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The Temporal Structure of the World

Keith Heard

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Abstract

The thesis starts from the position of Ontic Structural Realism, which holds that the world just is structure, and from the ontology of Rainforest Realism in which the only things that exist are (Dennettian) real patterns. I argue that the temporal structure of the world emerges from the temporal aspect of spacetime and consists in real patterns of time existing at different ontological scales. Such scale relativity of ontology allows the temporal structure of the world to display very different features. At the scale of instants and of extremely small duration, I argue that there is non-dynamic, tenseless structure to which the earlier than relation may be applied. At the scale of larger duration, I argue that there occurs robust objective becoming that just is dynamic composition of larger-scale material structure (as real patterns) – initiating a real, tensed, passage of time. Thus, something akin to a Block Universe can be found at the very small scales of time, from which emerges the dynamic world of our experience.

Key Words: structure, real pattern, scale relativity of ontology, non-dynamic, dynamic, tenseless, tensed, emergence, objective becoming, passage of time, spacetime.

Lay Summary

The thesis starts with an examination of how time appears to us in our everyday world. From this appearance we form our concepts of time, such as: past, present, future, earlier, later, and simultaneous. I maintain throughout, even as I discuss scientific theories bearing on the nature of time, that these everyday concepts are not only not naïve or (as some would claim) illusory but are necessary for what makes us human and are extremely impressive in their sophistication. I find that the one revision to the everyday concepts I propose in this thesis is that, although the past and future are objective, the *near* and *far* past and future are purely subjective notions. These subjective concepts are a great achievement as they make human agency possible. As to the more scientific part of the thesis, I find that the temporal structure of the world is split between that of a 'static' state where nothing really changes and a dynamic structure that continually changes. The 'static' structure is found at the very small scale of time, so we can rightly say that nothing does happen in an instant. The dynamic structure is seen at a scale of longer durations and consists of a continually changing present – together with the past and future.

Table of Contents

Acknowledgements	ii
Abstract	iii
Lay Summary	iv
1. Metaphysics of Time Naturalised	1
1.1 The Manifest Image of Time.....	1
1.2 Analytic and Naturalised Metaphysics.....	7
1.3 Ontic Structural Realism – There are No Things.....	14
1.4 Rainforest Realism – Things are Real Patterns.....	17
1.5 Emergence and Scale Relativity of Ontology.....	23
1.6 The Notional Category and Non-Redundancy of Information.....	27
2. The Emergence of Time I	31
2.1 Time and Space Emerge from Spacetime.....	31
2.2 The Structure of Time.....	37
2.3 Disentangling McTaggart’s <i>A</i> - and <i>B</i> -Series.....	39
2.4 The <i>A</i> -Scale and the <i>B</i> -Scale.....	46
2.5 Should We Care Whether McTaggart’s <i>A</i> -Series Is Contradictory?.....	50
3. The Emergence of Time II	56
3.1 Whitehead’s Abstractive Sets of Durations.....	56
3.2 Time-Atoms as Sets of Durations Covering a Single Instant.....	59
3.3 The Emergence of Ontic Scales of Time.....	65
3.3.1 The Micro-Scale of Instants.....	65
3.3.2 The Meso-Scale of the Individual Atom.....	66

3.3.3 The Macro-Scale of Aggregates of Atoms.....	67
3.4 The Passage of Time.....	71
3.4.1 The Emergence of the A-Scale.....	71
3.4.2 The Passage of Time.....	73
3.4.3 The Epistemic Re-entangling of the A- and B-Series.....	77
4. The Emergence of the Content of Time I.....	79
4.1 Content as Structure.....	79
4.2 Matter as Ontologically Dependent on Spacetime.....	81
4.3 Content at the Macro-Scale of Time.....	87
4.3.1 Content as Particles in the ‘Quantum Realm’.....	87
4.3.2 Content as Material Objects in the ‘Classical Realm’.....	91
5. The Emergence of the Content of Time II.....	100
5.1 The Transition from Quantum to Classical.....	100
5.1.1 Environmental Decoherence and Superselection.....	100
5.1.2 The Quantum Measurement Problem.....	104
5.1.3 The Quantum Measurement Problem and ‘the Collapse Problem’ in OSR....	111
5.2 Content at the Meso-Scale of Time.....	117
5.2.1 Quantum Entanglement as Content.....	117
5.2.2 Time-Atoms and Doubly Special Relativity.....	119
6. Dynamic Composition.....	123
6.1 Content of the Past, Present, and ‘Future’.....	123
6.2 The Present.....	125
6.3 Measuring Objective Time Lapse.....	128

6.3.1 Coordinate Time and Proper Time.....	128
6.3.2 How Fast Does Time Pass?.....	137
6.4 Composition of A-Series Real Patterns.....	139
6.4.1 Notional Causation and Notional Coherence.....	139
6.4.2 Composition of Real Patterns at Different Ontological Scales.....	143
7. The Language and Experience of Time.....	145
7.1 Folk Discourse.....	145
7.1.1 The Scope of 'Now'	145
7.1.2 All Content at the Meso-Scale of Time Exists Now.....	147
7.1.3 All Past and Future Times Exist Now.....	148
7.2 Metaphysical discourse.....	149
7.2.1 Making Sense of Eternalism.....	149
7.2.2 Is the Tensed-Tenseless Debate Substantial?.....	153
7.2.3 How Open is the Empty Future?.....	158
7.3 Experience and the Specious Present.....	163
8. Conclusion	175
References.....	178

It was Whitehead who was the serpent in this paradise of Mediterranean clarity. He said to me once: "You think the world is what it looks like in fine weather at noon day; I think it is what it looks like in the early morning when one first wakes from deep sleep." I thought this remark horrid, but could not see how to prove that my basis was any better than his.

Bertrand Russell

1. Metaphysics of Time Naturalised

1.1 The Manifest Image of Time

How time appears to us in our everyday lives just is the manifest image of time. Our behaviour is guided and limited by this image. We seem to be time's prisoner so that, though we can move freely in space – up, down, left, right, backwards, forwards – we are held firmly in the grip of the present. Meanwhile, the past has been and gone, never to return, and the future lies open before us. While we can't exit the present, we are forced to move with it into the future as the present continually changes. These are just a few of the ways in which we experience and think about time in our everyday lives. This is part of the manifest image of time. Another part of the manifest image is revealed in our understanding that our births happen before our deaths; that, although the lightning flash and thunder occur at the same time, depending on our spatial distance from the event, the thunder is usually heard after the lightning is seen; and that the sharp pain occurs at the same time as the cricket ball strikes the arm.

These two parts of our manifest image of time are together made manifest through the specious present. Indeed, the specious present just is the manifestation in thought and experience of these two parts of our image of time. Barry Dainton writes that the specious present is "the brief temporal 'window', perhaps no more than a second long in (apparent) temporal depth, through which change and succession are directly apprehended" (Dainton 2012 p. 125). Thus, when we listen to a succession of the musical notes Do-Re-Mi played swiftly on a piano, although we hear them together in the specious present we distinguish Do as happening before Re, and Mi as after Re. Furthermore, if three chords are struck in quick succession, then we hear the notes of each chord as struck at the same time but the chords themselves are experienced together successively. Thus, there is not only succession of experience but also experience of succession.

Dainton's 'directly apprehended' experience of succession is not of the past succeeding the present. The specious present is directly experienced as of one time and its contents are experienced as either earlier/later than each other or as simultaneous – not as various

degrees of pastness (or even presentness). The change that is directly apprehended within the (specious) present is of events as being before or after one another. The change of what was 'present' to now being 'past' is not immediately apprehended within (during – if it has temporal depth) the specious present. Rather, such change arises in cognition when content that had been directly experienced within the specious present is no longer directly experienced but is only remembered as having been so. Thus, there are two types of change involved with the specious present. One type is found within the structure of the specious present as the difference of earlier and later, and which is directly apprehended. The other type arises when content that was present to experience is no longer experienced as occurring now but is remembered and thought of as past by succeeding specious presents; and so is cognised indirectly. Thus, there is change and succession both within and between specious presents that together give rise to the two parts of the manifest image of time.

Although the manifest image of time has been part of the human experience since the dawn of humankind, it wasn't until 1908 that its two parts were explicitly separated in thought and categorised as two different series of the one manifest time. It was then that the Hegelian philosopher John McTaggart Ellis McTaggart classified them as the *A*-series and the *B*-series. The *A*-series is that part of the manifest image that consists in the positions in time known as past, present, and future, together with their content that moves from the far to the near future, through the present and onward into the recent past, only to then recede further and further into the past. The other part of the manifest image – those times that are permanently positioned as earlier or later than each other or else are simultaneous, together with their unchanging content – he called the *B*-series. The *A*- and *B*-series have haunted analytic philosophy of time ever since. Thus, dynamic, or tensed theories are generally known as '*A*-theories', whose adherents tend to call upon 'common-sense intuition' in support of dynamism and tense. Static or tenseless theories are called '*B*-theories' and their supporters tend to claim that the findings of science trump 'common sense' in the case of time. The *A*- and *B*-series are also invoked in the naturalised metaphysics that follows – though in a less familiar way.

It should be clear that this description of the manifest image of time is not that which is usually found within philosophy of time. The more usual description concerns itself only with features

associated with the dynamic A-series. For example, manifest time is described by Craig Callender thus:

In early childhood we come to model the world as having a special present that carves the world up into a past, present, and future. We regard the past as fixed and the future as open, and we feel that this structure updates itself, or flows. The core features of this conception of time – manifest time – appear to be virtually universal, and they pervade our language, thought, and behavior. Yet manifest time seems to conflict with time as understood by physics.
(Callender 2017 p. 1)

In other words, the ‘core features’ of the manifest image of time are held to be those of the A-series alone. However, McTaggart introduced his two series because he understood that: “Positions in time, **as time appears to us *prima facie***, are distinguished in two ways” (McTaggart 1908 p. 458, boldface added). Now, it seems to me that how time ‘appears to us *prima facie*’ just *is* the manifest image of time. Therefore, if McTaggart’s great advance was in separating the appearance of time into two series through his analysis, then he demonstrated that manifest time consists in the union of both A- and B-features. In which case, if we concede that scientific time is B-time, then, contra Callender, manifest time need not conflict with the time of physics since features of the physical concept of B-time are represented *within* the manifest image (as the B-series and its earlier than relation). It seems, then, that manifest time results from a combination of representations of both scientific time and some form of dynamic time. My claim, therefore, is that the core features of manifest time as discovered by McTaggart are those of *both* the A-series and the B-series. Thus, positions in time appear to us – are manifest – as past, present, future, *and* earlier, later, simultaneous.

This combined image of time is made manifest through specious presents by the two types of concomitant change: the one (earlier-to-later) apprehended directly within a specious present, the other (present-to-past) apprehended indirectly from the relation between specious presents. In this way, change of position in time (from earlier to later) is linked with the passage of time (from present to past), and this can result in the overall image of manifest time appearing to be one of dynamism, which in turn may lead philosophers to claim that the manifest image is itself wholly dynamic – i.e. with its core features being those of the A-series alone. This point will bear further examination.

The notion of 'passage of time' is much debated within metaphysics. Whereas I associate passage (as change from present to past) solely with indirect apprehension (inference), Robin Le Poidevin describes the more usual linkage of the passage of time with both indirect and direct (immediate) apprehension of change in this way:

We are indirectly aware of the passage of time when we reflect on our memories, which present the world as it was, and so a contrast with how things are now. But much more immediate than this is *seeing* the second hand move around the clock, or *hearing* a succession of notes in a piece of music, or *feeling* a raindrop run down your neck. There is nothing inferential, it seems, about the perception of change and motion: it is simply given in experience.

