mental properties in virtue of the relative relations among such content alone. Just as we cannot put all of the retentions that one experiences at a horse race in which one occasionally reads a newspaper into a single stack in virtue of the relative relations of the experienced stuff in the contents of these retentions alone, we cannot order the mental properties in a sequence in virtue of the relative relations of the stuff in their contents alone. Thus, the meta-time among the mental properties in a lifetime's worth of snapshots is not clearly reducible to such relative relations alone. In effect, the meta-time that results in psycho-physical dualism when applied to the specious lifetime presupposes there being some fundamental temporal relation among the snapshots. Thus, meta-time violates ONT.

To sum up the implications of this section for resolving the fourth clash: It seems that the retentional model is best suited to be wedded to a Machian QG in which GR's stacks are straightforwardly recoverable because of the apparent redundancy of the meta-time of dualism in this context.

On the other hand, a stackless Machian QG does not presently have a viable account of experience that can be associated with it. It was argued that, because some account of our largely sequential and linear experience is required on the stackless route for resolving T-POT, one should attempt to make sense of a specious lifetime given only a single c-space point. The resulting meta-time of the dualist account of the specious lifetime was argued to presuppose some irreducible temporal relations. Thus, this option is not viable due to its violation of ONT. Additionally, it was argued that the retentional model cannot account for one's specious lifetime without violating ONT or requiring much metaphysical development. So, an advocate of stackless QG should either attempt to develop the retentionist model to explain the specious lifetime or, perhaps more radically, deny that we do seem to experience a largely linear and sequential series of events. Because there are no connections among c-space points in stackless QG, this latter option is extremely radical: even granting that one may potentially experience a specious present, one, strictly speaking, may only experience a single specious present and, thus, the rest of one's apparent experience does not occur at any level. Thus, I struggle to see how this latter option can be viable at all in this context. In effect, a stackless QG requires the retentional model to be developed such that it offers an explanation of the specious lifetime.

In the final section of this chapter, I make some general conclusions regarding which route for addressing T-POT is more viable.

4 ACA's Implications for Barbour's Network

Before presenting the final results of ACA, it is useful to first summarize the results of our application of ACA to Barbour's network thus far.

By ACA, we first pounded Barbour's accounts into a single Machian network such that ONT and MP are upheld throughout them. Then, we identified *time* via the role it plays in this network. Because there are four roles that *time* plays, *time* is identified with four subconcepts and, thus, these four roles: being an infinitesimal instant, static existence, a time variable that is an arbitrary parameter and a derivative temporally ordered succession.

Next, we determined whether components of the temporal roles in Barbour's network conflict, are redundant or are irrelevant, with each other as well as with other concepts in the theory. Recall that if the role exhibits no such conflicts, incoherency or redundancy, then we accept this role and identify it with *time*. On the other hand, if the role exhibits such conflicts, incoherency or redundancy, then we must 'engage in metaphysics'.

Supposing that we can redefine instants such as to avoid the second clash noted above and given that the four clashes identified above are the only major clashes in the table, then it seems that there are no clashes among the infinitesimal instant and static existence roles in the QG, QT and GR parts of the network. In effect, by ACA, we can identify *time* with at least these two roles.

The arbitrary parameter role of the time variable, though it appears in GR, does not appear in QT or QG. The question of whether there should be such a role in GR, QT or QG seems to depend upon the manner of resolving the third clash. If one solves T-POT via eliminating GR's stacks, then the role seems to be irrelevant and, thus, eliminable. But, if T-POT is resolved via recovering stacks in QG such that a variable plays this role, then *time* should be identified with this role in addition to the first two roles. So, because the status of this role depends on the T-POT resolution, I leave it an open question as to whether *time* should be identified it.

This brings us to evaluating the clashes in the temporally ordered succession role. Due to these deep third and fourth clashes, we 'engaged in metaphysics' in an attempt to resolve them. Recall that if the concept is completely redundant, then one can eliminate it from such a list relatively easily. This can be exemplified by the possible treatment of the arbitrary parameter role in the preceding paragraph. However, barring such a result, 'engaging in metaphysics' involves either the construction of a coherent, relevant and non-redundant *time* or the reduction of its role to those played by other elements in the network.

Because Jackson characterized such metaphysics' aim as the creation of a list of what there is that is coherent, complete and parsimonious, we attempted to develop metaphysically coherent options such that they do not violate ONT.

The upshot of our attempt at resolving T-POT with this rough Jacksonian guide is as follows. There are two general options for resolving this clash between GR's having a derivative temporally ordered succession role and QG's denial that there is this role: recover in QG stacks that play this role, or eliminate GR's stacks. The latter option, though radical, was argued to provide a coherent Machian GR. The former approach, however, requires further work so that it does not violate ONT with the use of a stratified possible c-space, a WDE-generated hyperbola that has an ordering relation independent of the content of c-space points or a presupposed foliated stack.

Further, this engaging in metaphysics led to the following conclusions regarding resolving the fourth clash. This clash is between QG's not necessarily having linear stacks of points and our experience, which seems to be largely linear, sequential and extends beyond a specious present. Since Barbour's account of our experience is only presented for the specious present, it seems that, at the very least, his folk account requires further development in order to account for such experience. Moreover, because the resolution of this clash depends on the resolution to T-POT, we discussed means of resolving the clash in the context of both of the general T-POT options.

