The Passage of Time
and the Evolution of the Universe-Tree

by

Randy Reiffer

B. A., The University of British Columbia, 1988
A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in
THE FACULTY OF GRADUATE STUDIES

Department of Philosophy

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

1 May 1991

c  Randy Reiffer 1991
In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of **PHILOSOPHY**

The University of British Columbia
Vancouver, Canada

Date **23 MAY 1991**

DE-6 (2/88)
1.0 Abstract

McTaggart's paradox leads to the conclusion that time is unreal. The paradox has two key premises: the premise that time flow is a necessary component of time, and the premise that time flow entails a contradiction. The paradox therefore derives its strength from the apparent contradiction entailed by the passage of time. The conclusion of McTaggart's paradox, that time is unreal, could be otherwise stated as the claim that there are no logically possible models of time with both the property of the earlier/later relation and the property of time flow.

Given this analysis of the paradox, I claim that McTaggart's conclusion can be rejected. Bigelow (1989) has argued that the logic of McTaggart's paradox suggests a modal solution. One possible modal solution could be along the lines that McCall (1966, 1976, 1984, forthcoming) is developing. I show that McCall's model is a logically and physically possible model of time flow. McCall's model explains the passage of time through the metaphysical mechanism of the evolution of the universe-tree. The universe-tree is a changing set of connections between the physically possible worlds.

In the introduction, section 2, I present an overview of the two main groups of philosophical views on the problem of the passage of time. The debate between the two groups, that of tensers and that of non-tensers, serves to illustrate the difficulties that giving an account of the passage of time that must be confronted. The critical difficulty is shown to be to give an account of the changing temporal relation of nowness.

In section 3, I critically evaluate McTaggart's paradox. In so doing, I clarify the problem of giving an account of the changing temporal relation of nowness. I accept Bigelow's (1989) argument that the logical structure of the paradox, together with the elegance of tense logic, suggests a modal solution to the problem of temporal passage. In the remainder of this section, I show that McTaggart's paradox is logically valid, and that while some of McTaggart's claims are unsound, overall the paradox highlights a crucial philosophical puzzle: to give an account of the ever-changing moving now.

In section 4, I show that McCall's model is a logically and physically possible model of time flow. McCall's model objectively distinguishes the present from past and future events through the dynamic evolution of the universe-tree. The tree consists of a branching connectedness relation between the physically possible worlds. The branch-structure is not fixed; the change is asymmetric, and it is this asymmetry that is the ontological extension of the moving now. The asymmetric evolution
of the tree makes the branch-structure to be future-directed. The now moves up the tree of connections, actualizing one track as the non-selected branches vanish. I show that McCall's model is logically possible by proving that it is mathematically determinate in its ontological extension. Furthermore, the model is physically possible, since it contains enough topological resources to derive local Euclidean computability.

In the final analysis, section 5, I come to the conclusion that McCall's model is a good counterexample to the conclusion of McTaggart's paradox. McCall's model is a logically and physically possible model of time flow. The passage of time is explained by the evolution of the branch structure of the universe-tree. The universe-tree is the set of connections between the selected and nonselected physically possible worlds. The motion of the now in our topological space is the result of the metaphysics of the logical space within which our topological space is embedded. Thus the passage of time in the actual world is a function of the changing relation between the actual world and the other possible worlds.
Table of Contents

1.0 Abstract ......................................................... ii
List of Figures .................................................... v
Acknowledgments .................................................... vi
2.0 Introduction .................................................... 1

3.0 The Passage of Time ........................................... 18
  3.1 McTaggart's paradox ........................................... 18
    3.1.1 The Infinite Regress Problem ......................... 25
    3.1.2 The Possible Worlds Metaphysics Solution ........ 34
  3.2 The logic of McTaggart's paradox ......................... 43
  3.3 The soundness of McTaggart's paradox .................... 46
  3.4 The conclusion of McTaggart's paradox ................... 55

4.0 The Evolution of the Universe-Tree ........................ 56
  4.1 McCall's model .............................................. 56
    4.1.1 The Transfinite Plus Problem ....................... 62
    4.1.2 The Possible Worlds Metaphysics Solution ........ 68
  4.2 The logic of McCall's model ............................... 74
  4.3 The soundness of McCall's model ......................... 85
  4.4 The conclusion of McCall's model ....................... 90

5.0 Conclusion .................................................... 92

6.0 References ................................................... 93
List of Figures

Figure 1: A-series and B-series ......................... 3
Figure 2: A Light Cone ................................. 6
Figure 3: The universe-tree. ......................... 59
Figure 4: The now selects a branch. ................. 60
Figure 5: The universe-tree evolves. ............... 61
Figure 6: Bifurcation of space-time. ............... 65
Figure 7: Minkowski space. ......................... 72
Figure 8: Modal-Minkowski space. .................. 73
Figure 9: Light Cones in a Black Hole ............. 88
Acknowledgements

I would like to thank my parents for support and my girlfriend Bridget Minishka for encouragement. I would also like to thank Greg Hagen and Dr. Steven Savitt for helpful comments on earlier drafts of this thesis. I would like to thank Mr. Jack Stewart for his guidance and instruction. Finally, I thank Ian T. Sadler for his computer expertise and the use of his laptop computer.
2.0 Introduction

The passage of time seems real. Events seem to change from being future, to being present, and to then being past. Yet the passage of time also seems paradoxical. Real events are always an unchanging, fixed interval apart, described by either one of the earlier than or later than or simultaneous with relations. How can events have both changing and unchanging properties? Perhaps the central problem in twentieth century studies in the philosophy of time is to explicate the nature of the passage of time. A large spectrum of positions have been claimed in response to McTaggart's 1908 claim, and it would be a monumental task beyond the scope of this paper to completely evaluate all of the plausible candidates.

Most philosophers can be placed in one of two main camps of the plausible positions on the problem of the passage of time. One position is that of the non-tensers, who hold that time consists only of the uncontroversial unchanging relations, one of the set containing the earlier than, later than, and simultaneous with relations. Non-tensers appeal to the timeless sense of 'is' as demonstrated in the sentence: "Two plus two is four." The NT-position thus analyzes the temporal copula 'is' as one of only three possible relations: earlier than, later than, and simultaneous with. The NT-position has a long tradition of
defenders and has been developed by Russell (1903), Williams (1951), Smart (1955), and Grünbaum (1963).

The other main camp of philosophers may be called that of the tensers. The tensers' camp can be further subdivided into two exclusive groups: one, those who hold that time consists of both changing and unchanging relations; and two, those who claim that time intrinsically consists of a changing relation, and may therefore have unchanging extrinsic relations. Essential to the view of the tensers is that no analysis can be given of the meaning of 'is' as in such sentences as: "The cat is on the mat" which would reduce the 'is' to one of the earlier than /later than /simultaneous with relations. For a non-tenser, the 'is' is to be timeless; the sentence is analyzed to carry the information that the cat is on the mat at some time t. According to tensers, referred to as the T-position, the 'is' in such sentences is not timeless, but distinctively temporal; the sentence carries the information that the cat is on the mat now, at this present moment. The 'is' in such claims about physical events is, according to the T-position, necessarily tensed. For a tenser, the expression "at the present moment" is not further analyzable into "simultaneous with some time t." Similarly, the sentence "Two plus two is equal to four" is analyzed by a tenser to have a distinctively temporal copula. T-positions have had their advocates, though each defender has typically pursued a line inconsistent with the other non-standard lines. Recent defenders

The set of temporal relations thought to be ontologically prior by the NT-position, the set of earlier than, later than, and simultaneous with, is also known in the literature since McTaggart as the B-series, while the set of temporal relations thought to be ontologically prior by the T-position is known as the A-series, and consists of the relations of past, present, and future. The two temporal series, A and B, seem to be related to one another in a certain respect. C.D. Broad (1938) notes that, "At any moment any term in a B-series will be characterized by one and only one term in this series of A-characteristics"¹ and that the converse relation is also true. While it is usually thought that the A-series is moving and the B-series is static, motion is relative, and either series could be thought to be moving with

---

¹ "Ostensible Temporality", p. 290.
respect to the other (see figure 1).

The problem of temporal passage is to explain the phenomenon that an event is first future, then becomes present for an instantaneous moment, then vanishes into the past. What is this phenomenon? The passage of time is captured by such sentences as:

(1) The present was just future and will soon be past.

This fleeting phenomenon can be described in two other different but equivalent ways:

(2) The future will be present and then it will be past.

(3) The past was once present at a time when what is present was in the future.

The analysis will focus on (1).

The two sets of properties, A-series and B-series, also appear to be incompatible in certain respects. Analysis of sentences of A-series copulas shows that their truth-values change in time, while the truth-value of sentences with B-series copulas does not change in time. Thus, the A and B series may be thought to be incompatible, since one set of properties changes its truth-value in time; the other does not. The incompatibility is thought by some non-tensers to be due to an incoherency in the A-series. This NT-view is supported by the failure of the following three attempts to explicate the A-series. I will caution that while these attempts fail, they fail in interesting ways, and that the upshot of this analysis is that the now is not
what the NT-position has thought it to be, not that the A-series term now cannot be explicated at all.

Tensers might want to take the phenomenon of time flow as basic or primitive, and thus hold that no explication of its nature is possible. However, a refusal to submit one's view to interrogation by one's peers is seems quite suspicious in itself. Why should time flow be a primitive, unexplainable feature of our world? Why should anyone assume that time flow is unexplainable when there are some explanations available? Before tensers can prove statements about the passage of time, they must first explicate the nature of temporal passage. They must provide a non-circular and non-question-begging explanation of time flow. Tensers must avoid the threat of the infinite regress of explanation of the past, present, and future. So tensers must answer the question: How are the A-series terms related to one another?

In response to the question of how the A-series events are related to one another, one might hold that such events can be simultaneously past, present, and future. This attempt to explicate the A-series with the help of the B-series is of no use. Events cannot be simultaneously past, present and future. The simultaneous line fails because simultaneity is defined in terms of being present for an instant. Thus, explicating the A-
series in terms of the B-series, where the B-series is explained in terms of the A-series, results in a circular definition.

The simultaneous view entails the falsity of the following necessarily true proposition:

(4) What is past is not future.

If the simultaneous view were true, then what is past would simultaneously be future. Therefore the simultaneous line is false.

![Figure 2: A Light Cone](image)

At this point it is informative to consider whether or not the relativity of simultaneity in Einstein's theories may be of some help to our problem of explicating temporal passage with regard to the A-series relations (see figure 2). Certainly Earman (1974) is correct in "An Attempt to Add a Little Direction to the
Problem of the Direction of Time" when he suggests that by formulating the questions in the philosophy of time in a precise and formal manner we can achieve more useful results than otherwise.

However, the mathematical space-time formalism does not decide the question of the nature of the passage of time. Indeed, defenders of the NT-position have suggested that the present lack of a mathematical space-time formalism which would represent the passage of time, together with the fact that the present mathematical space-time formalism does explain many other features of our world, entails that the passage of time is unreal.

Defenders of the T-position have three possible responses to the NT-argument above: one, that the passage of time is not the sort of phenomenon which could be captured by a formal theory; two, that the formal space-time theories may represent temporal passage, but only in a metaphysically neutral way; and three, that the present formalism is simply false, and will have to be replaced with another formalism wherein passage is accounted for. Philosophers may well be suspicious of the first possible response, that temporal passage is not the sort of phenomenon which could be captured by a formal theory, since the purpose of seeking a formal space-time theory is to describe all and only the entities of space and time and their relations to one
another. But there are limits to what a formal theory, derived from empirical observation and testing, can inform about the reasons why it, as a formal theory, happens to be true of our world. Explication of passage requires a metaphysical theory. Philosophers, I argue, can accept the second possible response, that formal space-time theories may represent passage, but only in a metaphysically neutral manner. If so, then the support the NT-position derived from the failure of the present formal space-time theory to represent passage is defused, since even if the formal theory did represent passage, that representation would not be sufficient to decide the metaphysical problem. The formal space-time theories describe the ontological realm of physics, while explication of temporal passage cannot be decided through experiment and observation per se, but rather through metaphysical analysis. Therefore, the failure of the formal space-time theories to represent passage is not a failure at all, since the task is supererogatory. Hence, philosophers may remain skeptical of the third possible response, that the present formalism is simply false, and that passage needs to be represented therein. Rather, passage needs to be incorporated into a metaphysical account which accords well with the physical account given by the formal space-time theory.