(Le Poidevin 2007 p. 87)

However, Christoph Hoerl suggests that such immediate perceptual experiences of movement and change involve neither real nor apparent experience of (A-series type) passage from present to past, i.e. there is no phenomenology of passage involved in perceptual experience. Thus, for Hoerl, no-one even *seems* to perceive passage. In this, he argues against those B-theorists, such as L. A. Paul (2012) and Barry Dainton (2012), who agree that there is phenomenology of passage but claim that such experience of passage is perceptual illusion. Hoerl writes that "if there is no *perceptual* illusion of the sort envisaged by those who speak of an illusory phenomenology of passage, there must be a form of *cognitive* illusion they are under, which leads them to say that there is" (Hoerl 2014 p. 195, his emphasis). He then proceeds to diagnose the root cause of this cognitive illusion as

a conflation between the *correct* thought that only some changes can be perceptually experienced (others being too slow to be perceived), and the *incorrect* thought that some perceptual experiences involve not just an awareness of change, but that the change in question is itself experienced to have some special further ('animated' or 'flow-like') quality.

(Hoerl 2014 pp. 196, his emphasis)

The '*correct* thought' here rests on the difference between a succession of experiences and an experience of succession. Thus, changes that are perceptually (i.e. directly or immediately) experienced, such as the movement of the second hand of a watch – "that is, the hand's successively occupying different positions – can simply be *seen*" (Hoerl 2014 p. 197). This perceptual experience, then, is an *experience of succession*. Whereas, concerning changes

that are too slow to be (directly) perceptually experienced, such as the movement of the watch's hour hand, Hoerl writes: "We cannot see the hour hand move, although we know that it has moved because we can see it occupy one position now, and recall seeing it occupy a different position earlier" (Hoerl 2014 p. 197). In doing so, we infer the (too slow to see) movement from the *succession of experiences*. I believe Hoerl is right to claim this as 'correct thinking'. Also correct is his claim of 'incorrect thinking' – that *perceptual* experience of change is incorrectly thought to involve *perceptual* experience of passage. However, Hoerl concludes from this that, not only do we not perceive passage, but that we do not even *seem* to perceive passage. Therefore, all those who believe that they seem to perceive passage are suffering, not from *perceptual* illusion, but from a form of *cognitive* illusion. This is where I part company from Hoerl.

To understand this departure, we must return to my description of a specious present. Within a specious present, the direct perceptual experience of succession takes place over a time interval, or duration, but (in agreement with Hoerl) this experience is not accompanied by a direct perceptual experience of passage (whether real or apparent). Succession is directly perceived only as earlier events being followed by later events. The experience of passage is an indirect inferential cognitive experience that arises within a current specious present when direct perceptual experiences of succession that are recalled from previous specious presents are *imperceptibly* united to current direct perceptual experiences of succession sharing the same content. For instance, we can directly see a second hand moving continuously around a watch face. If we suppose that a specious present is a second long, then, as we observe the moving hand for several seconds, we simultaneously become aware that the hand that is now moving, say, past the number 5 on the watch face is the same hand that had just recently (seconds earlier) been moving past earlier numbers (i.e. 1, 2, 3, 4) consecutively, while at the same time anticipate that this same hand will continue moving past later numbers (i.e. 6, 7, 8, 9 . . .) consecutively.

This sophisticated cognition unites the memory of previous perceptual experience of succession with current perceptual experience of succession so imperceptibly that we are unaware of any change in the way the shared content is presented to consciousness. Thus, experience of succession (as direct perceptual experience of change and motion) is imperceptibly united with succession of experience (as indirect cognitive experience of

change and motion) *within* each successive specious present. This may be described as a 'seemingly seamless union' of the experience of succession with the succession of experience that ensures that time manifests in our consciousness as a unity – but one which is analysable into two aspects, hence McTaggart's *A*- and *B*-series. Thus, because of the *seemingly* seamless union of the two parts of the manifest image we are unable to separate them in the cognition of change and motion.

Therefore, contra Hoerl, we do indeed *seem* to perceptually experience the passage of time, although there is in fact no such perceptual experience. It is this unavoidable 'seeming' that leads philosophers (including *B*-theorists like Paul, Dainton, and Callender) to believe that the core features of the manifest image of time are solely those of the dynamic *A*-series. It is worth adding that this seemingly seamless union in our cognition explains how the length of a specious present has never been satisfactorily measured. There merely exist various 'estimates' that vary greatly. This is because in introspection we are simply unable to identify at which point in time (direct) perceptual experience of change and motion ends and (indirect) recall of the same content begins, and vice versa. The boundary is vague and seemingly seamless due to our inability to separate the two in cognition.

Now, although I agree with Hoerl that any experience of passage is cognitive (indirect) and not perceptual (direct), I disagree with his further claim that this experience is one of cognitive *illusion*. He thinks of the experience as illusory because, as a *B*-theorist, he believes that, since there is no passage in the mind-independent world, any cognition of passage must be illusory. But what if there is passage out there? And what if this combined *A/B*-series manifest image of time enables us to successfully navigate our way through such a world of time passing? Then ought we not talk of cognitive prowess instead? I will argue that there is indeed passage in the objective world, and hence will celebrate our manifest image of time as the great cognitive achievement that it is. We must be careful, however, not to read off the structure of time from the manifest image, but rather to judge the manifest image in the round by how it relates to the objective structure of time.

1.2 Analytic and Naturalised Metaphysics

There has been discussion in recent years about the relationship between analytic and naturalised metaphysics, that in turn concerns the relationship between metaphysics and science – especially fundamental physics. Differences in the two approaches to metaphysics is easily seen when the ‘extremes’ of each position are contrasted. The analytic extreme may be exemplified by George Bealer, who recommends what he regards as two traditional theses. One thesis he calls ‘The Autonomy of Philosophy’, which holds that most of the central questions of philosophy “can in principle be answered by philosophical investigation and argument without relying substantively on the sciences” (Bealer 1996 p. 121). The other thesis is ‘The Authority of Philosophy’:

Insofar as science and philosophy purport to answer the same central philosophical questions, in most cases the support that science could in principle provide for those answers is not as strong as that which philosophy could in principle provide for its answers. So, should there be conflicts, the authority of philosophy in most cases can be greater in principle.
(Bealer 1996 p. 121)

The evidence for such autonomous and authoritative philosophical answers is to be provided by ‘intellectual seemings’, which are “intellectual, *a priori*, rational intuitions” (Bealer 1996 p.122, his emphasis). As against this, the naturalist extreme may be exemplified by Don Ross, James Ladyman, and David Spurrett when they write:

By [radically naturalistic metaphysics] we mean a metaphysics that is motivated exclusively by attempts to unify hypotheses and theories that are taken seriously by contemporary science. . . [W]e take the view that no alternative kind of metaphysics can be regarded as a legitimate part of our collective attempt to model the structure of objective reality.
(Ladyman *et al.* 2007 p. 1).

In fact, there is an even more radical stance embodied in their Principle of Naturalistic Closure (PNC), which demands that at least one of the scientific hypotheses must come from fundamental physics (Ladyman *et al.* 2007 p. 37-38). This approach to metaphysics may be seen as recognising ‘The Authority of Science’ and is the opposite of Bealer’s ‘The Authority of Philosophy’ thesis. As indicated, these are the extremes and various other approaches can be found in the spectrum lying between these positions. The approach to metaphysics taken

in the present thesis broadly follows the naturalism of Steven French as expressed in the following two points:

(1) If metaphysics is to be taken to have something direct to say about reality, the implications of physics need to be properly appreciated and this will have certain implications for 'paradigmatic' metaphysical positions.

(2) However, one does not have to agree with the claim that *aprioristic* metaphysics should be 'discontinued', since various considerations suggest that we should *value* scientifically disinterested metaphysics as a 'toolbox' for philosophers of science. (French 2018 p. 212, his emphasis)

However, taking this 'lenient' approach to analytic metaphysics in general need not imply that it extends to all branches of metaphysics equally. When it comes to the metaphysics of time, I find that a much 'harsher' approach is required. The major problem with analytic metaphysics of time rests not so much with the analysis of concepts but with its reliance on intuition, specifically what is generally called 'common-sense intuition'. Such an approach to time may have been understandable before Einstein developed his theories of relativity, but to continue in it after that time I find much less so and slightly puzzling.

There is, however, a somewhat different puzzlement, concerning the allegedly more scientific approach of *B*-theorists towards the metaphysics of time, that is brought to our attention by Heather Dyke. She argues that *B*-theorists have mostly been dancing to the *A*-theorists' methodological tune. This is seen in the methodological strategies pursued by both camps. Dyke lists three such strategies followed by *A*-theorists: burden of proof, common-sense intuitions, and a linguistic strategy. She writes that "the *B*-theorist did not take issue with any of the *A*-theorist's key methodological strategies, but bought into them completely" (Dyke 2012 p. 172). In examining these favoured strategies of *A*-theorists even a little, this 'buy-in' by *B*-theorists comes to seem puzzling.

A burden-of-proof strategy insists that one side to a debate is set a higher bar to clear, when giving supporting evidence on its behalf, than the other side. This means that before the debate even begins one side takes a default position that the other side is then challenged to dislodge – all the while being required to provide arguments of a higher standard than those expected of the default position. In the debate between *A*-theorists and *B*-theorists, the former claimed the default position and the latter accepted their claim and thereby strove under the heavier burden of proof. Yet this claim to the default position rested on a further

claim, which is the second methodological strategy of the *A*-theorists: “that their theory better cohered with common sense intuitions about time” (Dyke 2012 p. 170). By accepting this further claim, *B*-theorists were tacitly agreeing to take part in a (now standard) ‘cost/benefit analysis’ of analytic metaphysics. In this analysis, while they agreed that common-sense intuitions support the *A*-theory, their counterclaim was that the cost of this to the *B*-theory was less than the benefits to be gained from accepting that theory – such as its better fit with relativity theory (Dyke 2012 pp. 170-171). Already we can see that *B*-theorists, whose theory supposedly drew its inspiration from physics rather than ‘common sense’ concerning the nature of time, were from the outset pushed onto the defensive, by their *A*-theory counterparts wielding that very same ‘common sense’. Meanwhile, the *A*-theorists’ linguistic strategy

was to point out that ordinary temporal language recognizes a distinction between past, present and future, and to wheel in the methodological principle that we should take ordinary language to be veridical in this regard unless we have good reason to think it misleads us.
(Dyke 2012 p. 170)

With this strategy *A*-theorists assume that between the structure of reality and that of ordinary language there holds an isomorphism. One might have expected *B*-theorists not to concur with such an assumption. However, Dyke argues that both the ‘old’ and ‘new’ cohorts of *B*-theorists accepted this assumption. The ‘old’ responded by arguing that, although ordinary language is indeed tensed, tense is not isomorphic with reality because it is not essential to language. Instead, they argued that language is essentially tenseless, hence the structure of reality is tenseless. The ‘new’ *B*-theorists seemed to have rejected the assumption of isomorphism by firstly agreeing with *A*-theorists that tense is essential to language but then declaring that nonetheless the structure of reality is tenseless because the truth conditions of all tensed sentences are in fact tenseless. But Dyke counters, concerning this claim of ‘new’ *B*-theorists:

However, I have argued that in so far as they rely on an argument from the fact that tensed sentences have tenseless truth conditions, they do assume an isomorphism between language and reality; between the tenseless meta-language in which we state the truth conditions of tensed sentences on the one hand, and reality on the other (Dyke 2008, chapter 2).
(Dyke 2012 p.176)

If we accept Dyke's argument, then it is difficult not to conclude that much of the debate between *A*- and *B*-theorists has been conducted in a manner that current naturalised metaphysics ought to reject. I do indeed accept Dyke's argument, and so: I reject the assumption of the *A*-theory being the default position; I reject the assumption that 'common-sense intuition' bears evidential weight in metaphysics; and I reject the assumption of isomorphism between language and reality. In other words, this thesis will not be concerned with such debates between the *A*- and *B*-theories of time. In this regard I agree with Steven Savitt when he writes:

I believe that philosophy of time should aim at a coherent naturalistic picture of the experiencing subject with its felt time in an experienced universe with its spatiotemporal structure. If this view is correct, then the victory of either side in the dialectic [of *A*- and *B*-theories] will result in a one-sided and shallow account of time. (Savitt 2006 p. 152)

Therefore, this does not mean that the manifest image of time is unimportant. On the contrary, the manifest image is what provides us with our original concepts of time. Through this manifest image and by using the temporal concepts it provides, we exercise agency in the world. These *A*-concepts of past, present, future, and *B*-concepts of earlier, later, and simultaneous exhibit a manifest image that is both sophisticated and indispensable to our being human.