For the option in which stacks are recoverable in QG, a retentional model provides a viable Machian route for explaining such experience, while our dualism's meta-time is redundant. Thus, it seems that the retentional model should be chosen if stacks are recoverable in QG. For the option in which stacks are not recoverable in QG, either some account of our specious lifetime must be given or, perhaps, biting a rather large bullet, deny that we seem to experience a largely linear and sequential series of events. Due to the latter route's clash with our experience and its resulting implausibility in a stackless QG context, the former route should be taken. Regarding the former route, psycho-physical dualism is ruled out due to its meta-time's violation of ONT. The retentional model, though, may be rendered such that it does not violate ONT; however, its temporal modes and means of stacking are in need of much development.

ACA dictates that we should aim to create a coherent, relevant and non-redundant *time*, reduce its role to those played by other elements in the network or eliminate the role if it cannot be salvaged. What should conclude about the Machian network from the results of our engaging in metaphysics given this aim?

The T-POT resolution in which one eliminates GR's stacks offers a coherent and Machian account by effectively eliminating the derivative temporally ordered succession role. However, as revealed by the fourth clash, the elimination of this role does not bode as well with Barbour's account of our experience, i.e., much metaphysical development of the retentional model is required to explain the specious lifetime.

The T-POT resolution in which one recovers GR's stacks in QG and, thus, creates a derivative temporally ordered succession role in QG, requires more formal and interpretive development of the WDE such that ONT is not violated. However, this resolution at least has a ready-made and ONT-friendly account of our largely linear and sequential experience via the standard retentional model.

So, it seems that ACA has generated two options according to which Barbour's Machian network may be coherently developed. In the former no-stack option, the derivative temporally ordered succession role is eliminated from his fundamental physics. So, strictly speaking, there is no such role. Moreover, pending the development of a retentional model of the specious lifetime that is in accord with ONT, the appearance of the role may be accounted for in terms of the stack-induced modes of one's large number of simultaneous retentions. In contrast, the derivative temporally ordered succession role is retained in the latter option. Because this role is retained, there are sequences of c-space points. Thus, a standard retentional model can be used to account for our experience in this context. However, further interpretative and formal work is required on the WDE is required to recover such stacks without violating ONT.

Thus, though our application of ACA to ONT has not resulted in specifying its *time* completely, we at least have a partial definition and have made clear the two complete concepts of time in the offing given certain developments of his network. Plus, we have identified two routes in which Barbour's network can be developed as well as the criteria they must fulfil such that ONT is not violated.

With the application of ACA to our Barbouric case study complete enough for our purpose of assessing ACA's viability as a means of analysing *time* in Barbour's accounts, let's turn to the final chapter's discussion of ACA's results, method and extendibility to non-Barbouric accounts.

Chapter 7: The Scope and Limits of ACA

To examine the viability of ACA itself, I discuss the scope and limits of ACA as well as its potential extendibility of ACA to non-Barbouric accounts.

In this chapter, I discuss the scope of ACA's applicability to non-Barbouric contexts. To do so, I first address the issue of whether the 'metaphysical engagement' exemplified in the previous chapter can be generalizable. Additionally, I examine whether the focus of this stage on such metaphysical engagement alone is limiting in that the possible formal development of a physical theory is bracketed off. Then, in the final subsection, I discuss the issue as to whether ACA is actually applicable to theories that are not explicitly principle-based.

1 Reflections upon 'Metaphysical Engagement'

This metaphysical engagement, as exemplified in the previous chapter, does not appear to be rendered schematically. There we generally attempted to spell out options that are in accord with Barbour's claims and, more importantly, in accord with ONT. In the processes, we made use of some existent metaphysical positions, e.g., retentionalism, and attempted to modify them, where required, to metaphysically develop such options.

Furthermore, at the beginning of the previous chapter, I flagged the issue of whether my focus on conceptual clean-up and development, while bracketing off the formal development of the resulting options, imposes undue limitations on metaphysical engagement in the context of conceptually analysing physical theories. I argue that this does not impose an undue limitation on ACA's scope. Rather, once a particular option that is proposed by ACA is developed formally for a theory, ACA can be applied again to the resulting theory. Recall that if one is considering more than one theory, ACA's first stage of obtaining the theory(s) that one is examining involves pounding all of the theories into a single network. Though a theory and a formal extension appended to the theory may not be standardly regarded as two different theories, it is beneficial to treat them as such by ACA: by pounding the theory and its formal extension into a single network underpinned by, e.g., ONT and MP, one can then use ACA to determine whether the combination of the original theory with a formal extension of it can be made conceptually coherent and non-redundant.

To see the merits of this further application of ACA as well as the fact that ACA can be used to examine formal mechanisms that may be formulated in view of the results of its initial application to physical theory(s), consider its application to Barbour's account above. By pounding our theories into a single network such that it fulfils certain metaphysical principles, i.e., ONT and MP, we are able to identify and keep track of our basic ontological commitments as well as make salient metaphysical commitments that result from the theories in conjunction with ONT and MP, e.g., all properties among c-space points must be reducible to the stuff and relative relations of a single c-space point. In effect, ACA allows us to identify the basic metaphysical structure of the theories and their implications. In this process, however, we did examine the foundational formal mechanisms of the theories, e.g., the best-matching procedure. In effect, ACA's first stage, as exemplified in Chapters 2-5 above, does examine the role and status of formal mechanisms in a network.