How could the formalism introduce temporal passage in a metaphysically neutral manner, if in fact that formalism does not, at present, represent passage? Light-cones are assigned a
direction of temporal orientation (see figure 2); they are intrinsically symmetric about the point of origin. The description of temporal passage in space-time theories is given in symbols as \(<<M,g,V>,0>\) where \(M\) is a manifold, \(g\) is a metric on \(M\), and \(V\) is the linear symmetric connective compatible with \(g\) which defines the affine structure. \(0\) is the temporal orientation at each point \(p \in M\). All affine geodesics are either timelike \((g(T_e,T_e)>0)\), spacelike \((g(T_e,T_e)<0)\), or null \((g(T_e,T_e)=0)\).\(^2\) But if the manifold \(M\) is temporally orientable, then it is distinguishable from another manifold, \(M\), \(M\neq M\), such that \(<<M,g,V>,0^T>\), where \(0^T\) is the opposite temporal orientation from \(0\). But, and this point is the key to the argument, the affine structure of \(M\) is the same as in \(M\), hence the affine structure alone is not sufficient to distinguish \(0\) from \(0^T\), hence the formalism is not sufficient to distinguish the direction of temporal orientation \(T\). Therefore, while Earman is correct that useful results can be obtained from studying the mathematics of space-time theories, in this case, the problem of the passage of time is metaphysical, and hence cannot be solved through mathematical-physical a priori theorizing alone. The problem of temporal passage is more complex, hence the formalism is neutral on the problem. Another way to put the point is that the formalism does not contain enough resources to distinguish the direction of temporal orientation \(T\), hence does not contain

enough explanatory resources to explain the passage of the moving now.

The reason why this result should be derived can be seen by anticipating the discussion of McCall's dynamic tree model. The phenomenon of temporal passage is the result not only of causal interactions within our own actual world \( a \), but also the result of the connectivity relation between \( a \) now and the changing set of physically possible future worlds. In other words, the formalism of physics only describes causal interaction within \( a \), while temporal passage is the result of interaction both within \( a \) and also between \( a \) and the set of physically possible future worlds picked out by the connectivity relation.

So the line to explicate the A-series in terms of simultaneity or the relativity of simultaneity has failed. Perhaps events are timelessly past, present, and future? Unfortunately, this line fails also. Events cannot be timelessly past, present and future. The timeless line fails because 'timelessness' is non-informative as an explication of the distinctly temporal relations of pastness, presentness, and futurity. In what sense could time be timeless? 'Timelessness' is either a metaphor, in which case it is ambiguous; or 'timelessness' should be interpreted literally, in which case the analysis reduces to claiming that there is no temporal passage and hence no time, which is clearly wrong.
Finally, one might suppose that events are successively past, present and future. The successive line seems to fail because it seems that it entails either a vicious circularity or a vicious infinite regress. However, it is the case that only most construals of the successive line will end in failure. Finding the correct analysis of a successive line of analysis of past, present, and future in order to provide an informative explanation without the vicious infinite regress will occupy the central logical lock to be picked in this paper. The reasons why the successive line generates an infinite regress of properties, and the proof that the attempts to explicate the infinite regress show it to be vicious, are covered in a later section (2.1). The solution I adopt is that events are successively past, present, and future, but that transfinitely many worlds are required. To anticipate, in McCall's model, the now moves up the universe-tree, successively actualizing one of a set of physically possible (future) worlds; in total, there are transfinitely many worlds, so that an infinite amount of branch-attrition can occur.

Radical skeptics might claim that the future and the past don't exist, and that there are no contrary A-series properties for an event to possess. Events only seemingly possess these temporal properties of futurity and pastness. This skeptical

\footnote{such as Hobbes, perhaps,}
position contradicts analysis of Indo-European grammar which suggests that our temporal copulas of past, present and future are referring terms which we take to be real. But if one is a realist about the future, present, and past, since after all temporal phenomenon of duration is a physical phenomena which can be objectively measured as the proper time along a trajectory; then such realists have adopted a burden of proof to explain the having of the apparently contrary temporal properties also entailed by the relations of past, present and future; and that burden of proof has proven quite difficult to dislodge.

One crucial point which helps to support the burden of proof that has been accepted by the realist of passage is that if passage is real, it is a pervasive feature of the actual world, and the more pervasive the asymmetry, the better candidate it is to be an intrinsic property of time. A necessary property of time is intrinsic to time, and if necessary, is true throughout time and space, and hence pervasive. Reasoning backwards from pervasiveness to necessity and thus to intrinsic properties is a compelling form of metaphysical argument, but it is not logically necessarily compelling. We certainly cannot verify whether or not a proposed causal asymmetry is pervasive by waiting and looking, since waiting and looking will generate only a finite amount of data and the metaphysical conclusion concerns an infinite number of events. Hence we cannot decide the matter of the status of temporal passage in a purely empirical, verificationist, or
instrumentalist manner. Hence, it should be no surprise that physical theory cannot analyze temporal passage, since temporal passage entails a larger ontology than that entailed by physical theory.

Yet it appears that time passes. A duration occurred between reading this sentence and the previous one. Is duration merely a B-series relation, or is there a distinctly A-series component? I assume hereafter that there is some real phenomena which is denoted by the phrase 'temporal passage'. That phenomena needs more explication. To provide that explication, metaphysicians are led to believe that temporal passage is the instantiation of some property or relation(s) and it is the nature of this property or relation(s) that a rational philosopher of metaphysics must explicate.

By postulating the reality of time and temporal passage I am inconsistent with the conclusion of McTaggart's profound paradox. I reject McTaggart's premise that temporal passage (in the form of the A-series) is or entails a contradiction. McTaggart must be credited with clarifying the distinction between the co-ordinate system of the A-series, 'past, present, and future', and the B-series co-ordinates of 'earlier than' and 'later than' and 'simultaneous with'. But McTaggart cannot be credited with proving the unreality of time; rather, the conclusion forces us
to reconsider the beliefs which led to the unpalatable conclusion.

I claim that the A-series and the B-series are compatible on a specific interpretation of the nature of time and temporal properties. Further, it is insufficient explanation to analyze temporal passage trivially as the NT-position (also known as a 'block universe' view) requires. I show that the passage of time can be given a non-question-begging and consistent modal interpretation. This interpretation adopts the possible worlds metaphysics as an explanatory framework for solving the problem, and postulates a complex physical accessibility relation between possible worlds.

McCall (1966, 1976, 1984, forthcoming) has been developing and continues to develop a modal model of objective time flow. Time objectively flows in the model, as the branch structure of the universe-tree evolves. The universe-tree consists of sets of physically possible worlds at a time. One of these worlds is selected by the now, or the property of actualization, which conjoins the property of being present. Once the selection process has occurred, then the non-selected worlds vanish from the tree, and the now moves to a new selection-set. In this manner each present is characterized by a unique state in the evolution of the universe-tree.
Furthermore, the choices we make, and the random quantum events that occur, alter the probabilities associated with future outcomes. Thus McCall's model provides a coherent metaphysics for the epistemology of time. The directed nature of the branch structure and branch-attrition constitutes the underlying causal process which Reichenbach sought for in the classic text *The Direction of Time*.

Is McCall's model a legitimate contender as a solution to McTaggart's paradox? I determine that McCall's model is a good one by answering the following questions:

(i) What is the logic of the model?

(ii) What is the metaphysical commitment of the model? These two questions determine whether or not McCall's model is worthy of deeper consideration. Then I ask:

(iii) Is the model really a model of time flow? I answer this question with reference to the tree-structure and branch attrition. Finally I ask:

(iv) Is the model not still a block universe like the other models if it is set in a five-dimensional space?

These last two questions strike at the heart of the matter. If McCall's model is really a model of time flow, then it must uniquely and coherently model time flow, and meet all the other requirements for a model of time such as consistency.
It might be thought that McCall's model is just another static, block universe. What if McCall's model is viewed as if it were five-dimensional? Then it would appear as a static, block universe. A universe is called a 'block universe' if the past, present, and future of the world can be all arrayed in a single unchanging structure without inconsistency. The term 'block universe' was originally meant to describe the Minkowski manifold space, a four-dimensional entity. The four dimensions are composed of three dimensions of space and one time dimension. So McCall's model, if viewed within a five-dimensional setting, would appear static, just as the world-line of a particle is static in four-dimensional Minkowski space-time.

But the model specifies only four-dimensions, and within those four-dimensions, time passes. Within those four-dimensions, it is not possible to give a complete set of the pictures of the universe from every time. The structure of the universe changes over time, so that it looks different to different observers. The universe-tree evolves, and different sets of physically possible worlds are future-directed at different times. To suppose that McCall's model should be judged by five-dimensional standards is incorrect. The four-dimensionality of McCall's model is important; it puts the model on a par with the current models which are four dimensional but do not incorporate time flow.
Storrs McCall has further suggested\textsuperscript{4} that if his model can do all that the non-time-flow models can do, plus include time flow, then that inclusion is itself a very strong metaphysical consideration which should favour acceptance of the truth of McCall's model over the NT-Minkowskian models. It is one step to suggest that the dynamic universe-tree model can do all the explanatory work that any non-time-flow model can do, plus include time flow, but it is a giant leap (I believe) to prove that the dynamic universe-tree model can do all the explanatory work that any non-time-flow model can do. I prove that McCall's model will do the required explanatory work. Thus, the evidence to date suggests the truth of a modal metaphysical solution to the problem of temporal passage.

\textsuperscript{4}at the Pacific Division meeting of the American Philosophical Association in L.A., Calif., U.S.A., March 1990.
3.0 The Passage of Time

3.1 McTaggart's paradox

In this section I shall discuss McTaggart's paradox. McTaggart's paradox is that since temporal passage is inconsistent and since temporal passage is also necessary for time, then time is therefore unreal.

McTaggart must be credited for recognizing a useful distinction between two types of temporal relations. Temporal relations between events are specified in two distinct systems of coordinates, termed the A-series and the B-series. The A-series co-ordinates locate an event as either past, present, or future relative to the 'now'. The B-series co-ordinates locate an event as occurring at a clock time t, such as: "This sentence was typed on the first day of April."

The truth-value of sentences with A-series temporal relations changes over time as the now moves into the future; the truth-value of sentences with B-series relations are fixed for all times. For instance, at one time, such as during Plato's lifetime, Newton's birth was in the future, while at another time, for instance, today, Newton's birth is in the past. Newton's birth has changed from being future to being past, and was now for only one instant. The A-series relation is dynamic,
and the B-series relation is static. McTaggart thought the A-series relation was somehow more fundamental because it reflects change in time. The B-series relation is unchanging, and free from the complications of tense in language.

McTaggart's classic argument for the unreality of time depends upon the distinction between the A-series and the B-series and upon his concept of genuine change. McTaggart argues that the A-series is necessary for genuine change, but that the A-series is self-contradictory; therefore time, which depends upon genuine change, cannot exist. McTaggart's argument is easily rejected, as his theory of genuine change is implausible. However, defenders of the T-position must explicate the nature of the A-series relation, and hence must overcome allegation that the A-series is a contradictory notion, or leads to contradictions.