Before proceeding, I propose to distinguish what I shall call a 'settled' from a 'contested' manifest image. The former is what appears as genuinely common to all folk, whereas the latter's domain is limited to some but not all folk. Thus, if all folk agree with the manifest image of time as it was initially portrayed at the beginning of 1.1, then that would qualify it as settled. Whereas a manifest image that appears as 'common-sense intuition' to some but not to others is contested. Now, what generally passes as 'common sense' is usually common to only a part of the folk. To accentuate contrast by extremes again, it is 'common sense' to capitalists that private property and the market are essential to freedom, whereas to socialists they are viewed as being the roots of wage-slavery. So, when the capitalist 'sees' private property, it manifests as an image of freedom; at the same time the socialist 'sees' only an image of exploitation and alienation.

In this case, the capitalists' claim to 'common sense' for their view is generally held as accurate because most folk would currently agree with them. However, if the capitalist view is false and the socialist correct, then the label 'common sense' is not only not a good guide to truth but is a positive block to gaining truth. That is because the phrase 'common sense' itself deters questioning of the legitimacy of the phenomenon it is applied to. Thus, 'common sense' not only describes widely held beliefs about the world but also helps to maintain them as such. The overwhelming majority of views that are passed off as 'common sense' are examples of contested manifest images. I suspect relatively few manifest images can be regarded as settled.

I am much more unforgiving of the notion of 'common sense' than most naturalist philosophers. Even those 'radical naturalists' Ross, Ladyman, and Spurrett can write:

Not only are genuine common-sense intuitions the product of cultural learning, but philosophers who have spent years customizing their cognition with recondite concepts and philosophical technology, as well as habituating themselves to interpreting the world in terms of specific philosophical theories, do not share as many intuitions with the folk as they usually suppose. What metaphysicians take themselves to know by intuition is independent of the latest scientific knowledge and is culturally specific.
(Ladyman *et al.* p. 12)

But if "genuine common-sense intuitions" of the folk are themselves products of cultural learning, and if philosophers' intuitions are "culturally specific", then such recondite philosophical intuitions must also qualify as 'genuine common-sense intuitions' – even when they conflict with 'genuine common-sense intuitions' of the folk. Hence, we will have conflicting 'genuine' common-sense intuitions that are not common to all but are distributed between different groups – only this time based on difference in 'cultural learning' rather than being explicitly political. 'Common sense' is put forward in arguments, such as those in analytic metaphysics of time, as a strategy whereby one side can – with no actual justification – claim the default position. I've already expressed puzzlement at the fact that *B*-theorists meekly accepted this strategy when it was used against them. Of course, this acceptance was partly due to both camps agreeing that 'common-sense intuition' can count as legitimate evidence in metaphysical disputes.

However, another part of the puzzlement concerning time and ‘common sense’ stems from the fact that *B*-theorists accepted that ‘common sense’ supported only one aspect of the manifest image (dynamic time) *after* McTaggart had made explicit the other (non-dynamic) aspect of its dual nature. This may seem puzzling, because by accepting ‘common-sense intuitions’ as legitimate evidence it was, thanks to McTaggart, now open to *B*-theorists to claim that the non-dynamic aspect neutralises the claim of the dynamic aspect as the default position in analytic metaphysics of time. Yet, this has never happened. For instance, here is a passage from Barry Dainton that comes just before he introduces McTaggart’s *A*- and *B*-series:

Common sense may tell us that time is dynamic rather than eternal or passage-free, but our ordinary ways of talking about time reflect both perspectives. There are two families of temporal terms and concepts that we commonly use, one of which embodies the dynamic view and the other the opposing non-dynamic (or block) view.

(Dainton 2010 p. 10)

It still seems to be taken as given by *A*- and *B*-theorists alike (as well as by upholders of *A/B*-hybrid theories) that only one part of McTaggart’s manifest image of time, i.e. the dynamic part, is part of ‘common sense’. In contrast to this, on starting my investigation of time I began with the assumption that both of McTaggart’s series, as parts of our genuinely common way of thinking about time – ‘as time appears to us’ – ought to be taken as equal parts of its manifest image. Thus, the (one-part) dynamic manifest image of time, although described by Callender as “virtually unanimous” (Callender 2017 p. 1), is not actually a settled manifest image. No-one would claim that this one-sided manifest image is incorrect *as far as it goes* – it just doesn’t go far enough. Only when the (dynamic) *A*-features are conjoined with the (static) *B*-features is the manifest image of time complete.

To counter this claim, upholders of the one-part dynamic manifest image would have to explicitly claim, contra McTaggart, that ‘positions in time, as time appears to us *prima facie*’ are **not** ‘distinguished in two ways.’ However, I am aware of no such explicit claim in the literature. As claimed in the previous section, this phenomenon of simultaneously accepting both McTaggart’s two-series description of how time appears to us, and a one-sided manifest image may be due to the ‘seemingly seamless union’ of these two parts of the manifest image

of time within our cognition of change and motion. Interestingly, the *B*-theorist Natalja Deng implies something very similar when writing of the passage of time:

At each time, we are inclined not only to posit a fundamental lack of parity between times, by assigning metaphysical privilege to that time, but also to posit a fundamental parity between times. Our intuitive picture of passage is the product of two essentially opposed elements.
(Deng 2013 p. 25)

It seems to me that Deng's 'intuitive picture of passage' just is the manifest image of time, which is the product of the union of the dynamic *A*- and static *B*-series as 'two essentially opposed elements'. It is telling, though, that Deng describes such a manifest image overall as a standard one of passage, or dynamism.

Thus, there is an awkward tension in the commonly held philosophical view expressed by Dainton above that common sense tells us that time is 'dynamic rather than eternal and passage-free' – even though our everyday discourse and way of thinking 'reflects both perspectives'. It is this commonly held view, together with the view that such 'common sense intuitions' hold evidential weight, that was partly responsible for *B*-theorists accepting the terms of the metaphysical debate as laid down by *A*-theorists. However, if I am right in claiming McTaggart's insight was to recognise a two-part manifest image of time, the *experience* of which is genuinely common to all but whose *analysis* is contested, this in no way implies that such an image must manifest metaphysical truth. The naturalised metaphysics pursued in what follows engages with both the scientific image of time and the manifest image, which has features of scientific time represented within it as one part of that image. It also seeks to reveal the nature and source of the dynamic time whose features are represented within the other part of the manifest image. Before beginning this pursuit, however, in the rest of this chapter I set out the nature of the specific naturalist metaphysics that is employed in its service.

1.3 Ontic Structural Realism – There are No Things

There is a widely held view within metaphysics that takes the world to be populated by individual objects that have intrinsic natures and are externally related by space and time. The laws of science are said to describe such natures (or properties) and relations. Structural realism has a different take on the world. This view holds that the best scientific theories of the time describe the structure of reality. There are variants of structural realism that Ladyman divides into two camps: epistemic and ontic (Ladyman 1998). Variants of epistemic structural realism (ESR) claim that, though we can know the structure of reality, the individuals that are so structured cannot be known. In other words, the extrinsic relations of things can be ascertained but their intrinsic properties cannot. The variants of ontic structural realism (OSR) claim that structure is ontologically fundamental in that it does not supervene on the properties of individuals.

Structural Realism is a radical departure from standard scientific realism, which holds that we ought to accept as existent any unobservable entities that are posited by our best scientific theories. One motivation for such departure stems from what is called the pessimistic meta-induction. Roughly, this is that time and again entities that were posited in the past in various empirically successful theories were later agreed not to exist. By induction, there will be entities posited in accepted theories today that will be agreed not to exist in the future. Therefore, we have reason to believe that current theoretical terms will fail to refer in the future; and so, there is no reason to believe in the existence of unobservable entities as posited by current empirically successful theories.

The standard realist can respond to this challenge along the lines of Stathis Psillos, who holds that only referring terms that play an explanatory role in a theory's success should be accepted as referring to entities. Further, reference is made possible by a 'core causal description' of the properties that enable the entity to perform the appropriate causal role in the world (Psillos 1999 p. 295). This is deemed to make a world populated by individuals, properties, and relations safe for scientific realism. A structural realist response to the pessimistic meta-induction is more prosaic. The challenge is seen as a pseudo-problem since metaphysical attention turns away from theoretical objects and towards the structure of successive theories as correctly describing the structure of the world. This approach meshes

with the no-miracles argument, according to which “realism...is the only philosophy that doesn’t make the success of science a miracle” (Putnam 1975 p. 73). However, as Ladyman and Ross write contra standard realism, it is the reality of structure alone that makes miracles redundant in science:

If general and universal structures can be identified – if to that extent, a unified account of the world can be found, based on science – then successful applications of particular instantiations of these structures in new domains, so as to generate novel but reliable predictions, will be explicable and non-mysterious.
(Ladyman *et al.* pp. 74-75)

Thus far, all variants of structural realism are in accord. The parting of the ways comes with epistemic varieties allowing the existence of unknowable individuals in addition to knowable structure, whereas ontic variants deny there are such individuals. French and Ladyman claim that there is a further challenge that ought to push the structural realist, who has come thus far, into the ontic camp. This is the notion of metaphysical underdetermination, particularly the underdetermination of individuality. There are two major examples of this underdetermination concerning physics. One is from quantum theory, the other from spacetime physics. Briefly, from quantum theory there appears two separate metaphysical choices available that are consistent with the known physics: “particle-as-non-individuals (described via quasi-set theory) and particles-as-individuals (subject to certain state accessibility constraints)” (French 2014 p. 37). Such underdetermination may lend support to a form of antirealism. However, it is here that the force of the advantage of ontic over epistemic structural realism can be felt. By limiting our metaphysical commitments to structure alone this challenge is avoided in a similar way to that of the pessimistic meta-induction ‘pseudo-problem’. French emphasises that it is “the metaphysical underdetermination as a whole . . . rather than the deficiencies of particular metaphysical approaches to object individuality, that I take to push us towards OSR” (French 2014 p. 37 n. 20.)

The metaphysical underdetermination concerning spacetime physics has a long pedigree: Is space a substance or merely relations between substances? In its modern guise, in relation to General Relativity (GR), there appears to be some support given to both metaphysical claims by the physical theory. Roughly, current substantivalism holds that spacetime points exist

independently of matter and could exist without there being any matter; relationalism denies this and claims that there is matter and that spatiotemporal relations hold between different events. According to Ladyman, Howard Stein seems to have been the first to avoid this metaphysical underdetermination in a structuralist manner when he denied both that spacetime was a substance and that it was relations between substances. Instead, he claimed it is “a structure in its own right” (Ladyman 2020).

More recently, Robert Di Salle notes in response to the ‘hole argument’ that, despite failing to supervene on spacetime points, we ought to take spacetime structure as existent (Di Salle 1994). (The ‘hole argument’ points to a breakdown in determinism since GR’s diffeomorphic models, when regarded as physical, do not determine the overlay of the metric field upon the points of the spacetime manifold in a unique way.) By following such a structural realist view, *an ontic structural realist can be a realist about spacetime without adhering to substantivalism*. This is precisely the realist view of spacetime that will be followed here, so that, as Stein wrote to Adolph Grunbaum, spacetime is “*an aspect of the structure of the world*” (Stein 1977 p. 397, his emphasis). In the next chapter I argue that it is from this real spacetime that time emerges.