So, though formal developments of the options resulting from our application of ACA may require further conceptual analysis, this analysis can be facilitated by ACA for a proposed formal development of an option suggested by an initial application of ACA to a network: ACA can be applied again to the theory with the additional or new formalism such that the new formalism is treated as part of a single Machian network. In effect, though my engaging in metaphysics above did not endeavour to spell out possible means of formally developing the options proposed, an additional application of ACA to a proposed formalization of one of the options can be used to assess the viability of such a mechanism in a Machian network.

Furthermore, this discussion highlights the fact 'engaging in metaphysics' is not limited to this above stage of ACA. Instead, ACA's initial stage as accomplished in Chapters 2-5, in which I presented Barbour's accounts and pounded them into a single Machian network, also involved doing metaphysics: the basic metaphysical commitments were made salient at each stage for his interpretations and use of various mathematical mechanisms and equations. Moreover, where development of the interpretation was required, e.g., his account of probability, options were suggested and their compatibility with his basic metaphysical commitments were assessed.

2 Generalizability of ACA to Non-Barbouric Accounts

Though we formulated ACA specifically to apply to Barbour's accounts, it does not seem restricted to his view only. However, one may consider it restricted to only physical theories that are principle-based. Because the Machian network into which we pounded his accounts make use of such principles, one may lament that it is not clear how ACA may be applied to a physical theory that is not formulated in view of specific metaphysical principles.

This may indeed be a restriction if one is only considering a physical theory that does not have many metaphysical and ontological commitments. Though a few temporal concepts will be delineated, such concepts may be limited to one similar to that of the arbitrary parameter role in Barbour's accounts. Moreover, it is unlikely that the table produced by such an application of ACA would have many clashes and, thus, may not offer much interesting metaphysical work to be done.

Nevertheless, ACA may be used to systematically evaluate a specific metaphysical position. If a physical theory is not explicitly formulated in view of certain metaphysical or ontological commitments, one may instead use ACA as a means of analysing whether a particular metaphysical thesis or specific ontological commitments may be appended to a physical theory(s). In effect, such a thesis or commitments can serve as the metaphysical principle(s) with which a network is constructed and evaluated. For example, if one wishes to systematically analyse whether presentism may be appended to standard GR, the ontological and metaphysical commitments associated with this view may play the same role that ONT and MP has in our application of ACA to Barbour's accounts. It seems that ACA can be then used as a means of identifying clashes in the role the time plays in GR with that played in a folk theory that arises from presentism. Thus, at least in principle, it seems that other physical theory's lack of explicit principles does not completely rule out an interesting application of ACA to them. But, of course, ACA needs to be applied such a physical theory(s) and metaphysical position in order to evaluate its actual efficacy in such a context.

Thus, it seems that ACA may be extended to non-Barbouric accounts Moreover, because it allows for an analysis of more than one physical theory, ACA is extremely useful for generating options to explore in attempts to merge QT and GR. In effect, ACA offers a schematic and largely viable means of systematically analysing *time* as it appears across folk and physical theories.

To conclude, at least for Barbour's account, ACA does indicate two ways in which his GR and QT may be reconciled such that his explicit Leibnizian and Machian metaphysical commitments are maintained. Thus, because it works in the Barbouric case study and is potentially applicable to other accounts, ACA is shown to offer a method of analysis that is applicable to *time* in physical theories and that may generally aid in the unification of GR and QT into a coherent QG.

Bibliography

Albert, D. *Quantum Mechanics and Experience*. (Cambridge: Harvard University Press, 1994).

Albert, D. "Elementary Quantum Mechanics." *Bohmian Mechanics and Quantum Theory: An Appraisal*. eds. Cushing et al. (Dordrecht: Kluwer, 1996).

Allori, V. et al. "Many Worlds and Schrödinger's First Quantum Theory." *The British Journal for the Philosophy of Science* 62, 2011: 1-27.

Amrein, W. *Hilbert Space Methods in Quantum Mechanics*. (Spain: EPFL Press, 2009).

Anderson, E. "Relational Particle Models. I. Reconciliation with standard classical quantum theory." (2006): arXiv:gr-qc/0511068v3.

Anderson, E. "On the recovery of geometrodynamics from two different sets of first principles." *Studies in the History of Modern Physics* 38, 2007.

Anderson, E. "The Problem of Time in Quantum Gravity." (2011): arXiv:1009.2157v2.

Arthur, R. "Time, Inertia and the Relativity Principle." (2007): http://philsci-archive.pitt.edu/3660/.

Bachtold, M. "Five Formulations of the Quantum Measurement Problem in the Frame of the Standard Interpretation." *Journal for the General Philosophy of Science* 39, 2008: 17-33.

Baierlein, R., Sharp, D. and Wheeler, J. "Three-Dimensional Geometry as Carrier of Information about Time." *Physical Review* 126, 1962: 1864-5.

Balashov, Y. and Janssen, M. "Presentism and Relativity." *The British Journal for the Philosophy of Science* 54, 2003: 237-46.
Barbour, J. "Relative-distance Machian theories." *Nature* 249, 1974: 328-9.

Barbour, J. "Relational Concepts of Space and Time." 1980: draft of 1982a.

Barbour, J. "Relational Concepts of Space and Time." *British Journal for the Philosophy of Science* 33, 1982: 251-74.

Barbour, J. "Leibnizian Time, Machian Dynamics and Quantum Gravity." *Quantum Concepts in Space and Time*. eds. Penrose and Isham. (Oxford: Clarendon Press, 1986).

Barbour, J. *Absolute or Relative Motion?* (Cambridge: CUP, 1989).