First, a brief explanation of why McTaggart's theory of genuine change is implausible. A poker's being hot at \( t_1 \) and cool at \( t_2 \) does not, according to McTaggart, suffice as proof of the existence of genuine change because these facts are true for all time. Genuine change requires that the sum total of facts at one time be not the same as the sum total of facts at another time. Thus genuine change occurs as the now moves into the future, because an event which was future becomes present and then past, and so the fact of its being future and its being past changes,
and hence the sum-total of facts of the world also change over time. The changing truth-value of A-series propositions marks the only type of genuine change possible, according to McTaggart. The contradiction within the A-series is expressed by saying that events which are future relative to one 'now' are past relative to another 'now'. Hence, explication of the sentence "The poker is hot now" when said at $t_1$ and when said at $t_2$ results in different truth-values, and hence there is no time-neutral body of facts of now-expressions.

McTaggart's argument regarding genuine change is an intellectually challenging reductio ad absurdum. If the truth-value of sentences regarding temporal facts, such as the fact that the poker is hot now when now is $t_1$ and not $t_2$, could change over time, then one could legitimately ask whether or not the second-order fact that first-order facts can change their truth-value over time, could change its truth-value over time? If sentences regarding second-order facts could change their truth-value, then it could be true that sentences regarding first-order facts don't change their truth-value, which is a contradiction with the changing truth-value of sentences regrading first-order facts. But if a sentence regarding a second-order temporal fact could not change its truth-value, then there is no really genuine change after all at the second-order level, contradicting the assumption that genuine change was possible.
Another way to put the absurdity of McTaggart's idea of genuine change is as follows. How could a fact about the past, such as the fact that McTaggart wrote a paper on the nature of time in 1908, change its truth-value over time, so that at some future time it won't be true that McTaggart wrote a paper in 1908? A commitment to a multiplicity of pasts is quite counterintuitive and hence an unwanted result. If McTaggart wrote a paper in 1908, then that fact cannot change its truth-value; a presumption of rational analysis is that facts cannot change their truth-value. Logical reasoning presupposes that sentences containing facts are, by their very nature, true for all time; to allow facts to change their truth-value over time would permit inconsistencies to occur over time. On this point, Horwich (1988) states that "...we reserve the term 'fact' for those aspects of reality whose explicit descriptions are sentences that are true simpliciter - and not merely true relative to some context or point of view, and false relative to others."\(^5\)

Thus McTaggart's paradox certainly must be resisted by rejecting his theory of genuine change. Change occurs when the temperature of a poker is hot at \(t_1\) and cool at \(t_2\). The difficult question is whether or not this observed physical change requires temporal passage as the T-position would have it, or whether it can be explained as the NT-position would have it, without

---

recourse to passage. As Broad (1938) points out, following Russell, the existence of the static B-series does not by itself rule out change in the world. The A-series is not necessary for a theory of causal change. Thus, the evidence so far would seem to support the NT-position, since the A-series appears to be a superfluous concept. If the A-series relation is a significant temporal phenomenon, then some underlying metaphysical mechanism must be found wherein the A-series relation plays a significant role.

So while McTaggart's paradox can be easily rejected by rejecting his theory of genuine change, there is a gem remaining buried in the rubble. McTaggart's argument shows that the 'moving now' engenders contradictions if it is assumed to mark a single ontological property that is both timeless as the B-series would suggest and yet also changing in time as the A-series would have it. A single ontological property cannot to the explanatory work required by both the A-series relation and the B-series relation.

The A-series engenders a contradiction only if some consistent point of reference cannot be found. Without a point of reference, some explanatory map which defines the A-series relation, the A-series relation will engender a contradiction which could be trivially transformed into a vicious infinite regress. The vicious infinite regress occurs when second-order facts about temporal relations, or second-order time dimensions,
are required, necessitating third-order temporal relations, and so on, in a never-ending attempt to plug the explanatory leak. If the A-series relation is to do real metaphysical work, then some other point of reference than the B-series relation needs to be found. McTaggart has not shown that no possible point of reference exists to do the required ontological work. He has only shown that the timeless truth of B-series propositions cannot do the distinctively temporal work of the A-series. In other words, while the A-series and the B-series are related, they are not one and the same relation - some third entity must be found to relate them together as both sets of properties of one and the same third entity.

Philosophers of the NT-persuasion have tried to reduce the notion of the A-series to the B-series, while philosophers of the T-position have tried to run the reduction the other way round. Both lines of inquiry have proven to be plausible, and it is quite difficult to determine which way the reduction should run, assuming a directed reductive account is needed. It turns out that each relation, A-series and B-series, can be defined in terms of the other. Hence it is quite unclear which relation would better serve as the underlying mechanism. Hence I believe that no directed reductive account should be sought for. That is, neither the A-series relation nor the B-series relation is more basic than the other. Rather, they are both necessary for time, and a third entity must be found which can relate them together.
So there is a third possibility: that neither relation is more basic than the other, but that both the A-series relation and the B-series relation are aspects of time. This view necessitates that the apparent contradiction between the A-series and the B-series be resolved. The changing truth-value of sentences using A-series relations must be reconciled with the nonchanging truth-value of sentences using B-series relations, in that both the A-series relations and the B-series relations are aspects of time. The reconciliation can be achieved by finding another metaphysical entity to do the work. Bigelow (1989) insightfully remarks that possible worlds will keep contrary properties out of each other's hair.
3.1.1 The Infinite Regress Problem

An immediate problem upon encountering possible worlds is that there are, possibly, very many of them, so many in fact that there are possibly more than infinitely many. Before I claim that in fact transfinitely many possible worlds are required in order to explicate temporal passage, I can show that an infinite number of entities won't suffice to explain temporal passage. The following line of argument will show that the infinite regress of temporal predication, suggested by McTaggart's paradox, is necessarily vicious, and hence this line of analysis must be abandoned.

Quentin Smith (1986) proposes that the regress is infinite but not vicious; this line will be shown to be based on a misunderstanding of the problem. However, analyzing just where Smith's argument goes wrong is a fascinating problem tackled by Oaklander (1987). I arbitrate this debate because I believe it will yield the necessary insight that indeed the solution of McTaggart's paradox when the A-series is construed as an infinite regress is vicious and therefore unhelpful.

If the regress of temporal attribution is both infinite and vicious, and if no single entity can be found to do the required metaphysical work, then if there is to be an explanation of temporal attribution, some other entity or entities must be found
to do the work. The only other candidate is a possible worlds metaphysics solution. I maintain that some explanation of the apparent motion of the 'now' is required. If the motion of the 'now' is a necessary component of the nature of time, then time is intrinsically asymmetric. So I grant one premise of McTaggart's paradox, the premise that time flow is a necessary property of time.

However, I examine closely the question of whether or not time flow entails a contradiction or an infinite regress in order to show that time flow can avoid both dangers by postulating transfinitely many entities (e.g., worlds). If the analysis of temporal attribution yields an infinite regress, then it must be determined whether or not the regress vicious or nonvicious. If the infinite regress is nonvicious, then there is no motivation to seek a possible worlds solution which requires transfinitely many entities. But the analysis will show that the infinite regress is indeed vicious. Hence a possible worlds solution must be sought for.

I thus return to consider Quentin Smith's argument that the regress exists but that it is nonvicious. I claimed above that Smith's argument is based on a misunderstanding of the strength of the problem. Below I argue that the regress is vicious by examining Smith's argument to the contrary.
First Smith outlines the regress as a modern McTaggartean philosopher might express it. The first level of temporal predication applies to events: every event is present, past, and future. Smith notes that since presentness, pastness, and futurity are incompatible predicates, they cannot belong to the same event simultaneously, but must hold successively. In tensed language, this expression means that an event is present, will be past, and has been future; or that it is past, has been future and has been present; or that it is future, and will be present and then will be past. In tenseless language, this expression means that an event is present at a moment of present time, is past at some moment of future time, and is future at some moment of past time. The 'is' in the tenseless use of language is the non-temporal copula much like the use of 'is' in "Two plus two is four."

The second level of temporal predication is specified in terms of the first level predicates. For example, in the statement, 'the event is present at a moment of present time', the moment of time referred to is not only a present moment, but is also a past and a future moment. Since it is contradictory to assert that the moment is present, past and future simultaneously, because these are incompatible predicates, it must be asserted instead, according to Smith, that the moment is present at some higher level present moment, and similarly for the past and future.
The third level of the regress is introduced by explicating the nature of the second level temporal predicates. The fourth level is introduced similarly, and so on to infinity.

McTaggart argued that this infinite regress was vicious because:

The attribution of the characteristics past, present, and future to the terms of any series leads to a contradiction, unless it is specified that they have them successively. This means, as we have seen, that they have them in relation to terms specified as past, present, and future. These again, to avoid a like contradiction, must in turn be specified as past, present and future. And, since this continues infinitely, the first set of terms never escapes from contradiction at all.

Smith betrays his lack of understanding of McTaggart's clear rendition of the viciousness of the infinite regress by calling McTaggart's remarks 'paradoxical.' Smith agrees that: "McTaggart is indeed correct that the attribution of presentness, pastness and futurity leads to a contradiction unless they are attributed successively." But then Smith goes on as if the contradiction can be avoided simply by attributing the temporal predicates successively. The problem is that as soon as the attributes are attributed successively, the analysis is driven onto a higher level of predication.

---

6 Parts of McTaggart's argument are reprinted in Gale (1967). This part is reprinted on p.96.

Oaklander, elsewhere a defender of a Russellian theory of time, argues persuasively against Smith's analysis of McTaggart's paradox. Oaklander notes that "...McTaggart's point is that an appeal to succession does not suffice to avoid the contradiction. Smith does not deal directly with McTaggart's argument." Smith states what he thinks the paradox is in McTaggart's argument, and argues that the paradox is based on an elementary logical blunder. But Oaklander points out, and I agree, that if McTaggart's argument were based on that blunder, then the argument would be invalid. But McTaggart did not make the elementary blunder of which he is accused by Smith (1986).

Smith believes that McTaggart's argument is paradoxical because the attribution of temporal predicates is nonproblematic; Smith says that:

...in each case it is specified that the terms to which they are attributed have them successively... How could [the infinite levels of predication] never escape from contradiction if it never was contradictory? The first set of terms, the events, are contradictory only if it is not specified that these terms have presentness, pastness, and futurity successively. But it is specified that they have them successively!

Oaklander (1987, p.425) points out that Smith simply asserts that succession avoids the contradiction. I hold that Smith is correct

---


on the point that succession avoids the contradiction, but for different reasons (namely, that the succession is transfinite).

Smith is not correct that McTaggart's argument is paradoxical.

Oaklander notes that Smith does not deal directly with McTaggart's argument, but instead gives an analysis of some other paradoxical claims.

Oaklander shows that Smith's argument goes off the rails when Smith claims that McTaggart believes that the first level of temporal attribution using the A-series relation is contradictory. Smith infers from

(5) The attribution of the characteristics past, present, and future to the terms of any series leads to a contradiction, unless it is specified that they have them successively

to

(6) The attribution of the characteristics past, present and future to the terms of any series leads to a contradiction, which is subsequently resolved by specifying that they have them successively.

If McTaggart's argument were based on the invalid inference that Smith claims it is based on, then McTaggart's argument would indeed be paradoxical. But McTaggart's paradox is shown to be a valid argument in a later section of this thesis (3.2). Smith's invalid inference is invalid because a statement of the form 'A unless B' does not entail a statement of the form 'A and B'.

---

McTaggart is not guilty of this sin.

Smith claims that the appeal to succession demonstrates that there is no problem in temporal attributions. But McTaggart is arguing that there is a problem in temporal attribution and that succession will not solve the problem. Oaklander remarks: "For detensers like myself the direction of time is based on the unanalyzable temporal relation of succession, but for McTaggart temporal relations are analyzable in terms of the flow of time or the moving now."\(^\text{11}\) Oaklander sympathizes with the NT-position. On the point of the unanalyzable succession relation, McTaggart remarks: "It is only when the A series, which gives change and direction, is combined with the C series, which gives permanence, that the B series can arise."\(^\text{12}\) For McTaggart, the B-series relation was defined in terms of the A-series relation.