Thus, the approach taken in the sequel is one of structural realism and stands on the side of OSR in the divide within the structural realist camp, particularly with the eliminativist variant of OSR as developed by Steven French and James Ladyman. In this OSR, objects as individuals are eliminated from fundamental ontology and objects are then seen as derivative or emergent. A major objection to such eliminativism is that there can be no relations without relata. However, eliminativism does not posit relations without relata, it need only insist that the relata cannot be individuals. A major motivation for the elimination of individuals here is the belief that there is a growing convergence among philosophers of physics that physics itself motivates the rejection of any metaphysics that require self-subsistent individuals as fundamental. A short description of OSR is given by Ladyman and Ross as:

the view that the world has an objective modal structure that is ontologically fundamental, in the sense of not supervening on the intrinsic properties of a set of individuals. According to OSR, even the identity and individuality of objects depends on the relational structure of the world.
(Ladyman *et al.* 2007 p. 130)

Another crucial aspect of the French and Ladyman variant of OSR is mentioned in this description, namely that the structure of the world is inherently modal. For Ladyman, objective modal structure is what unifies science, and this unity is revealed by “consilience in respect of the following: induction, the no-miracles argument, novel prediction, probability, information processing and computation” (Ladyman 2017 p. 154). But what in the world lies behind this display of consilience? Where does modality reside? French answers these questions by taking as inherently modal the laws and symmetries of physics and thus the structures that these laws and symmetries are features of are modal (French 2014 p. 231). Similarly, for Ladyman, the objective modal structure of the world “is described by the symmetries and laws of scientific theories” (Ladyman 2017 p.160).

1.4 Rainforest Realism – Things are Real Patterns

The main ontological lesson of OSR is that reality is not a sum of individuals. Ladyman and Ross argue that “rainforest realism and ontic structural realism are unified by the idea that [e]xistence should be explicated in terms of the theory of real patterns” (Ladyman 2017 p. 153). Rainforest realism is a theory of ontology that was initially introduced by Don Ross (Ross 2000) as building on the foundation of Daniel Dennett’s “Real Patterns” (Dennett 1991a). It is further developed by Ross in collaboration with Ladyman, (with David Spurrett, and John Collier) in the book *Every Thing Must Go* where Ladyman and Ross write: “From the metaphysical point of view, what exist are just real patterns” (Ladyman *et al.* 2007 p. 121). Thus, whatever are correctly referred to in everyday discourse as ‘objects’, ‘properties’, ‘processes’, and ‘events’ are just real patterns.

For Dennett there are two criteria for being a real pattern: *recognition* and *compressibility*. All patterns, obviously, meet the requirement to be recognised as a pattern. However, only real patterns can meet the compressibility criterion, thus distinguishing them from mere patterns. Compressibility is borrowed from information theory where mathematical randomness is defined as a random series if and only if the required information that describes the series accurately is incompressible – so that the complete verbatim bit map alone preserves the series. The converse of incompressible randomness is that: “A pattern exists in some data – is real – if *there is* a description of the data that is more efficient than

the bit map, whether or not anyone can concoct it" (Dennett 1991a p. 34, his emphasis). Ross takes this notion of real pattern and develops an ontology from it:

Rainforest Realism (RR)

To be is to be a real pattern; and a pattern is real if[f]

- (i) It is projectible under at least one physically possible perspective, and
- (ii) It encodes information about at least one structure of events or entities *S* where that encoding is more efficient, in information-theoretic terms, than the bit-map encoding of *S*, and where for at least one of the physically possible perspectives under which the pattern is projectible, there exists an aspect of *S* that cannot be tracked unless the encoding is recovered from the perspective in question.
(Ross 2000 p. 161)

Before discussing this definition, it is important to note with Ladyman that, although real patterns are defined here in information-theoretic terms, "[t]he theory of Real Patterns can be explicated in various ways, including in information-theoretic, statistical, and dynamical terms" (Ladyman 2017 p. 154). If this is borne in mind, unwarranted reification of real patterns as information can be avoided. (There is a slightly more sophisticated information-theoretic version of this definition of rainforest realism given in (Ladyman *et al.* 2007 p. 233)).

Now, in clause (i) 'projectibility' is a modal notion and refers to information-carrying possibility. This information will be about the real pattern itself or other real patterns. The clause allows a perspectival, non-reductionist but, importantly, non-anthropomorphic ontology. While clause (ii) confirms the non-anthropocentric nature of RR and by adhering to Occam's razor in information-theoretic terms demands a finite ontology (Ross 2000 pp. 161-162). The last part of (ii) ensures that a real pattern is not informationally redundant (Ladyman *et al.* 2007 p.231). Although this definition of RR builds on Dennett's notion of real patterns there is a real difference between them. Dennett makes use of Hans Reichenbach's *illata/abstracta* distinction in distinguishing kinds of real patterns (Reichenbach 1957). *Illata* are said to exist at the fundamental level of reality, whereas *abstracta* exist through our conceptualisation of mereological aggregates of *illata* and, for Dennett, are "definable in terms of physical forces and other properties" (Dennett 1991a p. 28). However, there are two objections to this distinction. First, it seems to imply that there are degrees to reality with *illata* real patterns being more real than *abstracta* real patterns (Ross 2000 p.160). Second,

our best current science does not support such a distinction; and so “it’s real patterns all the way down” (Ladyman *et al.* 2007 p. 228).

Although there is no division by kind among real patterns in RR, use is made of the philosophical terms ‘first-order’ and ‘second-order’. Thus, Ross, Ladyman, and Collier write that those real patterns that are representations

depend for their genesis and maintenance on their utility to observers as devices for tracking other real patterns. Then a real pattern R2 that exists because it is used to track another real pattern R1 may be said to be ‘second-order’ just with respect to this special type of genetic dependence on R1 . . . and so ‘is second order’ should always be understood as elliptical for ‘is second order with respect to pattern Rx’.
(Ladyman *et al.* 2007 p. 243)

Real patterns that are not second order to any other real patterns are termed ‘extra-representational’; all other real patterns are termed ‘representational’. Representational and extra-representational real patterns may be informally referred to respectively as ‘everyday or special science real patterns’ and ‘physical real patterns’ (Ladyman *et al.* 2007 p. 243). Though it is important to note that here ‘physical real patterns’ refers to those of ‘fundamental physics’, in the sense of “a set of mathematically specified structures without self-individuating objects, where measurements taken anywhere in the universe is in part measurement of these structures” (Ladyman *et al.* p. 44). Thus, fundamental physics “is in the business of describing the structural properties of the whole universe” (Ladyman *et al.* p. 286). All other sciences – including non-fundamental physics – are viewed as special sciences. With the notion of degrees of reality being blocked by the rejection of the illata/abstracta distinction, all real patterns (i.e. both representational and extra-representational) are viewed as equally real. Hence, ontologies of special sciences are no less real than the ontology of fundamental physics.

Now, there are many varied things that populate the ontologies of special sciences that are composite objects being composed of parts. Ladyman contrasts RR’s approach to composition with that of a more usual analytic metaphysical kind. Following Peter van Inwagen, metaphysicians tend to seek to answer the ‘special composition question’, which is, “under what circumstances do some objects compose a composite object?” (van Inwagen 1990).

Analytic metaphysicians may assume that the question can be answered without recourse to scientific accounts of composition or without reference to diachronic or dynamical terms, and instead can be answered in purely synchronic terms. The basic idea behind this approach is of an individual object that exists at a point in time and is composed of parts that also exist at the same point in time. However, as diachronic and dynamical terms usually constitute special science accounts, rainforest realism's attempt to answer the question will have diachronic and dynamical accounts. Ladyman gives this example:

Roughly speaking, chemistry says that atoms compose molecules when there are (relatively enduring) chemical bonds between them, and economics says that agents compose a market when there are financial transactions between them. In both cases, the systems in question are considered over time, and composition is a result of interactions between the parts of the whole. Hence, the answers that science gives to the special composition question make reference to causal processes, not to instantaneous facts about, for example, how close things are to each other. . . . Hence, in science the part/whole relation is shorthand for a process. (Ladyman 2017 p. 157)

In a very real sense, then, the 'things' of rainforest realism are composed of, or emergent from, specifically causal processes. Ladyman and Ross call such composition, or emergence, the "*scale relativity of ontology*" (Ladyman and Ross 2007 p.199, their emphasis). They take their cue from Dennett, who makes use of and notes a "distinct ontological shift as we move between levels" (Dennett 1991a p. 39). Thus, at the atomic scale there are no molecules. Molecules emerge from the atomic scale onto the molecular scale through the chemical bonds (interactions) between atoms. With composition being dynamical and diachronic, and since the relevant objects do not exist at other length scales, the notion of scale relativity of ontology is in respect of both time and space. In the sequel, I apply the notion to time and find that time itself is composed of different ontic scales.

The centrality of causation to the notion of composition in rainforest realism allows us to further contrast rainforest realism with analytic metaphysics. Here is a thought experiment from David Lewis:

Imagine a grid of a million tiny spots – pixels – each of which can be made light or dark. When some are light and some are dark, they form a picture, replete with interesting intrinsic gestalt qualities. The case evokes reductionist comments. Yes, the picture really does exist. Yes, it really does have those gestalt qualities. However,

the picture and the properties reduce to the arrangement of light and dark pixels. They are nothing over and above the pixels. They make nothing true that is not already made true by the pixels. They could go unmentioned in an inventory of what there is without thereby rendering that inventory incomplete.
(Lewis 1999 p. 294)

This is written to demonstrate what for Lewis is the obviousness of a materialist supervenience in which supervenience is reduction. Still, he admits that thousands claim the opposite, namely that materialist supervenience avoids reduction. A dispute such as this resides firmly within analytic metaphysics. Both sides in this dispute are wed to a fundamental level of reality on which all else supervenes. Their differences are better seen when it comes to dynamic patterns rather than the stationary image of Lewis's example. Take John Conway's Game of Life, which Dennett makes use of in "Real Patterns" (Dennett 1991a). Roughly, this is similar to Lewis's thought experiment but with the added twist that the images created by the pixels are seen to move as various adjacent pixels turn on and off. In the Game of Life, images such as 'gliders' and 'eaters' are seen to move across the screen. More than this, the images appear to interact so that a 'glider' may be seen to be consumed by an 'eater'. Of course, such dynamic patterns are merely virtual in these examples. However, they are useful because they place in sharper contrast what appears as obvious to both camps.

The reductionist holds that all images are ultimately composed of pixels. Since their switching on and off is strictly determined by the rules of the Game, images (things like 'gliders' and 'eaters') do not possess causal efficacy over and above that of the sum of the pixels composing them. The so-called interaction between images is merely appearance and can be viewed instrumentally as a practical heuristic. The anti-reductionist holds that, somehow, images are things over and above their base pixels and that, somehow, their interactions are real, due to their having causal efficacy over and above the sum of the composite pixels. The rainforest realist response to this dispute is provided by Ladyman and Ross thus:

In our view this whole debate is poorly motivated, because both sides in it presuppose that questions about ontology must be parsed as questions about *which individuals* are the 'real' ones: gliders and eaters (etc.) plus [pixels], or just [pixels]. We argue . . . that a main contributor to the confusion is a pre-scientific conceptualization of causation . . .
(Ladyman *et al.* 2007 p. 202)

In other words, both sides take as given the standard analytic ontology of individuals, and it is this very ontology that needs to be questioned. The pre-scientific notion of causation referred to is that of 'biff' between individuals, which according to Ross, Ladyman, and Spurrett is often dressed up by analytic philosophers in the apparently scientific garb of 'microbangings' (Ladyman *et al.* 2007 p. 258). From the rainforest realist perspective, what is missing from both accounts is causation (interaction) in the very composition of the images themselves; so that even Lewis's original 'static' image is composed dynamically and diachronically. Thus, rainforest realism's anti-reductionism is not that of analytic metaphysics. The notion of supervening individuals not reducing to their base individuals is simply not well motivated. For RR, real patterns cannot be reduced because they carry non-redundant information. This just means that were a real pattern to disappear then information would be lost to the world. In the Game of Life metaphor, if the viewer could no longer distinguish gliders and eaters from the individual pixels 'making them up' then Life (and along with it the practical heuristic) would be lost to them. Composite things are explored in Chapters 5, 6, and 7 as the content of dynamic time.