Barbour, J. "Einstein and Mach's Principle." *Studies in the History of General Relativity*. eds. Eisenstaedt and Knox (Boston: Birkhaüser, 1992).

Barbour, J. “Time and Complex Numbers in Canonical Quantum Gravity.” *Physical Review D* 47, 1993: 5422-9.

Barbour, J. “The timelessness of quantum gravity: I. The evidence from classical theory.” *Classical and Quantum Gravity* 11, 1994a: 2853-73.

Barbour, J. “The timelessness of quantum gravity: II. The appearance of dynamics in static configurations.” *Classical and Quantum Gravity* 11, 1994b: 2875-97.

Barbour, J. “The Emergence of Time and Its Arrow from Timelessness” *The Physical Origins of Time Asymmetry*. eds. Halliwell et al. (Cambridge: CUP,1994c).

Barbour, J. “General Relativity as a Perfectly Machian Theory.” *Mach’s Principle*. eds. Barbour and Pfister (Boston: Birkhaüser, 1995).

Barbour, J. *The End of Time*. (London: Phoenix, 1999).

Barbour, J. “The Development of Machian Themes in the Twentieth Century.” *The Arguments of Time*. ed. Butterfield (Oxford: OUP, 1999b).

Barbour, J. “On general covariance and best matching.” *Philosophy Meets Physics at the Planck Scale*. eds. Callender and Huggett (Cambridge: CUP, 2001).

Barbour, J. “Dynamics of pure shape, relativity and the problem of time.” (2003): arXiv:gr-qc/0309089.

Barbour, J. “The Nature of Time and the Structure of Space.” (essay submitted to fqxi: 2008).

Barbour, J. “The Definition of Mach’s Principle.” (2010): arXiv:1007.3368v1.

Barbour, J. “Shape Dynamics: An Introduction.” (2011): arXiv:1105.0183v1.

Barbour, J., Foster, B. and Murchadha, N. “Relativity without relativity.” (2002): arXiv:gr-qc/0012089.

Barbour, J. and Bertotti, B. “Gravity and inertia in a Machian framework.” *Nuovo Cimento* 38b, 1977.

Barbour, J. and Bertotti, B. “Mach’s Principle and the structure of dynamical theories.” *Proceedings of the Royal Society A* 382, 1982: 295-306.

Barbour, J. and Murchadha, N. “Classical and quantum gravity in conformal superspace.” (1999): arXiv:gr-qc/9911071v1.

Barbour, J. and Murchadha, N. “Conformal Superspace: the configuration space of general relativity.” (2010): arXiv:1009.3559v1.

Barbour, J. and Pfister. *Mach’s Principle*. (Boston: Birkhaüser, 1995).

Baron, S., Evans, P., Miller, K. “From Timeless Physical Theory to Timelessness.” *Humana Mente* 13, 2010: 35-60.

Bartnic, R. and Fodor, G. “Proof of the Thin Sandwich Conjecture.” *Physical Review D* 48, 1993: 3596-9.

Bealer, G. “Philosophical Knowledge.” *Philosophical Perspectives* 10. ed. J.Tomberlin. (Oxford: Blackwell, 1996).

Bealer, G. “A Theory of Concepts and Concept Possession.” *Philosophical Issues* 9, 1998: 261-301.

Beaney, M. “From Conceptual Analysis to Serious Metaphysics.” *International Journal of Philosophical Studies* 9, 2001: 521-9.

Bell, J. *Speakable and Unspeakable in Quantum Mechanics*. (Cambridge: CUP, 1988).

Belot, G. “Determinism and Ontology.” *International Studies in the Philosophy of Science* 9, 1995: 85-101.

Belnap, N. “Propensities and probabilities,” *Studies in History and Philosophy of Modern Physics* 38, 2007: 593-625.

Black, M. “The Identity of Indiscernibles.” *Mind* 61, 1952: 153-64.

Bonjour, L. *In Defence of Pure Reason: A Rationalist Account of A Priori Justification*. (Cambridge: Cambridge University Press,1998).

Boothby, W. *An introduction to differential and Riemannian geometry*. (Academic Press: 1986).

Brown, H. *Physical Relativity*. (Oxford: OUP, 2005).

Butterfield, J. “Seeing the Present.” *Mind* 93, 1984: 161-76.

Butterfield, J. “Julian Barbour, The End of Time?” (2001): arXiv:gr-qc/0103055v1.

Butterfield, J. “Julian Barbour, The End of Time.” British Journal for the Philosophy of Science 53, 2002: 289-330.

Butterfield, J. and Isham, C. “On the Emergence of Time in Quantum Gravity,” *The Arguments of Time*. ed. Butterfield (Oxford: OUP, 1999).

Butterfield, J. and Isham,C.J. “Spacetime and the Philosophical Challenge of Quantum Gravity.” *Philosophy Meets Physics at the Planck Scale*. eds. Callender and Huggett (Cambridge: CUP, 2001).

Callender, C. “What Makes Time Special.” (FQXi essay contest submission: 2008).

Callender, C. “Time’s Ontic Voyage.” *Future of Philosophy and Time*. ed. Bardon (Routledge: forthcoming).

Callender, C. and Huggett, N. “Introduction.” *Philosophy Meets Physics at the Planck Scale*. eds. Callender and Huggett (Cambridge: CUP, 2001a)

Callender, C. and Huggett, N. “Why Quantize Gravity (Or Any Other Field for That Matter)?” *Philosophy of Science* 68, 2001b: S382-94.