Therefore, McTaggart believed that an appeal to succession would fail because the B-series relation would in turn be analyzed using the corresponding A-series term, which would involve a vicious circle because

it assumes the existence of time in order to account for the way in which moments are past, present, and future. Time then must be pre-supposed to account for the A series. But we have already seen that the A series has to be assumed in order to account for time. Accordingly, the A series has to be pre-supposed in


\(^\text{12}\)McTaggart (1934) "The Unreality of Time." in: Philosophical Studies, p.118.
order to account for the A series. And this is clearly a vicious circle.

Consider the truth-value of a sentence such as "The poker is hot now." The word 'now' requires a determinate analysis of an A-series temporal relation if the sentence has a coherent meaning. The problem that the truth-value of such sentences with A-series relations changes from $t_1$ to $t_2$ suggests that the analysis of A-series relations should allow their truth-value to shift in time. McTaggart thought of the problem in terms of how to account for change in time, say the poker being hot at one time and cold at another. However, the problem of having a theory of change is a symptom of the deeper problem of finding an account of changing A-series truth-values. Changes in the truth-value of sentences containing A-series relations can have meaning, then, only if events acquire and shed the A-properties successively. Given the fact that the poker first is hot (at $t_1$), and then is cold (at $t_2$), however, the temporal relation of 'earlier than' is presupposed by the facts, and that temporal relation can only be explicatured by previous appeal to the A-series, since the B-series is defined in terms of the A-series and the C-series.

So far the paradox has been expressed in the logical form of a circle. But a circular argument can be transformed into a vicious infinite regress, and vice versa. In this case, it may be instructive to do so. If we avoid the original contradiction by

---

13 McTaggart "The Unreality of Time.", p. 124.
claiming that the terms never have the incompatible properties simultaneously but rather only at different times, that is, E is future at \( t_1 \), present and \( t_2 \), and past at \( t_3 \), the problem is avoided only if: \( t_1 \neq t_2 \neq t_3 \). For if events do not have their A-properties at different times, then they are either timelessly or simultaneously past, present, and future, and the paradox is unavoidable. What, then, is the basis for:

\[ t_1 \neq t_2 \neq t_3, \]

that is, for, say, \( t_1 \) being earlier than \( t_2 \) and \( t_2 \) earlier than \( t_3 \) (assuming, with common sense, that time has a complete linear ordering)? The resolution of this dilemma cannot be found by postulating another time dimension, for the new series is only a genuine temporal series if it is free of contradiction. The resolution of this dilemma can only be found by seeking greater explanatory resources. The surprising fact is not that those resources are available, though the explanatory framework of the possible worlds metaphysics, but that temporal passage should turn out to entail a metaphysical connection between the actual world and a set of possible worlds.
3.1.2 The Possible Worlds Metaphysics Solution

John Bigelow provides a tremendous insight into the nature of McTaggart's paradox in his (1989) paper "A Modal Theory of Time." Bigelow's key insight is that a modal solution to the paradox is suggested by the modal structure that underlies McTaggart's own argument. Bigelow achieved this insight by noting that McTaggart's argument reduces to two crucial premises. The first is that an essential, or necessary property, of time is that it passes. The second premise is that the passage of time is incoherent or inconsistent, and involves either a vicious infinite regress or a vicious circularity. Together these premises entail that time is unreal, there is no time, and that nothing ever really occurs before or after anything else.

What is the passage of time? On Bigelow's view, the passage of time is captured by such sentences as:

(5) An event was once future, became present, and has now become past.

(6) An event is past, had become present, and was future.

(7) The present event was just future, and will soon be past.

Sentences (5)-(7) are all equivalent, so analyzing (7) is enough, and it is (7) that Bigelow's analysis focuses on.

The NT-position analyses (7) as:

(8) What is simultaneous with $t$ is later than some time which is earlier than $t$, and is earlier than some time
which is later than \( t \).

The NT-position arrives at (8) from (7) by replacing the A-series terms with their B-series counterparts. (8) is trivially satisfied, and hence necessarily true. The NT-view is that since (8) is all there is to the passage of time, there is no problem about temporal passage.

But is (8) all that the passage of time amounts to? (8) is vacuous. (8) conveys no information, and hence reduces the passage of time to a merely abstract existence.

Bigelow argues that the NT-analysis leading to (8) is misdirected from the start. (8) analyzes the passage of time by appealing to the earlier/later relation. Bigelow states:

But this relation is presupposed to be a temporal ordering. Not every relation with the logical properties of the earlier/later relation, not every linear ordering, counts as a temporal ordering.

In order for the earlier/later than relation to be a temporal relation, there must be some property of this relation that makes it distinctively temporal. As it stands, the B-series is timeless; what makes the B-series a temporal relation is that what is earlier becomes present before what is later becomes present, and what is later is no longer future but becomes present and then too becomes past. On its own, the B-series relation is merely a linear ordering. Bigelow states the point:

\[ \text{Bigelow (1989), p.3-4.} \]
"...the earlier/later relation is a temporal one only if it concerns something which passes."\textsuperscript{15} This requirement entails that a complete analysis of time cannot be given without considering both the B-series and the A-series properties of time.

Questions of conceptual or logical priority are delicate because, particularly in the problem of temporal passage, there are plausible arguments running the reduction in both directions. Running the reduction in the direction of making the B-series basic, however, fails to be satisfying because of the triviality of the indexical analysis of time and tense. Running the reduction in the direction of the A-series entails taking passage as a primitive notion. But if earlier/later can be defined in terms of the A-series in a coherent explanatory framework, then the A-series is guaranteed to be more than mere metaphor.

The earlier than /later than relation can only be defined in terms of the A-series if some other entity, other than time itself, can be found as a point of reference for the nature of temporal passage. McTaggart has shown that time itself cannot be the point of reference required to explicate temporal passage. The possible worlds metaphysics is nominated to fulfil that function. The possible worlds metaphysics (PWM) holds that a possibility P exists in our world \( \omega \) if and only if there is an

\textsuperscript{15}Bigelow (1989), p.4.
accessibility relation \( R \) between the actual world \( \alpha \) and the possible world \( \emptyset \) in which \( P \).

Suppose that possible worlds \( \alpha \) and \( \emptyset \) meet the following three temporal conditions:

(i) everything past or present in \( \alpha \) is past in \( \emptyset \);
(ii) everything present or future in \( \emptyset \) is future in \( \alpha \);
(iii) everything future in \( \alpha \) and not future in \( \emptyset \) is present or past in \( \emptyset \).

If (i)-(iii) are true in both \( \alpha \) and \( \emptyset \) then \( \alpha \) is in the past of \( \emptyset \) and \( \emptyset \) is in the future of \( \alpha \). Thus if (i)-(iii) then there is an accessibility relation \( R \) between \( \alpha \) and \( \emptyset \) such that \( \emptyset \) contains a possible future of \( \alpha \). And mutatus mutandis for possible pasts of \( \alpha \).

The solution of the problem of the passage of time is to describe the restriction of this accessibility relation \( R \) between possible worlds. It turns out that \( R \) is itself a function from \( \alpha \) onto a set of possible worlds \( \Gamma \). This solution benefits from a conceptual mapping between previously developed tense logic (Prior 1957, 1958, 1959, 1967) and modal logic following from Kripke. Bigelow notes that: "The use of modal terminology enables us to assimilate the formal tricks of tense logic into the... ontological realm of individuals, properties, and relations, together with modalities."\(^{16}\)

\[^{16}\text{Bigelow (1989), p.10.}\]
The modal theory explicates the passage of time through a counterfactual analysis, as possible worlds analyses are given of the truth-conditions of counterfactual statements. Consider the counterfactual claim:

(9) What is present was once future because it would have been future if past things were present.

This claim, (9), is true if and only if there is the appropriate accessibility relation \( R \) between worlds \( a \) and \( \emptyset \) such that what is present in \( a \) was once future because what is present in \( a \) is mapped onto the future in \( \emptyset \) and consequently what is past in \( a \) is present in \( \emptyset \).

If we assume the existence of the properties of pastness, presentness, and futurity, and we assume that what is actually present could have been past or future, that is, that what is actually present is possibly past or possibly future, then we can give a non-circular definition of the distinctly temporal ordering of the earlier/later relation and hence avoid McTaggart's paradox. What is actually present, that is, present in \( a \), is possibly past or future in \( \emptyset \). The present in \( a \) is uniquely defined, defined that is by a world-relative index. The real present-in-\( a \) has, on Levisian counterpart theory, other counterparts, such as past-in-\( \emptyset \), while on other construals of the identity relation across possible worlds, the present-in-\( a \) has a transworld doppleganger. The key point for my purposes is that on the possible worlds analysis, explication of "The poker is hot
now" will result in the claim "The poker is hot at the present in a" where the 'is' in this latter claim is nontensed. The 'is' being nontensed has the result that every temporal object in a is present in a, but this result is welcome, since it is necessarily true. So, on the PWM analysis, a complete sentence involving A-series relations requires a world index (although, for most purposes, the relevant world is the actual world, a).

The earlier/later relation is a linear ordering, so if the earlier/later relation is a temporal ordering then because it is linear it has these five properties:

(10) irreflexivity (nothing is earlier than nor later than itself);
(11) asymmetry (if x is earlier than y then y is not earlier than x);
(12) transitivity (if x is earlier than y and y is earlier than z then x is earlier than z);
(13) connectivity (if x is earlier than y and z is not earlier than y then x is earlier than z);
(14) density (if x is earlier than z then there is a world y which is later than x but earlier than z).

In Gödelian worlds (12) does not hold; in discrete time worlds, (14) is false.

The account so far does not guarantee that it has sufficient content. In the interpretation of possible worlds semantics developed by Montague and Cresswell, it is possible for a thing to have a property in a world without existing in that world. A
property of a thing is taken to be a function from each individual to the set of possible worlds in which the individual (or in Lewisian semantics, the counterpart of the individual depending on the relation of identity across worlds) has that property. There is no set-theoretical difficulty in talking about the set of worlds in which an object does not exist. If the accessibility function is to sets of worlds in which objects don't exist, however, then this metaphysics results in a nonexistent future and past, and only successive instantiations of present events. If this metaphysical picture were true, then things in the actual world $\alpha$ would have the property of being future or being past only in virtue of the existence of the entity with that respective property in some other world $\delta$.

Bigelow notes that "This conception... as truncated to include only the present, requires us to rethink the modal theory of time in a number of ways... One world will be 'temporally' accessible from another only when they contain the same things and differ only in a systematic transposition of the properties of pastness, presentness, and futurity." (p.15). This truncated conception entails that temporal accessibility relations depend not only on the systematic transposition of the properties of pastness, presentness, and futurity with respect to world $\alpha$, but also with respect to things which have properties with respect to worlds even though they do not exist in those worlds (say in world(s) $\delta$).
But the truncated conception is not a sufficient analysis of the past and future. The truncated conception is designed to reflect the position of presentism, the view that only the present exists. This truncated view of the temporal spectrum entails radical skepticism about the past and future and is an untenable ontology because it is too parsimonious. The truncated conception attempts to remove the complexities of a theory involving the past and future, removing them only by postulating an assumption contrary to our ordinary intuitions about time.

McCall's model, by contrast, requires that the accessibility relation be far more complex than in the truncated modal conception wherein the ontology consists only of a set of events of which it is successively true to say that the event is present-in-a. In McCall's model, the accessibility relation is that of physical possibility. Hence, being present means that the event was selected from a range of physically possible events. Thus, what events become present are ones that are physically possible at the present-in-a.