There is no single correct way for the ontic structural realist to designate 'things'. French prefers the term 'node', so that things are nodes of structures or sets of structures (French 2014 p. 215). However, RR's designation of things (in the wide sense of objects, properties, processes, and events) as 'real patterns', particularly with its initial use of information-theoretic concepts, provides clearly defined notions that are advantageous when considering the metaphysics of time. Three such notions are: the scale relativity of ontology, non-redundancy of information (both already touched upon), and the notional category. These are examined in the next two sections.

1.5 Emergence and Scale Relativity of Ontology

‘Emergence’ and ‘levels’ are not things that Ladyman and Ross were happy to talk about in *Every Thing Must Go* (Ladyman *et al.* 2007 p. 57). However, that was a particularly polemical book where strict stances were taken that could later be relaxed. This proves to be the case here, as a decade later in his “An Apology for Naturalized Metaphysics” Ladyman is happy to use both the ‘levels’ metaphor and the term ‘emergence’ when defending rainforest realism. Thus, he writes there that: “real patterns at different scales are emergent structure not reducible to the sum of the parts”; and that “[i]t is a fact about the world (for all we know a contingent one) that it is ordered on many levels” (Ladyman 2017 p. 155 & 159). However, two caveats need mentioned. First, the levels that Ladyman refers to are not those of ‘levels physicalism’. No concession is given to either the idea that the world has a bottom level, or to the notion of ontological physicalism. As stated above, all sciences (fundamental physics and special sciences) track real patterns that are on an equal ontological footing: it’s real patterns all the way down. The ‘levels’ that Ladyman now refers to appear to be the standard levels of emergence, or in RR parlance ‘ontological scales’.

Before examining levels and emergence, a further word on the method of approach taken here is in order. Although I make use of many fundamental notions of rainforest realism, I am more accepting of analytic metaphysics and of less austere forms of naturalism than Ladyman and Ross find of value. Particularly, I do not fully endorse their Principle of Naturalistic Closure (PNC). This principle is used by them to clearly demarcate naturalised metaphysics from what they call ‘neo-scholastic’ analytic metaphysics. Ladyman sums up the PNC as follows:

If a metaphysical claim is to be taken seriously at a time t , it should, if true, show how two or more *scientific hypotheses*, at least one of them *specific* and at least one of them both specific and drawn from fundamental physics taken seriously at t , jointly explain more than the sum of what is explained by the two hypotheses taken separately. . . The PNC is an attempt to say what is required for metaphysics to be informed by science, and for it to contribute to the scientific image.
(Ladyman 2017 p. 151-152, his emphasis)

(The full definition is given in (Ladyman *et al.* 2007 p. 37-38)). While I think that this is a not unreasonable way to demarcate naturalised metaphysics, I do believe it is too strong and think as Andrew Melnyk does when he writes:

I still don't see why the unification of a specific scientific hypothesis with a specific hypothesis from fundamental physics *would* be metaphysical, whereas the unification of two specific hypotheses *not* drawn from fundamental physics would *not* be.
(Melnyk 2013 p. 91)

Also, although I believe that naturalised metaphysics ought to take the leading role within metaphysics in general, I also hold that some analytic metaphysics can be of use, and so should be taken seriously. In this respect, I am more in step with Steven French when he writes that:

whereas Ladyman has excoriated current metaphysics for its failure to accommodate the conclusions of modern physics, I think it can be plundered for appropriate resources that we can then use to articulate our structuralist ontology. I've called this the Viking approach to metaphysics . . . but a less brutal image has been suggested by Kerry McKenzie in which metaphysics is regarded as a toolbox, from which we can take various implements – 'dependence', 'supervenience', and so on – to use in order to fashion an appropriate notion of structure.
(French 2014 p. v)

However, as stated earlier, Ladyman is now happy to use the term 'emergence', which Timothy O'Connor and Hong Yu Wong refer to as "a notorious philosophical term of art" (O'Connor and Wong 2015). When this usage is combined with the recent widening of the notion of real patterns from being articulated in purely information-theoretic terms to (at least) those of statistical structures and the dynamics of phase space, there appears to be a more generally inclusive approach taken than was the case previously.

The main reason for the original reluctance to employ the term 'emergence' was due to its meaning so many different things to different people and in different disciplines. O'Connor and Wong give a rough characterization of this shared meaning as: "emergent entities (properties or substances) 'arise' out of more fundamental entities and yet are 'novel' or 'irreducible' with respect to them" (O'Connor and Wong 2015). The most important thing to be taken from this for our purposes is the notion that emergent entities are both novel and

irreducible. Alexandre Guay and Olivier Sartenaer provide a more formal general description of emergence thus:

Emergence is an empirical relation between two *relata*, namely an emergent *E* and its emergence basis *B*, such that the two following theses simultaneously obtain:

- (DEP) *E* is dependent on, or determined by, *B*; and yet
 - (NOV) *E* is novel with regard to, or autonomous from, *B*.
- (Guay and Sartenaer 2016 p. 298, their emphasis)

They then list the various forms that the notion of emergence can take: epistemological, ontological, weak, strong, synchronic, and diachronic. (DEP) can be taken as applying to ontological emergence due to the relation of dependence or determination that is found in the objective world, and is associated with novel properties, powers, or laws. Whereas (NOV) is applicable to either ontological or epistemological emergence such that if the novelty or autonomy resides out there in the world then it will be ontological; but if found solely in representations of the world then it will be epistemological emergence. Often in the literature, epistemological and ontological emergence are called weak and strong respectively. Alternatively, weak and strong can be used to distinguish different degrees in both epistemological and ontological emergence. Thus, regarding examples of unpredictability in epistemological emergence those that only apply in practice are held as weak, whereas those applying in principle are strong. As for ontological emergence the distinction can be applied to degrees of anti-reductionism; with weak being less, and strong being more, anti-reductionist.

The types of emergence that are most important to the emergent theory of time to be argued for here are synchronic, diachronic, and atemporal. Roughly, synchronic emergence is the simultaneous existence of novel 'higher level' emergent *E* with its emergence basis *B*, which exists at a 'lower level'. Diachronic emergence occurs across time, so that *E* and *B* can (but need not) exist at the same 'level'. Thus, *E* and *B* are individuated synchronically by belonging to different 'levels', and diachronically by occurring at different times (Guay and Sartenaer 2016 p. 298-300). Atemporal emergence is neither synchronic nor diachronic and applies to the emergence of pure time.

Jaegwon Kim seeks to provide necessary and sufficient conditions for emergence based on the “classic conception” of the British Emergentists such as Mill, Morgan, Broad, and Alexander, and by doing so rules out the diachronic variant from being emergence proper (Kim 2006 p. 555). This is precisely the sort of analytic argument that does not concern us here. If the ‘tool’ widely known as diachronic emergence is of use, then it will be utilised in the ‘Viking approach’ taken here. The label on the tool need not have any bearing on the work it performs. Therefore, I won’t go through all the conditions that concern Kim; instead, here are two of his conditions that Ross, Ladyman, and Collier find useful in explaining aspects of rainforest realism:

[1] *The unpredictability of emergent properties*: emergent properties are not predictable from exhaustive information concerning their ‘basal conditions’. In contrast, resultant properties are predictable from lower-level information.

[2] *The unexplainability/irreducibility of emergent properties*: emergent properties, unlike those that are merely resultant, are neither explainable nor reducible in terms of their basal conditions.

(Ladyman *et al.* 2007 p. 193, their emphasis)

They find these conditions uncontroversial and call this restricted notion of emergence “scale relativity of *epistemology*” (Ladyman *et al.* 2007 p. 199, their emphasis). This, then, is epistemological emergence in that it holds that ‘higher level’ theories are neither predictable, explainable, nor reducible to ‘lower level’ theories. Ontological emergence, as found in RR, “is the more daring hypothesis that claims about what (really, mind-independently) exists should be relativized to (real mind-independent) scales at which nature is measurable” (Ladyman *et al.* 2007 p. 200). This emergence is scale relativity of *ontology*. It is this variety of emergence that I claim for time: time exists as different ontological scales; so that different levels of emergent time just are distinct ontological scales of time. Ultimately, however, time emerges from spacetime.

For now, the core claim of this thesis can be roughly expressed as follows. Time ontologically emerges from spacetime at different ontic scales – neither synchronically nor diachronically but atemporally. This emergence is atemporal because no ‘higher level’ time can emerge from a ‘lower level’ time ‘at the same time’ (i.e. synchronically) since the ‘two times’ would then be a single identical time. Also, no ‘higher level’ time can emerge from a ‘lower level’ time over a length of time (i.e. diachronically), for all times within that stretch of time would belong

to a single level, not two. The next section introduces something called the ‘notional-world’ category as developed by Ross, Ladyman, and Collier from an original idea of Dennett, which will help us on the way.

1.6 The Notional Category and Non-Redundancy of Information

Dennett begins with fictional stories. A fictional story does not tell a true story. However, we can say that something is true within the story. Thus, it is true in certain Conan Doyle stories that Sherlock Holmes lives at 221^B Baker Street, his housekeeper is Mrs. Hudson, and his monarch is Victoria. It is not true that brother Mycroft is unintelligent. Dennett goes further and describes how coherence gives rise to constraints on how a ‘fictional world’ can be constructed. For instance, Holmes’s living in Victorian England prevents him from seeing a jet plane but allows him the possibility of meeting a piano tuner. And so, that which is true in a story is not merely what is explicitly asserted therein but also that which is implicit in the story’s fictional world (Dennett 1991b p.79).

Ross, Ladyman, and Collier take this idea of what is true or false or indeterminate in Dennett’s ‘fictional worlds,’ along with its accompanying constraints and apply it to what is called ‘notional worlds’:

A notional world is a network of background assumptions that permits, but also restricts, projections of objects by reference to their utility to some set of practical purposes. . . The actual world (including its representational real patterns) constrains human goals and purposes, and these in turn constrain the notional worlds that people use. . . In addition, there are constraint relations between notional worlds and representational real patterns that go in both directions: notional-world construction always includes representational real patterns among its basic elements, and many representational real patterns arise just in and for the construction of notional worlds.
(Ladyman *et al.* 2007 p. 244)

Such notional worlds are constructed to house special sciences, with their ultimate constraints being provided by the extra-representational real patterns of fundamental physics. This ultimate constraint is what Ross, Ladyman, and Spurrett call the ‘Primacy of

Physics Constraint (PPC)' – it demands that any special science hypothesis that conflicts with fundamental physics is rejected on those grounds alone (Ladyman *et al.* 2007 p. 44).