Campbell, S. “The Conception of a Person as a Series of Mental Events.” *Philosophy and Phenomenological Research* 73, 2006: 339-58.

Casullo, A. *A Priori Justification*. (New York: Oxford University Press, 2003).

Casullo, A. “A Priori Knoweldge.” *Encyclopedia of Philosophy*. ed. D.M.Borchert. (Detroit: Macmillian Reference USA, 2006).

Chalmers, D. *The Conscious Mind*. (Oxford: OUP, 1996).

Chalmers, D. and Jackson, F.. *Conceptual Analysis and Reductive Explanation*. *Philosophical Review* 110, 2001: 315-61.

Colosi, D. *On Some Aspects of Canonical and Covariant Approaches to Quantum Gravity*. (dissertation: 2004).

Craig, W. *Time and the Metaphysics of Relativity*. (Boston: Kluwer, 2001).

Craig, W. and Smith, Q.(eds.) *Einstein, Relativity, and Absolute Simultaneity*. (New York: Routledge, 2008).

Cushing, J. *Philosophical Concepts in Physics*. (Cambridge: CUP, 2003).

Dainton, B. *Stream of Consciousness*. (London: Routledge, 2000).

Dainton, B. “Time in Experience: Reply to Gallagher.” *Psyche* 9, 2003.

Dainton, B. “Temporal Consciousness.” (2010): http://plato.stanford.edu/entries/consciousness-temporal/.

Dainton, B. “Time, Passage, and Immediate Experience.” *The Oxford Handbook of Philosophy of Time*. ed. Callender (Oxford: OUP, 2011).

DeWitt, B. “Quantum Theory of Gravity. I. The Canonical Theory.” *Physical Review* 160, 1967: 1113-48.

DeWitt, B. “Quantum Mechanics and Reality.” *Physics Today* 23, 1970: 155-165.

DeWitt, B. and Graham, N. (eds) *The Many-Worlds Interpretation of Quantum Mechanics*. (Princeton: Princeton University Press, 1973).

DiSalle, R. "Newton's Philosophical Analysis of Space and Time." *The Cambridge Companion to Newton*. eds. B.Cohen & G.Smith. (Cambridge: Cambridge University Press, 2006a).

DiSalle, R. *Understanding Space-Time*. (Cambridge: Cambridge University Press, 2006b).

Dolev, Y. *Time and Realism*. (Cambridge: MIT Press, 2007).

Dorato, M. "Substantivalism, Relationism, and Structural Spacetime Realism." *Foundations of Physics* 30, 2000: 1605-28.

Dorato, M. "The Irrelevance of the Presentist/Eternalist Debate for the Ontology of Minkowski Spacetime." (2006a): http://philsci-archive.pitt.edu/id/eprint/2214.

Dorato, M. "Absolute becoming, relational becoming and the arrow of time." (2006b): http://philsci-archive.pitt.edu/2511/.

Dowe, P. "Philosophical Theories of Time meet Quantum Gravity." presented at *The Clock and the Quantum Conference*, 2008.

Dowell, J. "Empirical Metaphysics: the role of intuitions about possible cases in philosophy." *Philosophical Studies* 140, 2008: 19-46.

Dürr, D., Goldstein S., Zanghi., N. "Naïve Realism About Operators." (1996): arxiv.org/abs/quant-ph/9601013.

Eagle, A. "Twenty-One Arguments Against Propensity Analyses of Probability." *Erkenntnis* 60, 2004: 371-416.

Earman, J. and Norton, J."What Price Spacetime Substantivalism?" *British Journal for the Philosophy of Science* 38, 1987: 515-25.

Earman, J. *World Enough and Space-Time*. (Cambridge: MIT Bradford, 1989).

Esfeld, M. "Quantum Enganglement and a Metaphysics of Relations." (2004): http://philsci-archive.pitt.edu/1735/.

Esfeld, M. "The Impact of Science on Metaphysics and Its Limits." *Absracta* 2, 2006: 86-101.

Everett, H. "'Relative State' Formulation of Quantume Mechanics." *Reviews of Modern Physics* 29, 1957: 454-62.

Fine, K. "Essence and Modality." *Philosophical Perspectives* 8, 1994: 1-16.

Fischer, A. “The Theory of Superspace.” *Relativity-Proceedings of the Relativity Conference in the Midwest*. eds. Carneli and Fickler. (New York: Plenum Press, 1969).

Fischer, A. “Resolving the singularities in the space of Riemannian geometries.” *Journal of Mathematical Physics* 27, 1986: 718-39.

French, S. and Krause, D. *Identity in Physics*. (Oxford: OUP, 2006).

Friedman, M. *Foundations of Space-Time Theories*. (Princeton: Princeton University Press, 1983).

Fodor, J. *Concepts: Where Cognitive Science Went Wrong*. (Cambridge: MIT Press,1998).

Gallagher, S. “Sync-ing in the stream of experience: Time-consciousness in Broad, Husserl, and Dainton.” *Psyche* 9, 2003.

Gasco, E. “Mach’s Contribution to the origin of Inertia.” **(**2003): http://philsci-archive.pitt.edu/1259/.

Giulini, D. “The Superspace of Geometrodynamics.” (2009): arXiv:0902.3923v1.

Grush, R. “Internal models and the construction of time.” *Journal of Neural Engineering* 2, 2005: S209-18.