On McCall's model, being present is a world-relative phenomenon. Being relative in this sense does not undermine in any way the objectivity of the phenomenon. Motion is relative to a reference frame, but motion is nonetheless an objective phenomenon. So too with the passage of time, on McCall's model.
The passage of time, in the actual world, is a function from the actual world to a changing set of other possible worlds.
3.2 The logic of McTaggart's paradox

An outline of McTaggart's paradox is as follows.

1. Events are located in the B-series (ordered with respect to earlier than or later than or simultaneous with) only if time exists.

   \[ e_B \rightarrow T \]

2. Time exists, only if there is genuine change.

   \[ T \rightarrow gc \]

3. There is genuine change in the world only if events are located in the A-series.

   \[ gc \rightarrow e_A \]

Therefore, from 1. to 3.,

4. Events are located in the B-series only if they are located in the A-series.

   \[ \left( (e_B \rightarrow T) \land (T \rightarrow gc) \land (gc \rightarrow e_A) \right) \rightarrow (e_B \rightarrow e_A) \]

5. If events are located in the A-series, then each event acquires the absolute properties of being past, being now, and being future.

   \[ e_A \rightarrow bPNF \]

6. There is a contradiction in supposing that any event has any two of these three absolute properties.

   \[ -bPN \land -bPF \land -bNF \]

Therefore, from 5. and 6.,


   \[ \left( (e_A \rightarrow bPNF) \land (-bPN \land -bPF \land -bNF) \right) \rightarrow -e_A \]

Therefore, from 4. and 7.,

8. Events are not ordered with respect to the B-series.

   \[ -e_B \]

Therefore, from 1. and 8.,

9. Time does not exist.
In this section, I am only concerned with the logical structure of McTaggart's argument, not the soundness of the premises. I want to make the point that this version of McTaggart's paradox is a valid argument. If the premises are granted, then the conclusion follows. I can quickly prove that the above argument is valid, by generating a contradiction with the premises if the conclusion, (9.), is denied. I will carry out this proof using symbols keyed as noted above, following the strategy of reductio ad absurdum.

First, suppose the opposite of the conclusion (9.):
10. Time exists.

From 1. and 10.,
11. Events are located in the B-series.

From 11. and 4.,
12. Events are located in the A-series.

But:
   \((eA \rightarrow bPNF) \& (-bPN \& -bPF \& -bNF)) \rightarrow -eA

So from 12. and 7. we derive a contradiction:
13. Events are located in the A-series and events are not located in the A-series.
   \((eA \& -eA)

Therefore, McTaggart's paradox is a valid logical argument, since the denial of the conclusion is inconsistent with the premises.

---

\(17\) This explication is given by Horwich (1988, p.18).
The logic of McTaggart's paradox is to set up a contradiction within the A-series relation and then conclude that time is unreal since the A-series relation is necessary for time flow and flow is a necessary part of time. Hence, if the contradiction within the A-series relation can be resolved, the remainder of the paradox may be a salvageable line of argument. A possible worlds metaphysical analysis of the apparent contradiction entailed by the A-series relations will be seen to defuse the problem and hence salvage the remainder of McTaggart's paradox. Hence, the logical structure of McTaggart's argument, taken together with the substantive claim that time flow is necessary for a complete account of time, suggests that a modal solution to the problem of the passage of time would also serve to deny McTaggart's conclusion and thus vindicate our common sense belief in the reality of time.
3.3 The soundness of McTaggart's paradox

The escape from the conclusion of McTaggart's paradox can come, therefore, only by denying one of the premises, since we cannot escape the conclusion if we accept all the premises, since the conclusion is a valid inference from those premises. I will examine each premise in turn in order to determine what arguments can be marshalled to support each premise, in order to find if at least one premise can be rejected.

1. Events are located in the B-series (ordered with respect to earlier than or later than or simultaneous with) only if time exists.

   \[ eB \rightarrow T. \]

   Premise 1. is obviously true, since as Horwich notes, the consequent that time exists must be construed in a very broad manner, such as meaning that the world exhibits temporality in some sense. If the world exhibits temporality, then the temporal dimension of the world may have a B-series ordering.

2. Time exists, only if there is genuine change.

   \[ T \rightarrow gc \]
McTaggart has a particularly strange view of genuine change, and it is this premise of his argument that Horwich criticizes.18 According to McTaggart, change does not occur when a poker, hot at time $t_0$, becomes cold at a later time $t_1$. McTaggart is correct to note that the truth-value of these propositions regarding the poker are true throughout time, hence unchanging. McTaggart thought the only genuine change could be if the sum total of facts at one time is not the same as the sum total of facts at another time.

McTaggart's theory of genuine change can easily be resisted, by denying his concept of genuine change. A genuine change has occurred when the poker is hot at $t_0$ and cold at $t_1$. Horwich notes correctly19 that the unwelcome results that McTaggart derives from his theory of genuine change show not that time is unreal but rather that the theory of genuine change is implausible.

But Horwich is not correct to suppose20 that the tree model of reality, such as McCall's model, entails that the sum total of facts at one time is not the same as the sum total of facts at another time. On some tree models, such as Aristotle's, claims

---

about the past and present are determinately true or false, while claims about the future do not have a truth-value until the predicted events either occur or fail to occur. But on other tree models, such as McCall's model, the totality of facts can remain constant in time.

Horwich's criticisms of the claim that the totality of facts must change over time are bold, penetrating, and decisive. Horwich (1988) and Mellor (1981) have shown that McTaggart does not substantiate his theory of genuine change. Denial of the theory of genuine change is sufficient to undermine McTaggart's paradox. As Horwich remarks, "...change is always variation in one thing with respect to another, the totality of absolute facts about those functional relations remaining forever constant."21

However, while McTaggart's argument can be rejected simply by denying the theory of genuine change, there is much of value to be salvaged from the wreckage of the argument. McTaggart's paradox is the starting point for a theory of time based on the distinction between the A-series relations and the B-series.

3. There is genuine change in the world only if events are located in the A-series.

\[ gc \rightarrow eA \]

---

On McTaggart's theory of genuine change, there can be change in the totality of facts only when the now actualizes or fails to actualize a predicted future event. This movement of the now is described by the A-series relations.

There are two possible construals of the A-series terms of 'past', 'present', and 'future'. McTaggart must deny both possibilities in order to show that the A-series is contradictory. One possibility is that the A-series terms are relational or monadic predicates. The other possibility is that the A-series terms are simply indexicals. I agree with McTaggart that for there to be (genuine) change and a real A-series, then the A-series terms cannot be relational predicates nor monadic predicates, nor indexicals. I do not agree with Horwich that McTaggart has failed to show that time requires the existence of a moving now. Indeed, McTaggart's argument shows that time requires the compatible existence of the B-series with the A-series moving now.

Horwich is quite correct that McTaggart's reasoning is fine, that the moving now is self-contradictory, if the A-series relation is explicated in terms of the B-series relation. But Horwich would not be correct to suppose that all theories of the moving now are doomed to failure, but rather only those theories which require the B-series relation to be previously defined. If another point of reference can be found to do the work required,
then the moving now would be restored to legitimacy in our ontology.

But first, I will show that the A-series terms can be neither relational predicates nor monadic predicates, nor indexicals. If the A-series terms were construed as relational predicates, then the sentence:

(14) Event E is now.

could be construed as:

(15) Event E is at t₁.

However, this construal has replaced the distinctively temporal A-series term with a relative property whose exemplification is determined by the B-series. This attempt to explicate the A-series has resulted in throwing out the baby with the bathwater, replacing the A-series temporal component with the B-series co-ordinate system. For the B-series co-ordinate system is defined after an origin for the time scale is selected, and that origin is defined by the A-series term. Hence, (15) can only be unpacked to give a sentence exactly the same as (14).

Interpreting the A-series by analyzing it to be a monadic property of events only worsens the problem, for this move is to take nowness as a primitive property of events in the actual world. It would be impossible to give an account of why some events are actualized in w, and others not, if nowness is
analyzed as a monadic property, since each instantiation of nowness is ontologically distinct from each other.

An A-series term like 'now' appears to be an indexical expression. One manner in which time is like space is that referring words such as 'here' and 'now' function as indexical referring expressions. Certainly, each use of 'now' could be replaced with its B-series counterpart, as from (14) to (15). The 'now' in (14) is a manner of referring to the time which is simultaneous with the utterance. The construal of (15) would not be acceptable to McTaggart, since it results in the distinctively temporal component of (14) being explicated by the B-series. McTaggart held that for there to be genuine change, temporal statements would have to be explicated with reference to the A-series.

So while the word 'now' can be used to simply refer to the time of utterance, the now must have more intrinsic structure than to be simply an indexical. The indexical analysis is quite agreeable to non-tensers, because then there is no other component in A-series terms except their B-series counterparts. But the indexical analysis must be rejected by a tenser, because then the A-series terms remain not completely analyzable by their B-series counterpart, and hence there is real work for the A-series to do after all, and it is not dispensible and replaceable by the B-series alone without loss of information.
Therefore, from 1. to 3.,

4. Events are located in the B-series only if they are located in the A-series.

\[((e_B \rightarrow T) \& (T \rightarrow gc) \& (gc \rightarrow e_A)) \rightarrow (e_B \rightarrow e_A)\]

Premise 4. follows from 1. to 3.. As premise 2. has been rejected, premise 4. is consequently deniable.

5. If events are located in the A-series, then each event acquires the absolute properties of being past, being now, and being future.

\[e_A \rightarrow bPNF\]

Premise 5. is problematic. There are several distinct senses of the word 'absolute', and it needs to be clarified which sense is intended in this premise. McTaggart had in mind his theory of genuine change, in which case, the having of the absolute property of being past requires that being past cannot be translated into 'was once future', since to do so would transform 'being past' into a relative property. So, being past can be analyzed as 'was once future' only if the property 'was once future' applies to a second-order temporal fact about events. And of course, such second-order attributions are just as problematic as the original first-order attribution, and so the analysis is pushed to postulate third-order temporal attributions to repair the remaining deficiency. For 'being past' and 'was future' are compatible only if past, present, and future are disjoint regions
of time. But that assumption is contrary to the requirement that every event has the absolute qualities of being past, being present or being now, and being future. So the apparent contradiction within the A-series cannot be resolved by introducing second-order attributions.

McTaggart moved from the failure to resolve the contradiction at each level of the analysis to the conclusion that the concept of the moving now was not possible, and hence that time was unreal. Given that we should reject McTaggart's theory of genuine change, we need not conclude that the concept of the moving now is contradictory, but only that the A-series cannot be explicated in terms of itself nor can it be explicated in terms of the B-series. Some other point of reference must be found to handle apparently contradictory properties if a coherent analysis is possible. That point of reference will turn out to be possible worlds. All premise 5. really informs us is that the A-series cannot be explained in terms of itself. So premise 5. is rejected, since there is a possible worlds account which will solve the problem.

6. There is a contradiction in supposing that any event has any two of these three absolute properties.

-\text{bPN} \& \text{-bPF} \& \text{-bNF}
Premise 6. is correct if construed with McTaggart's sense of absolute properties.

Therefore, from 5. and 6.,


\[((eA \rightarrow bPNF) \& (-bPN \& -bPF \& -bNF)) \rightarrow -eA\]

Line 7. does not follow from 5. and 6. Premise 5. must be rejected, since unless possible worlds are introduced, the explication of the A-series is impossible. Even though premise 6. is acceptable, line 7. cannot be derived.

Therefore, from 4. and 7.,

8. Events are not ordered with respect to the B-series.

\[-eB\]

Line 8. does not follow, since 7. does not follow.

Therefore, from 1. and 8.,

9. Time does not exist.

\[-T\]

Line 9 does not follow, since 8. does not follow. Hence, the conclusion of McTaggart's paradox can be denied, if the interpretation suggested in the analysis of premise 5. can be carried out. That is the task of a later section (4).
3.4 The conclusion of McTaggart's paradox

McTaggart introduced the key distinctions and set up the problem of the passage of time. But McTaggart's analysis was led astray by an unsubstantiated and unhelpful theory of genuine change. The theory of genuine change, that the sum total of facts must change over time, confuses the epistemology of time with the metaphysics of time.