Recall from 1.4 that the 'things' that populate special sciences are representational real patterns that are of dynamic and diachronic composition brought about by causal processes. As such, all special science notional worlds find the concept of causation to be indispensable. Therefore, causation is also an indispensable concept to the very construction of notional worlds themselves. Ross, Ladyman, and Spurrett write of causation:

It is a concept that structures the notional worlds of observers who must book-keep real patterns from perspectives that involve temporal and other asymmetries they cannot ignore on pain of discarding information. Appreciating the role of causation in this notional world is crucial to understanding the nature of the special sciences, and the general ways in which they differ from fundamental physics.
(Ladyman *et al.* 2007 p. 258)

However, they also note with Bertrand Russell, physicists have no need of the concept of causation when making fundamental generalizations, and thus claim that projecting causation onto fundamental physics, at least currently, is not justified (Ladyman *et al.* 2007 p. 280). This creates a problem for their naturalism: on the one hand, causation may not appear in fundamental physics and on the other hand, it appears indispensable to special sciences. They believe that this "shows the need for a more sophisticated category space for concepts than the simple binary opposition of 'scientific' and 'folk'" (Ladyman *et al.* 2007 p. 248). They supply this need by introducing what they call the 'notional-world category', though I propose to refer to this category from here on simply as 'notional category'. Any concept that has no role in fundamental physics but plays an indispensable role in special science will be a 'notional' concept. Hence, Ross, Ladyman, and Spurrett write:

Causation, we claim, is, like cohesion, a notional-world concept. It is a useful device, at least for us, for locating some real patterns, and fundamental physics might play a role in explaining why it is. Or, if fundamental physics does not directly do this, then the PPC at least requires that such time-asymmetry as appears to be characteristic of our region of the universe be compatible with fundamental physics, and the ubiquity of such time-asymmetry would in turn explain the value of the 'causation' locator in special sciences.
(Ladyman *et al.* 2007 p. 277)

However, they still recognize a folk concept of causation that is useful in everyday life (Ladyman *et al.* 2007 p. 268). They also allow that physicists may in future use ‘causation’ within fundamental physics generalisations, in which case that concept would belong to the scientific category. Assuming such future discourse was not accompanied by a successful reduction of all special sciences to fundamental physics, there would then be three different concepts of causation: scientific, notional, and folk. Both notional and folk causation (along with notional coherence) are examined in 6.4.1.

Thus far there has been mention of only the two notional concepts of causation and coherence. I propose to include concepts of time (and space) in the notional category. Ross, Ladyman, and Collier write that, since scientific measurements so far have demonstrated that the Second Law of Thermodynamics governs our region of the universe, “the notional worlds we must construct to track most local real patterns are irreducibly dynamic and time-asymmetric” (Ladyman *et al.* 2007 p. 246). My claim is that the irreducibility of dynamism and time-asymmetry of these notional worlds is afforded by representational real patterns of time that are themselves dynamic and asymmetric and are to be categorised as ‘notional’. Such a proposal is resisted by Ross, Ladyman, and Collier because they believe that, in contrast to notional worlds in which we track local real patterns,

the actual world occupied by all observers we know about is *either* truly tensed, or merely seems to us to be so given the measurements we can obtain, but is in fact a block universe. A PNC-compatible metaphysics should avoid presupposing either side of this disjunction.

(Ladyman *et al.* 2007 p. 246, their emphasis)

I have already in the previous section distanced myself from the PNC, and so feel no obligation towards this injunction. Besides, as will become apparent, I dispute that it is necessarily an either/or situation that confronts us.

A stepping-stone on the way to understanding the emergence of time is through recognising that the structure of time requires concepts of time to be distributed over all three categories. This thesis argues that time emerges from the temporal aspect of spacetime as instants, this is scientific time; durations emerge from instants, this is notional time; and the combination (in thought) of instants and durations within the same category is folk time. In other words,

scientific time of instants consists in extra-representational real patterns; and notional time of durations consists in representational real patterns. (As for space, I merely claim here without argument that there is scientific space of points, and notional space ‘extending over’ these points (up to at least three dimensions). The former consists in extra-representational, and the latter in representational, real patterns. Thus, space emerges from the spatial aspect of 4D spacetime just as time emerges from its temporal aspect. The union of the two spatial categories in thought is folk, or the manifest image of, space.)

Non-redundancy of information, as mentioned in 1.4, is a necessary condition for being a real pattern. Ross, Ladyman, and Collier write that a real pattern “must be informationally non-redundant, that is, must be *required* if some counterfactual-generalization-supporting information is not to be lost” (Ladyman *et al.* 2007 p. 231, their emphasis). The rainforest realist claim that composition is a dynamical, diachronic process that results in an irreducible (i.e. informationally non-redundant) representational real pattern finds an echo in O’Connor and Wong’s examination of emergence thus:

Composite objects having ontologically emergent features appear to be truer unities than those lacking such features. Since such features will make a nonredundant difference to the dynamical unfolding of the physical universe, one *must* quantify over their bearers in giving a minimally complete account of this evolution. Indeed, in some austere ontologies, there simply are not composite systems *lacking* emergent features.

(O’Connor and Wong 2015, their emphasis)

Now, if asymmetric time just is real patterns, then all such patterns must be non-redundant bearers of information, and so notional time will be irreducible to scientific time. When conjoined with the idea that notional time is ontologically dependent on scientific time, this just is the claim that the relation holding between instants and durations is one of emergence. The two ideas at the centre of this section – the non-redundancy of information and the notional category – are crucial in the argument for this claim.

2. The Emergence of Time I

2.1 Time and Space Emerge from Spacetime

In 1.3 it was claimed that structural realists can be realists about spacetime without being substantivalists. However, there is much debate within philosophy of physics about the precise nature of spacetime structuralism. Dean Rickles and Steven French go so far as to claim that more recent positions of both (particularly ‘sophisticated’) substantivalists and relationalists turn out to be structural positions. Be that as it may, for Rickles and French the basic idea of spacetime structuralism is:

that the fundamental ontology of the theory is given by relational structures rather than individual objects; inasmuch as objects exist at all, they derive their properties and individuality from the relational network in which they are embedded.
(Rickles *et al.* 2006 p. 4)

As such, there is no commitment to spacetime points as part of fundamental ontology. Although it does allow for them existing as derivative entities or, as rainforest realism would have it, real patterns. The present work is an exercise in metaphysics, not philosophy of physics, and so the spacetime I will be referring to is the ‘complete’ spacetime consisting of both four-dimensional manifold and spacetime points as extra-representational real patterns of fundamental physics. From this perspective, spacetime points are real but non-substantial. Recall from 2.2 that RR allows a perspectival ontology, which is very important when spacetime is viewed as structural. Mauro Dorato and Laura Feline, in their defence of a structuralist approach to Minkowski spacetime, answer the question “are they real?”, when posed concerning special relativistic phenomena such as clock retardations and rod contractions, thus:

Of course the answer to a question like this depends on what one means by the metaphysically appealing but philosophically treacherous adjective “real” in our context. If “real” means “measurable”, then the answer ought to be an uncontroversial “YES” written in capital letters, as every experimental physicist working . . . could guarantee. If “real” means “invariantly true”, then the answer should also be “yes”, written in small letters though, considering the (italicized) relativization involved in the following claim: for all possible inertial observers, it

seems true to say that, “*relative to observer O*, the rod contracted a certain amount x in the direction of motion” . . . We don’t need forces to account for the relativistic phenomena of contractions and dilations: after all, can’t we explain such effects as, respectively, *cross sections of four-dimensionally conceived rods and projections of four-dimensionally conceived clocks* onto different, arbitrarily chosen inertial frames of Minkowski spacetime?

(Dorato and Fellingine 2010 p. 194, their emphasis)

The rainforest realist may have a slight difference of opinion only when it comes to the writing of “yes” in small letters in answer to the question if real means “invariantly true”. In the metaphysics of RR what is real just are real patterns, which are (by definition) both perspectival and modal (i.e. projectible); and so, if it is “invariantly true” for “all possible inertial observers” that the rod contracts in the direction of motion “relative to observer O”, the answer ought to be “YES” in capital letters. In other words, forces are redundant as explanations since such contractions and dilations are simply the ‘points of view’, or perspectives, of real patterns that are “cross sections of four-dimensionally conceived rods and projections of four-dimensionally conceived clocks”. Thus, all possible perspectives of all possible inertial observers just are real patterns. All are equally real.

Dorato and Fellingine add to the above quote that all phenomena such as rod contraction and clock dilation can be explained “*via structural explanations*, based upon the geometrical features of Minkowski spacetime” (Dorato and Fellingine 2010 p. 194, their emphasis). This is correct as far as it goes, but I don’t think it goes far enough. Einstein’s theory of general relativity (GR) shows how mass and spacetime are intimately linked; so that any physical rods and clocks will exist in a spacetime that is (at least locally) curved. This then rules out the existence of such physical objects being in Minkowski spacetime. Before developing this idea further, a little groundwork is called for.

Now, it was further claimed in 2.4 that concepts of time belong to all three categories of scientific, notional, and folk. I now claim that scientific spacetime is a unitary four-dimensional manifold with spacetime points. Each spacetime point has two aspects: one temporal and one spatial; that is, scientific instants and scientific spatial points. From these instants and points emerge respectively notional time and space. It is worth stressing the claim of the unitary nature of four-dimensional Minkowski spacetime; so that this four-dimensional spacetime is not, strictly speaking, the result of a union of 3D space and 1D time. On the contrary, such

(notional) space and time emerge from the indivisible spacetime points of 4D spacetime. In other words, each spacetime point is viewed from the perspective of notional space as a (spatial) point, and from the point of view of notional time as an instant. Thus far, there is agreement with John Earman when he writes: “Space-time is the basic spatiotemporal entity” and “that talk about space and time is really talk about the spatial and temporal aspects of space-time” (Earman 1970 p. 259). That is, the agreement lasts so long as such talk is solely of scientific space and time.

If an instant is viewed as an aspect of a single spacetime point then when we speak of a hypersurface of spacetime as a three-dimensional slice through spacetime at an instant, we do not in fact refer to a single instant but to a set of instants that are the temporal aspects of a set of spacetime points whose other aspects are a set of spatial points. It is the set of spacetime points that constitute the hypersurface. However, this hypersurface may be legitimately viewed as a three-dimensional hyperplane of space at a moment of time. Yuri Balashov gives the term ‘achronal’ to such a region of spacetime, where no spacetime point absolute-chronologically precedes any other, writing that achronal regions “generalize the classical notion of a moment of time” (Balashov 2010 p. 24). A moment strictly refers to a set of instants that neither absolute-chronologically precede nor succeed one another. Thus, moments are instantaneous in that they have no extension in time.

This implies that when we refer to such hypersurfaces of spacetime points as ‘hyperplanes of simultaneity’ then the term ‘simultaneity’ is being somewhat loosely used to refer to a set of achronal instants. All of this agrees with Alfred Robb when he writes that “the only really simultaneous events are events which occur at the same place”, and that “there is no identity of instants at different places at all” (Robb 1914 p. 6 and p. 12). However, I disagree with other notions of Robb concerning relativity. He objects to the notion expressed by ‘hyperplane of simultaneity’ because, with each spacetime point being uniquely ‘here-now’, he claims that “the present instant, properly speaking, does not extend beyond here” (Robb 1914 p. 13).

For me, however, the very idea of ‘present instant’ is a category mistake; I argue that ‘present’ is a notional term while ‘instant’ is scientific (as explained in 3.2). What we have been discussing so far is scientific spacetime with its spacetime points, spatial points, and instants. There has been no need to mention ‘the present’. Each spacetime point is indeed uniquely

'here-now', but this 'now' is simply an indexical that refers to its temporal location, just as 'here' simply refers to the point's spatial location. It does not refer to any notion of present time as opposed to past or future time. As for moments, as hyperplanes of simultaneity, they are sets of achronal spacetime points; and so, if the argument against the idea of a 'present instant' succeeds, none ought to be regarded as present either.

Thus, besides a 4D spacetime manifold we now have spacetime points, spatial points, and instants. These have been categorised as scientific, and in RR as extra-representational real patterns. A hypersurface may be viewed as resulting in the foliation of time and space; more precisely, it is a set of spacetime points that may be viewed as a set of spatial points and a set of instants arranged as a moment. This is the spatiotemporal framework that is said to contain the block universe of the *B*-theory of time. Indeed, it is the very thing that apparently ensures that the universe must be a block. For instance, Vesselin Petkov purports to show that the only view consistent with the special theory of relativity (SR) is that of the block universe, i.e. that the world is a timelessly existing four-dimensional block. He also has an interesting argument that only SR can resolve the question of whether the world is three- or four-dimensional (Petkov 2006 pp. 207-228).