Grush, R. “Time and Experience.” *The Philosophy of Time*. ed. Muller. (Frankfurt: Kloasterman, 2007).

Grush, R. “Temporal representation and dynamics.” *New Ides in Psychology* 26, 2008: 146-57.

Hall, G. *Symmetries and curvature structure in general relativity*. (Singapore: World Scientific Publishing, 2004).

Harman, P. *Metaphysics and Natural Philosophy*. (Brighton: Harvester Press, 1982).

Hartle, J. and Hawking, S. “Wave function of the Universe.” *Physical Review D* 28, 1983: 2960-75.

Heisenberg, W. *The Physical Principles of Quantum Theory*. (Chicago: Chicago UP. 1930).

Henderson, D. and Horgan, T. “What Is A Priori, and What Is It Good For?” *The Southern Journal of Philosophy* 38 (Spindel Supplement), 2001: 51-86.

Hendry, R. “Two Conceptions of the Chemical Bond.” *Philosophy of Science* 75, 2008: 909-20.

Hestevold, H. and Carter, W. “On Presentism, Endurance, and Change.” *Canadian Journal of Philosophy* 32, 2002: 491-510.

Hitchcock, C. “Probability and Chance.” *International Encyclopedia of the Social and Behavorial Sciences* 18, 2002: 12089-95.

Huffman, C. *Archytas of Tarentum: Pythagorean Philosopher and Mathematician King*. (Cambridge: CUP, 2005).

Hume, D. *Enquiry Concerning Human Understanding.* ed. Sekby-Bigge (Oxford: OUP, 1978).

Hoefer, C. “The Metaphysics of Space-Time Substantivalism.” *The Journal of Philosophy* 1996: 5-27.

Hughes, R. *The Structure and Interpretation of Quantum Mechanics*. (Cambridge: Harvard UP, 1989).

Iftime, M. and Stachel, J. “Fibered Manifolds, Natural Bundles, Structured G-Sets and all that.” (2005): gr-qc/0505138.

Isham, C. “Canonical Quantum Gravity and the Problem of Time.” (1992): arXiv:gr-qc/9210011v1.

Isham, C. “Prima Facie Questions in Quantum Gravity.” (1993): arXiv:gr-qc/9310031v1.

Ishmael, J. “Rememberances, Mementos, and Time Capsules.” *Time, Reality, and Experience*. ed. Callender. (Cambridge: CUP, 2002).

Jackson, F. “Epiphenomenal Qualia.” *Philosophical Quartely* 32, 1982: 127-36.

Jackson, F. “Armchair Metaphysics.” *Philosophy in Mind*. eds. O’Leary-Hawthorne and Michael. (Dordrecht: Kluwer, 1993).

Jackson, F. “Metaphysics by Possible Cases.” *Monist* 77, 1994: 93-110.

Jackson, F. *From Ethics to Metaphysics*. (Oxford: Oxford University Press,1998).

Jammer, M. *Concepts of Simultaneity*. (Baltimore: John Hopkins University Press, 2006).

Jung, K. “Can the Schrödinger wave function be associated with a concrete physical wave?” *Annales de la Fondation Louis de Broglie* 34, 2009: 143-63.

Kant, I. *Critique of Pure Reason*. trans. W.Pluhar. (Indianapolis: Hackett, 1996).

Kiefer, C. *Quantum Gravity*. (Oxford: OUP, 2007).

Kitcher, P. *The Nature of Mathematical Knowledge*. (New York: Oxford University Press, 1983).

Koch, C. *The Quest for Consciousness*. (Roberts: Colorado, 2004).

Kuchař, K. "Time and Interpretations of Quantum Gravity." *Proceedings of the Fourth Canadian Conference on General Relativity and Relativistic Astrophysics.* eds. Kunstatter and Williams (Singapore: World Scientific, 1992).

Kuchař, K. "The Problem of Time in Quantum Geometrodynamics." *The Arguments of Time*. ed. Butterfield (Oxford: OUP, 1999).

Ladyman, J. and Bigaj, T. "The Principle of the Identity of Indiscernibles and Quantum Mechanics." *Philosophy of Science* 77, 2010: 117-136.

Leibniz, G. "Leibniz-Clarke correspondence." *Space from Zeno to Einstein*. ed. Huggett (Cambridge: MIT Press, 1999).

Leibniz, G. *Philosophical Papers and Letters*. ed. and trans. Loemker (Dordrecht: Kluwer, 1975).

Le Poidevin, R. *The Images of Time*. (Oxford: OUP, 2007).

Le Poidevin, R. "The Experience and Perception of Time." (2009): http://plato.stanford.edu/entries/time-experience/.

Laurence, S and Margolis, E. "Concepts and Conceptual Analysis." *Philosophy and Phenomenological Research* 67, 2006: 253-82.

Laurence, S. and Margolis, E. "Concepts and Cognitive Science." *Concepts: Core Readings*. (Cambridge: MIT Press, 1999).

Lewis, P. "Life in Configuration Space." *British Journal for the Philosophy of Science* 55, 2004: 713-29.

Lewis, D. "How to Define Theoretical Terms." *Journal of Philosophy* 67, 1970: 427-46.

Lockwood, M. "'Many Minds' Interpretations of Quantum Mechanics." *British Journal for the Philosophy of Science* 47, 1996: 159-88.

Loewer, B. "Comment on Lockwood." *British Journal for the Philosophy of Science* 47, 1996: 229-32.