However, the logic McTaggart's paradox contained the suggestion of a modal solution. The remaining task is to flesh out the nature of that modal solution, a task that is taken up in the next section.
4.0 The Evolution of the Universe-Tree

4.1 McCall's model

In "Objective Time Flow" McCall presents a theory of temporal passage which is objective, in the sense that the 'now' characterizes the universe independent of the existence of consciousness. Thus McCall's view is in direct opposition to Grünbaum's mind-dependence theory of becoming. The representation of objective temporal becoming is accomplished through a model of the universe in which the past is a single four-dimensional manifold, while the future consists of a branched structure of physically possible manifolds. Time flow is relativistic in this model in that time flow is frame dependent (but not observer dependent). McCall believes that since spatial length is frame dependent but nonetheless objective, so too time flow can be frame dependent and objective.

For the most part McCall merely presents this view of time without offering evidence that it best describes our universe; however, it is claimed that the view of the future as a branched structure is in accord with our ordinary language assumptions.

---


(which is supposed to be a point in its favour), and second, that since this view allows the notion of physical law to be defined in terms of physical possibility, it allows for the empirical possibility that the physical laws change over time, just as the physical possibilities change over time.

Such reasons are not sufficiently compelling to accept the metaphysical truth of the future-directed branched structure theory. A metaphysical theory in complete agreement with the precepts of ordinary language is a metaphysical theory infected with the presuppositions inherent in the tensed structure of language. Hence ordinary language does not provide good independent reasons for accepting the metaphysical truth of the theory. Second, while it is possible that certain physical constants, assumed to be invariant over time, such as the gravitational constant, do as a matter of fact change, instead of concluding that the notion of a physical law must be amended to admit of change over time, one could merely conclude that the satisfaction of the gravitational constant is not a law, and physical laws never change over time.²⁴

²⁴ Inflationary cosmological models have been developed in which the expansion of the universe is assumed to have been greater in the early stages of the universe than at present, but no amendment in the semantic notion of a law is entailed by empirical assumptions about changes over time in the cosmological constant.
Certainly there appears to be a deep structural difference between the past and the future in need of some explanation; however, Grünbaum argued that this difference is due only to the manner in which our consciousness perceives events. That is, only the B-series of earlier and later relations characterizes mind-independent time, while the A-series (including the 'now') is mind-dependent. The classic statement of this view is by Weyl:

The objective world simply is, it does not happen. Only to the gaze of my consciousness, crawling upward along the life-line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time.  

The view McCall directly opposes thus holds that future events are as much 'fixed' as past ones, in that there is no real structural difference between past and future events.

Well, it may be asked at this stage, in what way does time flow in McCall's model? In the model, the actual world $a$ is embedded in a modal phase space together with other possible worlds, $B_1, B_2, \ldots$. The actual world evolves through its changing connection with various other worlds. The connection is that of physical possibility. Each world is a set of physically possible events, where the nature of the embedding relation is given by the connections (see figure 3). The fundamental laws $L$ of $a$ determine which worlds are physically possible at a time.

---

The now, a property of instantiation or actualization, selects one of the branches.

As the now selects one of the branches, the other non-selected branches drop off and vanish from the tree (see figure 4). This selection-and-vanishing process within the model is a unique ontological structural distinguishing feature the past from the future. The now selects from the physically possible worlds at a branch node. The branches may have probabilities associated with them; if so, the now selects accordingly. Of course the total of the probabilities at each node will sum to 1.
figure 4: The now selects a branch.
Finally, a new set of physically possible worlds are determined, and the procedure repeats (see figure 5) as the now must make a new selection. At the time of the Big Bang, the entire universe-tree of all the physically possible futures were laid out. Then, as time passes, the tree is continuously pruned, losing branches. The tree has been simplified to show only binary branching. In reality, there may be more branches, and a varying number of branches from node to node. The tree may be imagined to have ten branches at each node, a move which McCall adopts in order to simplify calculations of quantum probabilities across the nodes.

figure 5: The universe-tree evolves.
4.1.1 The Transfinite Plus Problem

Why adopt the possible worlds metaphysical framework to solve the problem of the passage of time? In other words, how does the PWM account explicate the A-series? The possible worlds metaphysics embeds the actual world $a$ in a continuum of possible worlds, in an analogous manner to the way that matter and energy are embedded in the actual world. Just as matter and energy exhibit temporal passage in $a$, temporal passage is explained with reference to the possible worlds with which $a$ is connected. What is the nature of this embedding space and its interconnections?

Thermodynamic behaviour of a system is described by imaginging a 'phase space' within which all the possible states of the system are embedded, and then determining the probability that any one of those possible states will be realized. Similarly, quantum behaviour of a system is described by the Shrödinger equation with reference to an ensemble of systems, each of which is a possible state of the system. The explanation of the asymmetric behaviour of the now will also require a meta-space just as the explanation of asymmetric thermodynamic and asymmetric collapse of the wave function require a meta-level explanatory structure. The trick is to derive such an explanation that is consistent with the symmetric aspect of time, the B-series language which maps so well onto the static Minkowski world-view.
Possible worlds metaphysicains differ in their ontological commitment. At one modal extreme in the debate over the collapse of the wave function, one option is termed the Many Worlds Theory. This theory, proponded by Wheeler and de Witt, holds that each of the infinitely many worlds, ensembles of systems, is real. de Witt (1970) required that the universe was:

...constantly splitting into a stupendous number of branches, all resulting from the measurementlike interactions between its myriads of components. Moreover, every quantum transition taking place on every star, in every galaxy, in every corner of the universe is splitting our local world into myriads of copies of itself.

At one modal extreme in the debate about time would be the view that all of the possible sets of events forming the past, present, and future would exist in some real world or other, and our world is one of these worlds. To some, such as van Fraassen (1970), belief in continuum-many or more real worlds is belief in an inflationist metaphysics.\(^{26}\) Certainly explanations which take a smaller ontological loan are to be preferred; but the loan must be enough to do the explanatory work, and the more explanatory work that can be done justifies the larger ontological loan. Occam's Razor does not say to choose the theory that requires the least number of entities, but rather, to choose the theory that requires the least number of entities that fits all the facts. So if temporal passage is a fact, then we must accept the all the

\(^{26}\) See, e.g., van Fraassen, Bas C. (1970) *An Introduction to the Philosophy of Space and Time.*
entities required by the theory that most adequately explicates temporal passage. Lewis (1986) certainly thinks that only absolute modal realism, the view that each possible world is real, is the only view that fits all the facts. The large ontological commitment is the Achilles' heel of PWM. The Quinean objection "How many possible men are there in the doorway?" is answered on the PWM account by: "Possibly one, possibly two..." This virtually limitless commitment to real possibilities is what I call the 'transfinite plus problem.' There are as many possible worlds as sets, namely, transfinitely many.

But I hold that we need not postulate entities to supply truth-conditions for all counterfactual statements. McCall's model places a restriction upon the number of possible worlds it requires. Not every possible world is in the model; only those possible worlds which are physically accessible from the actual world \( a \) are real. The worlds which are accessible are those worlds which are possible given the fundamental laws \( L \) of \( a \), i.e., physically possible, and therefore connected to \( a \) by the accessibility or connectivity relation.

Earman is a substantival realist about spacetime, and hence rejects a simple modal interpretation. Earman (1986) rejects the many worlds interpretation (MWI), and claims:

What has rarely been explored is the implication for space-time structure of taking [MWI] seriously. To make sure that the different branches cannot interact even in principle they must be made to lie on sheets of
space-time that are topologically disconnected after measurement, implying a splitting of space-time... I do not balk at giving up the notion, held sacred until now, that space-time is a Hausdorff manifold. But I do balk at trying to invent a causal mechanism by which a measurement of the spin of an electron causes a global bifurcation of space-time. \[27\]

![Diagram of bifurcation of space-time](image)

**figure 6: Bifurcation of space-time.**

Figure 6 is an attempt to diagram the topological splitting of space-time that Earman is talking about. Such a splitting of space-time requires a weakening of the topological requirements upon the space, since in the usual Hausdorff space such disconnections are not possible. But there is a weaker space described by the $T_1$ axiom within which such topological disconnections are possible. The cost, if any, of weakening the topological requirements, and the implications of the $T_1$ axiom,

\[27\text{found in Hughes (1989) The Structure and Interpretation of Quantum Mechanics.}\]
will be taken up in a later section of this thesis (4.2).

Thus while Earman (1974) should be well respected amongst philosophers of time for the insightful "An Attempt to Add a Little Direction to the Problem of the Direction of Time", nonetheless Earman is not on the right track in his comment reproduced above. Clearly while the truth of MWI seems to some, e.g., David Lewis, to be self-evident, to many other philosophers it is absurd. No extraordinary causal mechanism is required of PWM models; as McCall has shown, when a quantum particle determines which of two possible states it is in, then the quantum particle has selected one global space-time manifold from a choice of two possible manifolds or worlds. The quantum 'choice' is the bifurcation within the space-time model.

It certainly can be shown that McCall's model requires giving up the Hausdorff separation axiom for its topology (since the alternative is to give up local Euclidean computability, which is clearly untenable). But Earman does not balk at giving up Hausdorff, presumably because the theorems regarding local Euclidean computability can still be derived in the weaker $T_1$ space. Again, this line of argument will covered in more detail in a later section of this thesis (4.2).

Earman should not balk at postulating a global bifurcation of space-time. The modal logic of PWM models is sufficiently well
developed to handle a description of a bifurcational model. Perhaps Earman is simply an actualist in his intuitions; if so, then it will take a separate argument to show that actualism can solve the problem of the passage of time. All I intend to show in this thesis is that there is a PWM model which solves the problem of the passage of time, namely McCall's model. The existence of one model of time flow is sufficient to show that McTaggart's paradox is unsound.
4.1.2 The Possible Worlds Metaphysics Solution

The problem of the passage of time was reduced by McTaggart's paradox to the problem of explicating the A-series relation. The A-series temporal relation can be explicated, I argue, with the help of adopting the possible worlds metaphysics (PWM). The PWM has various different interpretations as given by various authors in the field: Lewis, Montague & Cresswell, Adams, Plantinga, Kaplan. But all PWM interpretations have in common the Kripkean origin that a possible world is a set which is an ordered quadruple \( \langle P, W, R, K \rangle \). The set \( \langle P, W, R, K \rangle \) is such that \( P \) is a sentence (or set of sentences) expressing a proposition that is true in world \( W \), e.g., 'The cat is on the mat now'; \( W \) is the name of a particular possible world, e.g., the actual world \( o \); \( R \) is the accessibility relation between worlds that describes transworld identities/counterparts and \( K \) is the background set of worlds such that \( W \in K \), e.g., \( K \) might be the set of all possible worlds, or the set of all physically possible worlds. The A-series relation is explicated via \( \langle P, W, R, K \rangle \) on McCall's model, since on that model, the A-series relation nowness is a world-relative property. Hence, on McCall's model, the A-series relation nowness \( n = \langle P, o, R, K \rangle \) where \( R \) is an asymmetric relation from \( o \) to a set of physically possible worlds \( \emptyset \), and where \( K \) is the set of physically possible worlds relative to \( o \) at \( t \) where \( t \) is the instant picked out by \( n \).
The full import of $n = \langle P, \alpha, R, K \rangle$ cannot be appreciated without contrasting the interpretation of $R$ and $K$ required by McCall's model with the $R$ and $K$ selected by other interpretations. I consider the Lewisian or Many Worlds interpretation on the one extreme, and the actualist interpretation typified by Adams on the other extreme.