Petkov begins by arguing that presentism has two defining notions that are linked intrinsically. These are that the world is three-dimensional, and that the world exists only at the present moment. Thus, he writes that "if the world is three-dimensional it exists only at one moment of time and vice versa" (Petkov 2006 p. 208). He quotes Augustine to the effect that the present can be of no duration, for if it were it could be divided into past and future. Petkov agrees with this and from it draws out the implication that if the present were extended in time, then any object that exists in the present would also be extended in time and hence be four- and not three-dimensional. Thus, he concludes that any three-dimensional view of the world, not just presentism, implies that "the present moment must be an instant with no duration" (Petkov 2006 p. 208).

There is much to question here. There is an ambiguity concerning Petkov's notion of the world, which he inherits from Minkowski. Thus, he writes:

The scientific birth of the block universe view . . . was in 1908 when Minkowski proposed that space and time should be united into an inseparable four-dimensional entity – spacetime – which he called *the world*.
(Petkov 2006 p.209, his emphasis)

Such equating of spacetime with the world is problematic. ‘The world’ is usually used to refer to all that exists, and by using it as synonymous with ‘spacetime’ implies that spacetime is no mere framework but is a container with material contents that makes up the world. ‘The block universe’, in such a fashion, becomes just another name for ‘the world’, which has become just another name for ‘spacetime’ This notion is confirmed by Daniel Peterson and Michael Silberstein when they write that eternalism

was translated into the language of relativity by Herman Minkowski in 1908 to suggest that time and space should be united in a single, four-dimensional manifold. Thus arose the notion of a 4D “block universe” (BU) in which the past, present, and future are all equally real.
(Peterson and Silberstein 2010 p. 210, emphasis added)

Such a ‘translation’ is commonly accepted throughout the literature. However, I propose to separate out the three terms ‘spacetime’, ‘world’, and ‘block universe’ and refer them to three distinct notions. Firstly, we need to realise that this standard BU notion is imbued with what Ross, Ladyman and Spurrett call the “doctrine of ‘containment’”. In this doctrine the world is a kind of container bearing objects that change location and properties over time.” (Ladyman *et al.* 2007 p. 3). This notion of the world as some sort of container is rejected by OSR and by RR, where it is viewed as an instance of domesticated metaphysics through which radical contemporary science is transformed into a homely metaphor (Ladyman *et al.* 2007 p. 4).

I disclaim any notion that four-dimensional Minkowski spacetime is any sort of container. Recall that even spacetime points are derivative of structure and are to be viewed as real patterns within the ontology of rainforest realism. The scale relativity of ontology also precludes the notion of Minkowski spacetime being a container – for there is nothing else existent at that scale that could be candidates as content. To see this, we need only recall Eddington’s two tables. One is the familiar object at which he sits, the other is the scientific

table that is “mostly emptiness” (Eddington 1928 p. x). Ross, Ladyman, and Collier note concerning these tables:

The everyday table is probably a real pattern. Strictly speaking *there is no scientific table at all* because there is no single candidate aggregate of real microscopic patterns that is best suited to be the reductive base of the everyday table. We deny that everyday or special science real patterns must be mereological compositions of physical real patterns, and we deny the local supervenience of the table on a real pattern described by physics.

(Ladyman *et al.* 2006 p. 253 emphasis added)

This may seem to raise a problem for science; for it implies that strictly speaking, just as there are no scientific tables, so there can be none of those scientific ‘rods’ and ‘clocks’ that are integral to Einstein’s theories of relativity. And so, this returns us to the discussion concerning there being no physical objects in Minkowski spacetime (such as rods and clocks) that can be candidates for contraction and dilation. However, because such rods and clocks are indispensable to science they will be viewed within RR as representational real patterns (akin to Eddington’s everyday table) that track the notional representational real patterns of space and time. (The sequel sets out to show precisely how such emergent time accurately tracks scientific time – analogously with that of space.)

More generally, when it comes to the scale of Minkowski spacetime there are no objects that exist at that scale that could be considered as candidates for being the contents of spacetime. From this perspective Minkowski spacetime is not the world, for there is so much else (i.e. real patterns at other scales) existing in the universe that does not and cannot exist within (or at the scale of) this 4D spacetime. Additionally, the world is not a block universe because it consists not only of extra-representational real patterns of fundamental physics but also of representational real patterns of special science and of the everyday – many of which are dynamic – that are not, and cannot be, contained in 4D Minkowski spacetime. As to eternalism, the response is a little more nuanced. Though I agree that they are equally real, the past, present and future are found at a different ontic scale to that of Minkowski spacetime. It may be objected that this cannot be right as there are ‘future’ and ‘past’ light cones as structures of spacetime. However, Minkowski originally, and accurately, termed these ‘after’ and ‘before’ respectively.

If there are such things as everyday tables and chairs and cats and dogs but they are not to be found in Minkowski spacetime, then where and when are they found? The answer is that they exist in notional space and notional time. Recall the discussion in Chapter 1 concerning the composition of everyday and special science objects that populate the world. These were viewed as representational real patterns of dynamic and diachronic composition brought about by specifically causal processes. In other words, such things not only exist over time but are created through time, specifically the durations of notional time. It was further argued there that notional durations emerge from scientific instants. Just as durations that emerge from instants are not contained in instants, so everyday and special science objects that emerge within duration are not contained in instants nor, by extension, in Minkowski spacetime.

Therefore, those things that are imagined by the eternalist to be encased in a block universe for every instant at which they exist, and that are imagined by the presentist to only exist at the 'present instant', do not in fact exist at any instant. Only scientific 'things' that are extra-representational real patterns can exist at the scale of scientific Minkowski spacetime. All other things are representational real patterns that exist within notional time and/or notional space at different ontological scales from that of Minkowski spacetime. Thus, when we speak of Minkowski spacetime there should be no question of it being identified with the world that we inhabit with all its varied 'rainforest' content. To further equate all of this with a block universe compounds the error.

2.2 The Structure of Time

From what has been declared before, I am now able to set out a brief claim of how time is structured. After this section, the reader should have a clear idea of what the sequel will be expanding upon and arguing for. This is a precis of how I understand time to be structured and, ultimately, emergent from Minkowski spacetime:

1. Minkowski spacetime is a unitary 4D manifold with spacetime points.
2. Spacetime points are without extension but have dual aspect in that they can be viewed as either instants or (spatial) points – that are also without extension.

3. Instants are partially ordered according to the 'earlier than' relation and constitute the ontic scale of time that I term 'micro-scale'.
4. Emergent from each instant are (Whiteheadian) 'abstractive sets' of durations that 'cover' and 'point to' their own instant of origin. Larger and larger durations of the set also 'cover' more and more instants.
5. Within each abstractive set of durations there is a subset of smaller durations that 'covers' just a single instant – the original of the set. This subset I term 'time-atom'.
6. These smaller durations constitute the ontic scale of time that I term 'meso-scale'.
7. Time-atoms are constrained by their instants of origin to be sequenced according to the 'earlier than' relation; thus, if one instant is earlier than another instant, then the time-atom that covers the first instant must appear as earlier than the time-atom covering the second instant.
8. Such sequentially ordered aggregates of time-atoms constitute the ontic scale of time that I term 'macro-scale'.
9. Length of durations at the macro-scale begins from the largest duration of a single time-atom, while larger and larger durations are constituted by the addition of more and more such atomic lengths.
10. All durations emerge atemporally from instants.
11. The meso-scale atemporally emerges from the micro-scale, and the macro-scale atemporally emerges from the meso-scale.
12. Past, Present, and Future can exist only at the macro-scale and emerge diachronically with the emergence of content at that scale.
13. The passage of time occurs strictly at the macro-scale and in such a way that the present, consisting in a single time-atom (thus having duration, contra Augustine), gains content at the macro-scale; this atom with macro-content then becomes past, and the next atom in sequence that was future and empty of macro-content now becomes present. (This process is explained in 3.4)
14. Since all durations exist together with all instants, the past, present and future (as positions in durational A-time) exist together: all are equally real. Hence, they constitute an existent A-scale.

15. Scientific Minkowski spacetime has neither past, present, nor future; and hence no becoming. Only notional, emergent *A*-time can sustain becoming – though this makes becoming no less real.

Before giving substance to these points in the next chapter, in the rest of this chapter I examine McTaggart's *A*- and *B*-series, from which so much analytic philosophy of time takes its cue. Although analysis of concepts is by no means a major task of naturalised metaphysics, it is nevertheless not unimportant. Perhaps, particularly with the addition of the new notional category, rainforest realism has more call to examine concepts than other approaches to scientific metaphysics. Certainly, being armed with this additional category, I find it necessary to revisit the foundations of much analytic metaphysics of time and to analyse and re-categorise some basic concepts. I derive encouragement in doing so from what Einstein wrote to Born (as quoted in Ismael 2013):

Concepts which have proved useful for ordering things easily assume so great authority over us, that we forget their terrestrial origin and accept them as unalterable facts. . . It is therefore not just an idle game to exercise our ability to analyze familiar concepts, and to demonstrate the conditions on which their justification and usefulness depend, and on the way these developed . . . in this way they are deprived of their excessive authority.
(Ismael 2013 p. 208)

What follows reinforces the analysis of the manifest image of time (or folk time) as set out in the previous chapter.

2.3 Disentangling McTaggart's *A*- and *B*-Series

Although McTaggart was a well-known Hegelian idealist, it is his distinction of two series of time that lies at the origin of so much analytic metaphysics of time. This is not so surprising as the distinction does reveal something fundamental in the way we commonly view time. However, there is no little ambiguity in McTaggart's presentation of the *A*- and *B*-series of time which stands in need of clarification. Here is his introduction of these series:

Positions in time, as time appears to us *prima facie*, are distinguished in two ways. Each **position** is Earlier than some, and Later than some, of the other positions. And each **position** is either Past, Present, or Future. The distinctions of the former class

are **permanent**, while those of the latter are **not**. If M is ever earlier than N, it is always earlier. But an **event**, which is now present, was future and will be past. . .

For the sake of brevity I shall speak of the **series of positions** running from the far past through the near past to the present, and then from the present to the near future and the far future, as the A series. The **series of positions** which runs from earlier to later I shall call the B series. The **contents** of a position in time are called **events**. . .

A position in time is called a **moment**. . . Thus the **events** of time, as observed by us, form an A series as well as a B series.

(McTaggart 1908 p. 459, boldface added)

The middle paragraph has the A- and B-series as series of *positions* in time. The last paragraph has these series formed by *events* in time. However, events in the second paragraph are not positions in time but are *contents* of such positions. A series of positions in time (moments) is quite different from a series of events in time, although they may exhibit the same order. Events, McTaggart informs us, are contents of moments; and so are not themselves moments. In the first paragraph, positions in time are either earlier/later than other positions or they are past, present, or future. So far so good, but a problem then arises when McTaggart designates the former (B-series) as permanent positions and the latter (A-series) as not permanent positions. For the B-series, he has as examples M and N as *bona fide* positions in time and uses these to show the permanent relation (earlier than) holding between them. However, for the A-series he has as examples, not positions in time (past, present, or future) as he did for the B-series but, an *event* in time which changes its *position* from future to present to past. He then claims on this basis that A-series *positions* in time are not permanent. This is not quite right. McTaggart has not shown that A-series positions in time are not permanent, he has simply claimed that events change their position in A-series time.

On this reading, we are only entitled to conclude that, although the positions in time of both series are permanent, B-series events cannot change their position in time but that events in the A-series can do so. Thus, if a present event becomes a past event, then that event has changed its position in time. The present (which is simply a position in time) has not become the past (position in time); these positions are as permanent as those of the B-series. Hence, the only difference in permanence concerning the two series is that the position in time of B-series events is permanent whereas A-series events can and do change their position in time.

Confirming the claims of the first paragraph, McTaggart later writes that the *A*- and *B*-series, respectively, “must be distinguished as past, present and future, and must likewise be distinguished as earlier and later” (McTaggart 1908 p. 463). However, in the second paragraph of the indented quote the *A*-series had already been expanded through the recognition of a multitude of different positions *within* both the past and the future, ranging from the far past to the near past, through the present and on to the near and far future. At that point in his article McTaggart gives no indication of just what allows these further distinctions of position within the past and future. He simply states these positions as they appear to us in the manifest image.