Margolis, E. and Laurence, S. *Concepts: Core Readings*. (Cambridge: MIT Press, 1999).

Margolis, E. and Laurence, S. "The Ontology of Concepts- Abstract Objects or Mental Representations?" *Noûs* 41, 2007: 561-93.

Maudlin, T. "Completeness, supervenience and ontology." *Journal of Physics A* 40, 2007: 3151-71.

McDonough. “Leibniz: Creation and Conservation and Concurrence.” *Leibniz Review* 17, 2007: 31-60.

McRae, R. “The theory of knowledge.” *The Cambridge Companion to Leibniz*. ed. Jolley (Cambridge: CUP, 1995).

Melia, J. “Holes, Haecceitism and Two Conceptions of Determinism.” *British Journal for the Philosophy of Science* 50, 1999: 639-64.

Mercer, C. and Sleigh, R. “Metaphysics: The early period to the *Discourse on Metaphysics*.” *The Cambridge Companion to Leibniz*. ed. Jolley (Cambridge: CUP, 1995).

Mercer, C. *Leibniz’s Metaphysics*. (Cambridge: CUP, 2001).

Miscevic, N. “Deep and Superficial Apriori.” *Acta Analytica* 15, 2000: preprint.

Miscevic, N. “Science, Commonsense and Philosophy: A Defence of Continuity (a critique of ‘network apriorism).” *International Studies in the Philosophy of Science* 15, 2001: 19-31.

Miscevic, N. “Rescuing Conceptual Analysis.” *Croatian Journal of Philosophy* 5, 2005: 447-63.

Miscevic, N. “Empirical Concepts and A Priori Truth.” *Croatian Journal of Philosophy* 5, 2005b: 289-315

Monton, B. “Wave Function Ontology.” *Synthese* 130, 2002: 265-77.

Monton, B. “Presentism and Quantum Gravity.” (2005): http://philsci-archive.pitt.edu/2308/.

Monton, B. “Quantum Mechanics and 3N-Dimensional Space.” *Philosophy of Science* 73, 2006: 778-89.

Mott, N. “The Wave Mechanics of α–Ray Tracks.” *Proceedings of the Royal Society of London A* 126, 1929: 79-84.

Moore, W. *Schrödinger, life and thought*. (Cambridge: CUP, 1992).

Nagasawa, Y. “The Knoweldge Argument and Epiphenomenalism.” *Erkenntis* 72, 2010: 37-56.

von Neumann, J. *Mathematical Foundations of Quantum Mechanics*. (Princeton, Princeton UP, 1952).

Ney, A. “The Status of our Ordinary Three Dimensions in a Quantum Universe.” *Noûs* 2010 (preprint).

North, J. “The Structure of a Quantum World.” *The Wavefunction*. eds. Ney and Albert (Oxford: OUP, forthcoming).

Norton, J. “Mach’s Principle before Einstein.” *Mach’s Principle: From Newton’s Bucket to Quantum Gravity*. eds. Barbour and Pfister (Boston: Birkhaüser, 1995).

Norton, J. “What Can We Learn about the Ontology of Space and Time from the Theory of Relativity?” (2003): http://philsci-archive.pitt.edu/225/.

Norton, J. “A Conjecture on Einstein, the Independent Reality of Spacetime Coordinate Systems and the Disaster of 1913.” *The Universe of General Relativity*. eds. Kox and Einsenstaedt (Boston: Birkhaüser,2005).

Papineau, D. “Theory-Dependant Terms.” *Philosophy of* Science 63, 1996: 1-20.

Papineau, D. “A Fair Deal for Everettians.” *Many Worlds- Everett, Quantum Theory, and Reality*. eds. Saunders et al. (Oxford: OUP, 2010).

Parfit, D. “Personal Identity.” *Philosophical Review* 80, 1971: 3-27.

Parkinson, G. “Philosophy and Logic.” *The Cambridge Companion to Leibniz*. ed. Jolley (Cambridge: CUP, 1995).

Parsons, G. and McGivern, P. “Can the Bundle Theory Save Substantivalism from the Hole Argument?” *Philosophy of Science* 68, 2001: S358-70.

Peacocke, C. “Rationale and Maxims in the Study of Concepts” *Noûs* 39, 2005: 167-78.

Perez, A. “Spin Foam Models for Quantum Gravity.” (2008): arXiv:gr-qc/0301113v2.

Pettit, P. “Descriptivism, Rigidified and Anchored.” *Philosophical Studies* 118, 2004: 323-338.

Plebański, J. and Krasiński, A. *An Introduction to general relativity and cosmology*. (Cambridge: CUP, 2006).

Pooley, O. “Relationalism Rehabilitated? II: Relativity.” (2001): http://philsci-archive.pitt.edu/221/.

Pruss. *The Principle of Sufficient Reason: A Reassessment*. (Cambridge: CUP, 2006).

Pullin, J. “Canonical quantization of general relativity: the last 18 years in a nutshell.” (2002): arXiv:gr-qc/0209008v1.

Putnam, H. *Philosophical Papers 3: Realism and Reason*. (Cambridge: Cambridge University Press, 1983).

Rey, G. “Philosophical Analysis, Cognitive Psychology, and the Importance of Empty Concepts.” 2004, preprint.

Rickles, D. “Time and Structure in Canonical Gravity.” *Structural Foundations of Quantum Gravity*. eds. French et al. (Oxford: OUP, 2006).