The Lewisian $R$ is symmetric between all worlds in $K$, and $K$ is the set of all logically possible worlds. The Lewisian $K$ is the largest ontology possible, and is therefore not parsimonious at all. All other things equal, Occam's Razor says that it is good to be parsimonious. Hence, if there is a model that is parsimonious to any degree at all, then that model should be preferred, by Occam's Razor, to an ontology of the Lewisian $K$. The set of physically possible worlds is smaller than the set of logically possible worlds. Hence the McCall $K$ is smaller than the Lewisian $K$, and should be preferred on those grounds.

The actualist $R$ is asymmetric since priority is given to $\alpha$ over all other worlds and $K$, on the other hand, is very parsimonious. Actualism is the view that only the actual world $\alpha$ is real. The actualist model within the PWM is that all other worlds are only possible worlds relative to $\alpha$. Clearly, the actualist $K$ is smaller than the McCall $K$, since there are physically possible events which are never instantiated in $\alpha$. Proof that there is one such physically possible event never
instantiated in $\sigma$ can be given as follows. Suppose that in $\sigma$, Caesar ate eggs for breakfast before crossing the Rubicon river (denote this claim $\sigma Ce$). Then Caesar's not eating eggs for breakfast before crossing the Rubicon river is a physically possible event in $\sigma$ never instantiated in $\sigma$ ($-\sigma Ce$). According to actualism, since, in $\sigma$ the claim '$\sigma Ce$' is true, then it's not possibly real, relative to $\sigma$, that $-\sigma Ce$ is also true; in other words, it's not physically possible that Caesar didn't eat eggs before crossing the Rubicon. In this respect, actualism can be seen to be another truncated conception of the needed ontology, since McCall's $K$ encompasses both possibilities ($\sigma Ce$ & $-\sigma Ce$). Both $\sigma Ce$ and $-\sigma Ce$ are mapped onto exclusive future branches. Only what actually occurs is physically possible on actualism, whereas McCall's ontology includes events/worlds which are not, in fact, instantiated in $\sigma$ at any time.

The upshot of the above analysis is that the PWM framework has allowed a fair comparison of different models of time. Furthermore, on this PWM analysis, McCall's model explicates the $A$-series relation through an asymmetric $R$ and where $K$=the set of physically possible worlds at where $n = \langle P, \sigma, R, K \rangle$. This PWM analysis thus demonstrates its usefulness to solving the problem of the passage of time for three reasons. One reason is that the logic of McTaggart's paradox suggests a modal solution. A second reason is that McCall's model is obviously a modal model of objective time flow. And a third reason for adopting the possible
worlds metaphysics is, as Bigelow notes, that we can adopt the tricks of modal logic to solve problems in the logic of time. The problem of giving a logical analysis of the properties of the A-series relation has been solved by adopting the trick of modal logic that contrary properties (such as \( \omega \text{Ce} \& \neg \omega \text{Ce} \)) are relegated to different possible worlds (such that \( \omega \text{Ce} \& \emptyset = \neg \omega \text{Ce} \)). The possible worlds metaphysics (PWM) gives the general structure of a logical space within which different models of time can be compared. In McCall's model, that structure is like a tree, so that the connectedness relation describes the set \( K \) of physically possible events, and the evolution of that structure describes \( \alpha \) and hence which propositions \( P \) are true in \( \alpha \).

The general setting of the PWM within which the tree structure is embedded can be understood as analogous to a 'phase space'. A 'phase space' is a conceptual entity used in thermodynamics, a space which represents all the possible entropic states for a closed system. Similarly, the logical space of the PWM given by set \( K \) describes the space of possibilities. Exactly what entropic state the system in at a time may be given in the phase space by points on a line. Similarly, the exact location of the actual world \( \alpha \) (as given by the possible worlds that are accessible from \( \alpha \)) may be given by the relation \( R \).

To find a more general setting for modal models of time, the concept of a Minkowski space is expanded upon. A Minkowski space
Minkowski space–time

one dimension of time

world–line of a particle

three spatial dimensions (two supressed)

figure 7: Minkowski space.

is a four-dimensional manifold which can be resolved into three spatial dimensions and one dimension of time (known as hypersurfaces). A massive particle traces a four-dimensional path in the Minkowski space during its lifetime, where the path is the space–time history of that particle (see figure 7). To generalize upon Minkowski space, imagine the Minkowski space to be a sub-set of a still larger entity. This larger entity is called a supermanifold, and it contains many Minkowskian space–time manifolds. Each manifold is known, loosely, as a world. The worlds are connected in a structured array, so that some worlds are 'closer' to each other than others. The exact manner in which possible worlds are connected or not is determined by the accessibility relation R; all and only the worlds in the supermanifold are in K. According to McCall's model, α evolves
from K through the successive instantiation of a physical possibility.

![Modal space diagram](image)

**figure 8: Modal-Minkowski space.**

But a particle within the supermanifold thus traces out a world-line, a history, just as it did within a single Minkowski manifold. We can trace the path of a particle within the supermanifold, or within the Modal-Minkowski space as Yourgrau refers to it (see figure 8).
4.2 The logic of McCall's model

If, as holds on McCall's model, the world is such that at each instant of time two or more alternative future courses of events are open, then how many physically possible futures are there? McCall's modal model has the resources to answer this question precisely, to determine the exact transfinite size of $K$. The fact that the mathematics of the model are such that it can provide a determinate proof of the number of worlds required is a point in favour of the model. MWI PWM models would not have such resources. The answer to this question helps to show that McCall's model is determinate, and hence logically possible.

Suppose that each possible future may be represented as a branch of a continuously branching tree. Each branch is composed of a continuum of binary branch-points. McCall argues that for every branch of the tree there corresponds a function from points on the time-axis measuring the height of the tree to the set $\{1, 2\}$ and vice versa. Given any point $x$ on any branch, assign 1 if the branch goes left, 2 if right. Hence every branch uniquely determines a function $f$. And conversely, every function $f$ uniquely determines a branch structure, in that given any point $y$ on the time-axis, we can determine the corresponding branch point $x$:

For each $x$ on the same level as $y$, consider all the predecessors of $x$, each of which is a left-branch point of a right-branch-point, and construct the function $g_x$ corresponding to them. $x$ corresponds to $y$ if and only
if \( f=g \) for predecessors of \( y \). Hence the number of branches equals the number of functions. But the number of functions from the time-axis continuum into \( \{1,2\} \) is \( 2^\infty \). Hence there is something - the number of possible futures - which has physical significance and which has a cardinality higher than that of the continuum.

This result holds because McCall assumes that the branch structure of the world is such that earlier events are proper subtrees of later events; that the branches "fall off" the tree as the now moves up the time-axis. This view entails that the outcome of events in this world is not entirely fixed by events in this world, but by events across all physically possible worlds.

The exact manner in which the property of the present is distinguished in McCall's model is given by its unique topology. That topology is the weaker \( T_1 \) axiom only, rather than the topology of the standard Minkowski models, which are all \( T_2 \) or more generally known as \( H \) for Hausdorff. How does this line go?

By definition, a topological space \( X \) is a \( T_1 \)-space if and only if whenever \( x \) and \( y \) are distinct points in \( X \), there is a neighbourhood \( N \) of each not containing the other. Obviously, every \( T_1 \) space is also a \( T_0 \) space. It can also be easily shown that there is a distinguishing property of \( T_1 \) spaces not had in a \( T_0 \) space only. If \( X \) is a \( T_1 \) space, then each one-point set in \( X \)

---

is closed, which is equivalent with the statement that each subset of X is the intersection of the open sets containing it.\textsuperscript{29}

The more restricted Hausdorff space, a refinement of the $T_2$ space, has the properties of $T_1$, that one-point sets are closed, but also the property that each net or filter on X converges to no more than one point, and no less than one point either. By definition, a space X is a $T_2$ space if and only if whenever $x$ and $y$ are distinct points of X, there are disjoint open sets U and V in X with $x \in U$ and $y \in V$. Another interesting feature of Hausdorff spaces (as the definition above is known as the Hausdorff separation axiom) is that the diagonal is closed in a H space; in symbols, the diag $A = \{(x,x) | x \in X\}$ is closed in $X \times X$. But interesting features aside, if the physical laws of the actual world are irreducibly stochastic, then for each here-now in space-time, there is a set of physical possibilities and a selection from that set, and the selection given by an actualization function that goes from a world-at-a-time to a physically possible future world.

So the decision on the part of a scientific realist to adopt and accept into his or her ontology temporal passage can be interpreted as a decision to weaken the topological requirement of the model space, whether or not, in other words, the

\textsuperscript{29} For a clear and simple proof, see: Willard. (1970) \textit{General Topology}. p. 86.
actualization function is one-one or one-many, whether or not the set of physical possibilities is the identity class with this world \( \omega \), or whether there is a further physical feature of our world that distinguishes being present in \( \omega \).

What is at stake in this decision? McCall's model requires us to weaken the topological requirement from \( H \) to \( T_1 \), to allow bifurcation and thus a branch-structure. The requirement that is weakened is a local requirement on the geometric structure from one point to another 'nearby' point in the manifold. The manifold, the set of points with geometric structure, in turn breaks down into four dimensions, three of space and one of time. The weakening of the topology allows the time dimension to refer to a non-identical set of manifolds-at-a-time, manifolds which have a global time function and manifold in which time is linear (non-circular).

Why weaken the requirement? McCall advances many reasons for his model, a model which entails the weakening of the topology from \( H \) to \( T_1 \), reasons ranging from the decision theoretic to the theory of quantum mechanics to astrophysics and cosmology. It would be a compendious task beyond the scope of this paper to evaluate McCall's model in each of these sectors. Suffice it to note that if the metaphysics of McCall's model holds, then it follows that the trickle-down effects of that metaphysics will have profound consequences on the nature of causal interaction,
which in turn will have affect the natures of the matter-energy entities in the world such as you and I and how we go about making decisions and what decisions are physically possible and what decisions are in fact actualized.

Another way to understand the trickle-down effect of the metaphysics of McCall's model is that the trickle-down follows from the fact that the dynamic motion of the now is asymmetric in time. It is this asymmetry that distinguishes the motion of the now in time.

For two reasons topologists have studied in great detail the theorems provable on the Hausdorff level, and consequently not studied the nature of theorems provable in weaker spaces such as the $T_1$ or the $T_0$ space. One reason is that Hausdorff spaces have a 'nicer' property than in $T_1$ spaces. The underlying reason for this niceness or greater aesthetic value is the existence of unique limits in Hausdorff spaces, which has pleasant consequences (for example, continuous functions with Hausdorff range are determined by their values on a dense set, or that the diagonal $\Delta = \{(x,x) | x \in X\}$ is closed in $[\text{the continuous closed image}] X \times X$.) $^{30}$ Of course, the continuous closed image of a $H$ space need not be an $H$ space, but it may.

The other reason why topologists have studied \( H \) spaces more than \( T_2 \) is that the standard Minkowskian models that physicists were working on were \( H \) spaces. The underlying reason for this neglect is that workers benefit from looking to the needs of Mother Nature.

But the physicists were working within a too-limited conceptual framework. The Minkowskian model is forced to deny the existence of a property that distinguishes the uniqueness of the present events, that they are present in \( \mathbb{R} \). Some models go so far as to deny the existence of a cosmic time function, contrary to the observed evidence of very-large-scale structures of matter-energy in the universe (e.g., the "Galactic Wall") which suggests that there is a unique trajectory of the mean motion of matter in space-time, and a proper time along that privileged trajectory. McCall's model, by contrast, takes the proper time along that trajectory to demarkate the evolution of the universe-tree for the cosmos.

The universe-tree, in McCall's model, is a branched-connected structure of manifolds, or worlds. The tree loses branches, where the branches represent a probabilistic, but not necessarily deterministic, set of physical possibilities at-a-time. The branches which are non-instantiated vanish, and the now selects the instantiated branch after the node of possibilities at-that-time.
McCall's model is committed to a unique topological feature of the branching structure that distinguishes the branches from the trunk. Without that distinguishing feature, the Minkowskian proponent can agree with McCall's premises and deny his conclusion by arguing that the identity relation trivializes the supposed unique determination of a specific set of worlds in the future direction from the world in the past direction of the trunk. That distinguishing feature of McCall's model is the fact that if the branching structure is upper cut, then the space is $T_1$ and not Hausdorff. If the branching were lower cut then the space could be Hausdorff and not $T_1$, although it could also be $T_1$. In a lower cut space, the tree and the branches are indistinguishable from branches and branches. In an uppercut space, the union of the trunk and the branch is the same as a lower cut space, but the union of any two branches is either disconnected or itself an uppercut space. The distinguishing feature is the existence of doubled paths under $T_1$-upper cut but not under $H$-lower cut, and hence not under $T_1$-lower cut. If there are undoubled paths, then the image of the function is also a function, whereas if there are doubled paths, then the image of the function is not a function. The failure of the $f_1$ function to exist when doubled paths exist distinguishes the upper cut space
from a lower cut space. This asymmetry distinguishes the trunk from the branches. \(^{31}\)

To the further skeptical charge, on behalf of the Minkowskian proponent, that local Euclidean computability would fail on the T\(_1\) axiom only, without the Hausdorff axiom, it can quickly be shown that since each one-point set in X is closed under T\(_1\), there is sufficient logical structure for a metric. The Hausdorff axiom has a unique limits property; on the T\(_1\) axiom, functions don't necessarily converge to a unique limit. The function which describes the motion of the now, in particular, does not converge to a unique limit, but instead continuously selects from a set of real possibilia, the physically possible worlds.

Now the cat is finally out of the bag. It must be shown that the possible worlds distinct in order that the possible worlds be real possibilia. Otherwise, Quinean objections about the number of possible fat men in the doorway would apply and the PWM program undermined, as there would be no determinate ontology implied by real possibilia.

McCall can show that his model is committed to \(2^C\) worlds, 2 to the power of the continuum. The radicalness of McCall's

\(^{31}\)For more information, see: McCall, S. "Choice Trees."
proposal is that one must be a realist about transfinitely many existents, rather than merely infinitely many on the standard non-tenser Minkowski view. But McCall's model is not nonsensical or out of the ballpark by any means, despite the apparent size of the ontological commitment. After all, the distinctness requirement mentioned in the above paragraph has been met by McCall's model.

McCall holds that time's arrow points the way it does as a matter of semantic necessity, not due to empirical facts about thermodynamic processes. If the world were completely deterministic, then a state description of the world, together with the laws of nature, would entail every other state of the world at any time. If the world is indeterministic, then the complete state description of the world is different at different times. McCall's theory entails that the state-description at a later time is a proper subtree of the universe at an earlier time.

On McCall's model, the local Euclidean computability of the world holds. It is a global requirement that has been weakened, while the local considerations remain the same. I submit that where a global requirement can be weakened at no cost to local considerations, then the global requirement was superfluous in the first place. Local Euclidean computability (LEC) must be
preserved; but we need not be generous in our global attributions.

LEC holds on $T_1$ as every point set is closed. It's just that functions behave more 'reasonably' in a Hausdorff space and hence they have been studied more (convergent functions converge to a unique point).

The trivial level of topological structure, $T_0$, makes a topology on $X$ look not much different from a single point. It would be much nicer if some set-theoretic structure of $X$ were reflected in its topology. If so, then we can assimilate the tricks of set theory into the topological analysis. What is needed, apparently, is the requirement that the topology of $X$ contain enough open sets to distinguish between the points of $X$ in some way. Increasing the levels of geometric structure from $T_0$ to $T_1$ and then to $T_2$ gives more and more richness of set-theoretic character to the topological space $X$.

But how much set-theoretic structure on $X$ is enough? What do we lose in the weakening of the topology from $T_2$ to $T_1$? In a nutshell, we lose a more global restriction on the $T_2$ space which is not true of a merely $T_1$ space; the global restriction of the Hausdorff axiom. But the loss of the global restriction of $H$ does not necessitate a lack of locally Euclidean computability. As indicated above, the global restriction is locally superfluous.
Hence McCall's model sacrifices an unnecessary global restriction of the possible topology of X. That sacrifice entails boosting the ontology of the model, as the ideology specifies a greater than continuum number of physically real branch nodes. So the sacrifice, such as it is, is worth it. The benefit, the unique evolution of the universe-tree in time, demarkates the nature of the privileged property of being present, or now.

Therefore, the passage of time is an instructive case showing the inter-relation between mind and mind-independent nature, and how the model in the mind evolves to match, correspond to, or in the jargon, to be an isomorphic diffeomorphism of, the relations in the objective and mind-independent world.
4.3 The soundness of McCall's model

McCall has argued that his model can derive some support from the observed quantum indeterminism in our world. Certainly the idea of real alternative physically possible futures derives some support from the indeterministic nature of quantum events. On this point, Reichenbach argued that temporal becoming, or in my terms the actualization of nowness, should be understood in terms of 'becoming determined', because it is only now that the quantum wave function collapses and achieves a fixed, definite value. This causal feature defines a structural difference between the past and the future, since past events are specific and identifiable, whereas future events are indefinite. On Reichenbach's analysis, the present divides the future from the past and it is the moment at which probabilities change into actuality.

McCall's claim that his view escapes the problems of Reichenbach's view betrays a weakness of his tree model. McCall notes that Grünbaum has shown that Reichenbach confused the epistemological discovery of the actual event-properties of the once-future event out of the wider matrix of possible properties allowed by the quantum-mechanical probabilities with the
metaphysical or existential becoming of such a property. The becoming determined of an event is always now, relative to that event, and hence it appears that Reichenbach has failed to identify a unique property that intrinsically characterizes the now and singles out a unique present for each moment.

While indeed McCall is correct that it is not arbitrary what future possibilities are open at a time, the fact that we have no epistemological access to the future is does not entail the metaphysical conclusion that future is indefinite. Some event or other will constitute the being present of the year 2,000 AD, and some event or other will constitute the being present of the year 20,000 AD. Hence for all observers the relative past is fixed, and since one observer's relative past is another observer's relative future, the relative future is as fixed as the relative past. While this argument does not hold for the absolute future being necessarily fixed if the absolute past is fixed, assuming that an absolute past and absolute future can be defined for all observers, this failure does not detract from the metaphysical point. On McCall's model, the future of a is necessarily indefinite, and so no epistemological conclusions can be derived from present evidence regarding which future physical possibility will be instantiated. Even if an event E lies in the absolute

future of an observer \( O \) at \( t_0 \), in McCall's model, \( E \) is indefinite until actualized. The fact that it is only after \( E \) is in the absolute past of \( O \) that \( O \) can recognize that \( E \) was in the absolute future of \( O \) at \( t_0 \) is a fact that can be inferred by abstractly reconstructing the universe-tree.

Another consideration about McCall's model must be noted. McCall allows that the progressive falling off of future branches does not take time, but 'generates' time. But 'generates' is a metaphor that without further explanation is incoherent. T-theorists have often thought that an essential part of the moving now was to see the motion, the directed nature of time flow, as a process. A process is a continuous causal chain, with phase-changes. McCall's model represents the flowing aspect of the A-series by the evolutionary process of pruning the universe-tree.

McCall states that the reason there exists a method of transforming a later universe-picture into an earlier one, within the same frame of reference, but not an earlier one into a later one, is that earlier branches are preserved and recoverable while there is no distinguished future branch. However, one future branch will become so distinguished. Hence that set of events can be seen retrospectively to have been the ones that were going to be distinguished. That set of events is distinguished by having the property of being the set that would be distinguished by retrospective analysis in the future.
There are still technical details that need to be worked out in McCall's model. For instance, in the curved space-time region of a black hole, there would be an additional complexity in the branching-structure of the dynamic model of time (see figure 9). For an entity in a region of tightly curved spacetime, the motion of the now ceases because the curvature of that region entails that no future-pointing light-cones exist, hence no future-pointing branches exist. After the black hole evaporates, in accordance with the Hawking-Ellis theorem, the motion of the now will resume with respect to the remainder of the space-time. Considering the supermanifold containing \( \mathfrak{m} \) in which this black hole exists, the motion of the now up the universe-tree will have a gap or discontinuity which represents the duration, relative to
the rest of the space-time, that the now spent in the black hole. That gap will appear to be infinite, since analogously, an object entering within the Swartzchild radius of a black hole appears to recede from view forever. The presence of gaps complicates the picture of the binary branching tree.

Furthermore, it must be noted that McCall's model must explicitly introduce the assumption that there are no closed timelike curves. Hawking has shown that this assumption is equivalent to the assumption that there is a cosmic time function. If there is a cosmic time function, then that function can measure the motion of the now for the entire universe. If closed timelike curves were instantiated in our universe, then for an entity travelling along that inertial trajectory, there would be continuous 'lopping off' of the future-directed branches as the now moves up the world-line, yet the entity would return to its own past, where the branches have already been 'lopped off'. Hence no such curves exist on the dynamic tree model.

4.4 The conclusion of McCall's model

McCall's model of a binary branching tree can specify precisely the number of physically possible worlds, 2 to the power of the continuum. Despite the fact that the number is greater than aleph null, the countable infinity, the model is nevertheless logically well-defined, hence logically possible. Furthermore, although the model requires a weakening of the global topological requirements, it has been shown that the global topology can be weakened and yet local Euclidean computability is preserved. In other words, even in the branching model, the world would continue to appear to conform to a Euclidean space in the small, while the global topology could vary from point to point (within some constraints). McCall's model successfully incorporates time flow through the fact that the now picks out a unique tree-structure. The tree evolves in time, so that the past is the trunk, fixed and determined; and the future is a set of branches, open and not-yet-determined. The tree-structure can distinguish between the past and the future, and hence provides a unique manner of characterizing the motion of the now. On the model, nowness is a quadruple relation \(<P, a, R, K>\) where \(R\) is asymmetric and where \(a, K\) evolve.

McCall's model solves the problem of the passage of time, and avoids the infinite regress of temporal attributions, by positing time flow within a transfinite set of manifolds or
worlds. The passage of time is explicated as a world-relative relation, a relation between a and the set of physically possible worlds at that time. The ontological commitment of the model is justified as a moderate position between actualism and the complete Many Worlds Interpretation.
5.0 Conclusion

The conclusion of McTaggart's paradox is that there are no logically possible models. The existence of McCall's dynamic universe-tree model contradicts McTaggart's claim, since McCall's model is logically possible. Since McTaggart's paradox is a valid argument, at least one of its premises must be denied. It is clear that the premise that needs to be denied is the premise that the A-series leads to a contradiction. McTaggart's metaphysics was fuzzy on this point. McCall's modal analysis of the flow of time replaces this fuzziness with a definite function, the evolution of the universe-tree. Thus McCall's modal solution is a counterexample to the conclusion of McTaggart's paradox, a solution which the hidden modality of the logic of McTaggart's paradox permits.

The existence of McCall's model entails that the conclusion of McTaggart's paradox cannot be accepted. The passage of time is an intrinsic part of the nature of time. The passage of time is explained by the asymmetric evolution of the universe-tree. The passage of time and the motion of the 'now' is thus intrinsically related to something literally out of this actual world, namely, the nonselected branches of the physically possible worlds.
6.0 References


Bigelow, John. (1989) "A Modal Theory of Time" (forthcoming retitled as "Worlds Enough for Time")


---------- (forthcoming) "Choice Trees"

---------- (forthcoming) "Interpreting Quantum Mechanics via Quantum Probabilities"


-------------- (1934) Philosophical Studies, London. Ch. 5.


---------- (1967) Past, Present and Future, Oxford UK.


Smart, J.J.C. (1964) Problems of Space and Time, New York USA.