Rickles, D. “Quantum Gravity: A Primer for Philosophers.” *The Ashgate Companion to Philosophy of Physics*. ed. Rickles (Aldershot: Ashgate, 2008).

Rips, L. “The Current Status of Research on Concept Combination.” *Mind and Language* 10, 1995: 72-104.

Rodriguez-Pereyra, G. “How Not to Trivialise the Identity of Indiscernibles.” *Concepts Properties and Qualities*. eds. Strawson and Chakrabarti (Aldershot: Ashgate, 2006).

Rovelli, C. *Quantum Gravity*. (Cambridge: CUP, 2004).

Rovelli, C. “Notes for a brief history of quantum gravity.” (2008): arXiv:gr-qc/0006061v3.

Rutherford, D. “Metaphysics: The late period.” *The Cambridge Companion to Leibniz*. ed. Jolley (Cambridge: CUP, 1995).

Rynasiewicz, R. “The Lessons of the Hole Argument.” *British Journal for the Philosophy of Science* 24, 1994: 407-36.

Rynasiewicz, R. “Is There a Syntactic Solution to the Hole Problem?” *Philosophy of Science* 62, 1996: S55-62.

Salmon, W. “Objectively Homogeneous Reference Classes.” *Synthese* 36, 1977: 373-8.

Saunders, S. “Physics and Leibniz’s Principles.” *Symmetries in Physics: Philosophical Reflections*. eds. K.Brading and E.Castellani. (Cambridge: Cambridge University Press, 2003).

Saunders, S. “Time, Quantum Mechanics, and Decoherence.” *Synthese* 102, 1995: 235-66.

Saunders, S. “Time, Quantum Mechanics, and Probability.” *Synthese* 114, 1998: 373-404.

Saunders, S. “Physics and Leibniz’s Principles.” *Symmetries in Physics: Philosophical Reflections*. eds. Brading and Castellani (Cambridge: CUP, 2003).

Saunders, S. “Are Quantum Particles Objects?” *Analysis* 66, 2006: 52-63.

Saunders S., “Chance in the Everett Interpretation.” *Many Worlds- Everett, Quantum Theory, and Reality*. eds. Saunders et al. (Oxford: OUP, 2010).

Saunders, S. and Wallace, D. “Branching and Uncertainty.” *British Journal for the Philosophy of Science* 59, 2008: 293-305.

Schlosshauer, M. and Fine, A. "Decoherence and the foundations of quantum mechanics." *New Views of Quantum Mechanics*. eds. Evans and Thorndike (Chicago: University of Chicago Press, 2004).

Schrödinger, E. "An Undulatory Theory of the Mechanics of Atoms and Molecules." *Physics Review* 28, 1926: 1049-70.

Smolin, L. "The Present Moment in Quantum Cosmology: Challenges to the Arguments for the Elimination of Time." (2001): arxiv:gr-qc/0104097.

Stachel, J. "The Rise and Fall of Geometrodynamics." *PSA* 1972: 31-54.

Stachel, J. *Einstein from B to Z.* (Boston: Birkhaüser, 2002).

Stalnaker, Robert. "Metaphysics Without Conceptual Analysis." *Philosophy and Phenomenological Research* 62, 2001: 631-6.

Tidman, P. "Justification of A Priori Intuitions." *Philosophy and Phenomenological Research* 56, 1996: 161-71.

Torretti, R. "Can Science Advance Effectively Through Philosophical Criticism and Reflection?" (2006): philsci-archive.pitt.edu/archive/00002875/.

Torretti, R. *The Philosophy of Physics*. (Cambridge: CUP, 1999).

Unruh, W. and Wald, R. "Time and the interpretation of canonical quantum gravity." *Physical Review D* 40, 1989: 2598-2614.

Vaidman, L. "Time Symmetry and the Many-Worlds Interpretation." *Many Worlds- Everett, Quantum Theory, and Reality*. eds. Saunders et al. (Oxford: OUP, 2010).

Vickers, P. "Frisch, Muller, and Belot on an Inconsistency in Classical Electrodynamics." *British Journal for the Philosophy of Science* 59, 2008: 767-92.

Wallace, D. "Everettian rationality: defending Deutsch's approach to probability in the Everett interpretation." *Studies in the History and Philosophy of Modern Physics* 34, 2003: 415-39.

Wallace, D. "Decoherence and Ontology." *Many Worlds- Everett, Quantum Theory, and Reality*. eds. Saunders et al. (Oxford: OUP, 2010).

Wallace, D. and Timpson, C. "Quantum Mechanics on Spacetime I: Spacetime State Realism." (2009): http://philsci-archive.pitt.edu/4621/.

Weingard, R. "A philosopher looks at string theory." *Philosophy Meets Physics at the Planck Scale*. eds. Callender and Huggett (Cambridge: CUP, 2001).

Weinstein, S. “Absolute Quantum Mechanics.” *British Journal for the Philosophy of Science* 52, 2001: 67-73.

Wheeler, J. *Geometrodynamics*. (New York: Academic Press: 1962).

Wheeler, J. “Geometrodynamics and the Issue of the Final State.” *Relativity, Groups and Topology*. eds. DeWitt and DeWitt (New York: Gordon and Breach, 1964).

Zimmerman, D. “Persistence and Presentism.” *Philosophical Papers* 25, 1996: 115-23.

Zurek, W. “Quantum Jumps, Born’s Rule, and Objective Reality.” *Many Worlds- Everett, Quantum Theory, and Reality*. eds. Saunders et al. (Oxford: OUP, 2010).