McTaggart believes that taking “the terms of the *A* series as relations of events” is “more reasonable” than viewing them as “qualities of events” (McTaggart 1908 p. 467). There would be three such qualities: futurity, presentness, and pastness; but “there is very little to be said for the view that the changes of the *A*-series are changes of qualities” (McTaggart 1908 p. 469). If we stay with McTaggart’s preferred view of *A*-series terms as relations of events, we are left wondering what relation could separate out the far past from the near past and all positions between, and the same for the future. The only candidate would appear to be the earlier than relation. Thus, the far past is distinguished from the near past because the positions that the far past occupy are earlier than the positions that the near past occupy in the past. As for the future, the positions that occupy the near future are distinguished from the positions that occupy the far future by being earlier than those positions. What separates all terms within the past and future, then, is the earlier than relation. This fact is recognised by D. H. Mellor when he argues that these (additional) positions reflect different degrees of pastness and futurity and make up a very large part of what he calls the ‘*A*-scale’. I examine his argument along with the *A*- and *B*-scales in the next section.

McTaggart also (at least implicitly) recognises this need for the earlier than relation to expand both the past and the future into near and far. Here, I propose to make explicit what is implied by his arguments. McTaggart maintains that, although both the *B*-series and the *A*-series are equally essential to time, the *A*-series is more fundamental. Equally fundamental with the *A*-series, though, is what he calls the ‘*C*-series’, which “is not temporal, for it involves no change, but only an order. . . It is only when change and time come in that the relations of this *C* series become relations of earlier and later, and so becomes a *B* series” (McTaggart 1908 p. 462).

This change, though, must be in one direction along the *C*-series for there to be time, and this direction is provided by the *A*-series. Thus, McTaggart argues that

the *A* series, together with the *C* series, is sufficient to give us time. For in order to get change, and change in a given direction, it is sufficient that one position in the *C* series should be Present, to the exclusion of all others, and that this characteristic of presentness should pass along the series in such a way that all positions on the one side of the Present have been present, and all positions on the other side of it will be present. That which has been present is Past, that which will be present is Future. (McTaggart 1908 p. 463).

We can take from this that since the earlier than relation is second order to both *A*- and *C*-series it plays no part in the ordered placement of the fundamental positions of the *A*-series – the three positions of Past, Present, and Future. Thus, these *A*-positions are primitive and not ordered by the earlier than relation. Therefore, while Past, Present, and Future, along with their temporal order, are primitive, the multiple positions in both the past and future are (at this stage) *C*-series positions and not those of the *B*-series. Since *C*-series positions are non-temporal, these ‘internal’ positions of the past and future are not temporal positions. In which case, there can be no question of these positions being more (or less) past or future than each other. All such positions are equally past or equally future – for none is earlier or later than another. Indeed, at this stage, *no* position in the *A*-series can be earlier than another; and so, the Past is not earlier than the Present, nor is the Present earlier than the Future. This demonstrates that there are just three fundamental (primitive or ultimate) *temporal* positions in the fundamental *A*-series. And yet, McTaggart immediately undermines what he writes in the above quote by adding in a footnote:

This account of the nature of the *A* series is not valid, for it involves a vicious circle, since it uses ‘has been’ and ‘will be’ to explain Past and Future. But as I shall endeavour to show later on, this vicious circle is inevitable when we deal with the *A* series, and forms the ground on which we must reject it. (McTaggart 1908 p. 463, n. 1).

This alleged vicious circle, then, is the basis on which McTaggart builds his case for the *A*-series being contradictory. However, in the very next paragraph he proceeds to (unwittingly) undermine the claim in the footnote by writing the following:

The distinctions of the A series are ultimate. We cannot explain what is meant by past, present and future. We can, to some extent, describe them, but they cannot be defined. We can only show their meaning by examples. "Your breakfast this morning," we can say to an inquirer, "is past; this conversation is present; your dinner this evening is future." We can do no more.
(McTaggart 1908 p. 463)

Here, McTaggart rightly notes that what is ultimate (or primitive) cannot be explained. Therefore, his footnote entirely misses the mark, for *any* attempt to explain an ultimate is nonsensical. Besides, there is no attempt 'to explain Past and Future' in his previous paragraph; that paragraph is merely a consistent *description* of what is the case when the two ultimate (primitive or fundamental) A- and C-series are united. If there is inconsistency in McTaggart's approach here, then I believe it can be traced to the fact that his overall arguments in fact demonstrate not one but two A-series. One is an ultimate, three-positioned, A-series that along with the C-series gives rise to a B-series. The other is an expansive A-series having multiple temporal positions within the past and future that is due to the introduction of the second order B-earlier than relation that transforms the C-positions found there into B-positions. It seems that McTaggart is unaware of this implication of his argument, with the result that an ambiguity concerning which A-series is being referred to at any one time in his argument may lead to inconsistency.

However, (following on from the last indented quote) precisely because the additional positions within the past and future are second order, we *can* go on to define how they become temporal positions. Thus, McTaggart continues in the next paragraph:

The B series on the other hand is not ultimate. For, given a C series of permanent relations of terms, which is not in itself temporal, and therefore not a B series, and given the further fact that the terms of this C series also form an A series, and it results that the terms of the C series become a B series, those which are placed first, in the direction from past to future, being earlier than those whose places are further in the direction of the future.
(McTaggart 1908 p. 464)

In this way, not only are earlier and later positions within the past and future established as such, but for the first time the Past, Present, and Future themselves are viewed as earlier or later than each other. The expansive A-series is here fully formed.

Together, these last four indented quotes from McTaggart reveal the following. First, with the union of the *A*- and *C*-series, the Present is found at one position of the *C*-series while the Past and Future each cover multiple positions of that series. These further positions found at the Past and Future are initially those of the ordered *C*-series, which is not a temporal series; and so, these *A*-positions within the past and future are not temporal positions. The temporal *A*-positions remain Past, Present, and Future *simpliciter*. Second, the fourth quote makes clear that the new positions at the Past and Future only become temporal positions with the rise of the earlier than relation and the *B*-series; only then can they be defined as earlier or later than each other (as can the positions of Past, Present, and Future themselves). Third, the earlier than relation, which is required to separate out different *temporal* positions of near and far in both past and future, is the result of the union of the fundamental *A*-series (having only the three fundamental positions) with the equally fundamental *C*-series (having multiple ordered terms). With this union, the *C*-series becomes a *B*-series, and only then do the ordered *C*-relations become *temporal* (earlier than) *B*-relations. Fourth, from all this we can conclude that what is widely known as *the A-series* of McTaggart, i.e. that *expansive A-series* which runs from far to near future, through the present, and on to the near and distant past is not the ultimate or *fundamental A-series*. Hence, there are two *A-series* to be found within McTaggart's article with one (ultimate or fundamental) series being logically prior to the other (expansive) series.

The problem with this result for McTaggart, however, is that the initial distinction he drew between the *A*- and *B*-series must be renounced in order to allow the formation of *the* (expansive) *A-series*. Since, what is held to be the distinguishing feature of the *B-series* (earlier than) is now seen to be integral to the distinguishing of times within two of the three distinguishing features of the expansive *A-series*, i.e. the past and the future. Insulating this expansive *A-series* from the earlier than relation results in the past and future having no additional internal *temporal* positions. As these positions revert to being those of the *C-series*, the expansive *A-series* in turn reverts to the three fundamental positions of Past, Present, and Future; and so, the expansive *A-series* deflates to the fundamental *A-series*. The implication for us is that McTaggart's expansive *A-series* – what is generally known as *the A-series* – turns out to be a union of the fundamental *A-series* and the second order *B-series*. This is the (sort of) union that is experienced as the manifest image of time. Again, recalling the argument

from Chapter 1, this helps to explain why the manifest image has generally been thought of as solely a dynamic one; for the manifest image just is *the* (expansive) A-series, which is viewed as being the dynamic series of time.

However, we must bear in mind that what the *B*-series is second order to is the fundamental *A*-series and the equally fundamental *C*-series. Thus, the genealogy of McTaggart's series is as follows:

1. Fundamental *A*- and *C*-series, whose union forms:
2. The second order *B*-series.
3. The *B*-series union (in thought) with the fundamental *A*-series forms:
4. The expansive *A*-series.

When we dissolve this union in thought of the *B*- and fundamental *A*-series, the expansive *A*-series deflates to the fundamental *A*-series. In the next section, I show how Mellor's clearing up of an ambiguity found in McTaggart presentation of the *A*- and *B*-series fails to avoid the problem of 'deflation' that afflicts McTaggart's (expansive) *A*-series. Mellor demonstrates how to keep the *A*- and *B*-series separate by allowing, from the beginning, the earlier than relation to order both the *A*- and *B*-series (while abandoning McTaggart's *C*-series) in such a way that the two series are now distinguishable by the difference in the relata of that relation rather than the relation itself. However, I argue, *contra* Mellor, that this method of distinguishing the two series works only for McTaggart's fundamental *A*-series and not his expansive series, with the consequence that Mellor's expansive *A*-scale deflates to McTaggart's fundamental three positions of Past, Present, and Future. With no escape from 'deflation' available, I examine the consequences of reverting to McTaggart's fundamental *A*-series – so that, with the past and future each being just a single position in time, all contents of the past are equally past, and all future contents are equally future. Interestingly, such a 'deflated' *A*-series is not as absurd as it may first appear.

2.4 The A-Scale and the B-Scale

With the scale relativity of ontology being a central notion in the form of realist metaphysics being practiced here, Mellor's temporal scales are clearly of great interest. Mellor's presentation of his scales is designed to clear up a particular ambiguity found in McTaggart's original presentation of the two series. Mellor specifically finds ambiguity in McTaggart's terms 'A-series' and 'B-series' since the sequences referred to may be either those of times or of events. Mellor introduces his A- and B-scales in this way:

Then there is the obvious fact that **pastness and futurity come by degrees**. Past events are not equally past, nor are future events all equally future. . . The time order of the world's events is that in which they become present, thus forming what McTaggart (1908) called the 'A-series'. But his term, though now standard, is ambiguous. It may mean either the sequence of what I shall call '**A-times**', **defined by how much earlier or later they are than the present**, or the sequences of events located at those times. Since, as we shall see, the difference matters, I shall call the former sequence the 'A-time scale', or 'A-scale', reserving 'A-series' for the latter. . .

Dates . . . form a sequence of times that are not A-times, because they are not defined by how much earlier or later they are than the present. This sequence, and that of the events which have them, McTaggart called the B-series. As with his 'A-series', I shall remove this ambiguity by calling the sequence of what I shall call '**B-times**' the '**B-time scale**', or '**B-scale**'. Keeping 'B-series' for the sequence of events with those times. . .

How are **B-times** defined, if not by how much earlier or later they are than the present? The answer is that they are **defined by how much earlier or later the events which have them are than each other**. . . This shows how alike the A- and B-scales are. **They are defined by the same temporal relations**, put events in the same order and measure time intervals in the same way.
(Mellor 1998 p. 8-11, boldface added)

Thus, Mellor's A- and B-scales are both defined by the earlier than relation, which, as we saw in the previous section, is that which McTaggart initially reserves to the B-series as its distinguishing feature. However, the threat to Mellor's expansive A-series (with its degrees of pastness and futurity) is not that of 'deflation' in the manner of McTaggart's but an initial inability to 'inflate' the past and future. To see this is so, we must examine how the earlier than relation orders the two series.

B-times are defined by 'how much earlier or later the events which have them are than each other', whereas A-times are now defined by 'how much earlier or later they are than the

present'. Thus, although they share the (previously exclusive to the *B*-series) earlier than relation, it is now the difference in the relata of this relation within the two series that is the distinguishing feature that maintains their separation. *B*-relata of the earlier than relation are events only, *A*-relata are an (earlier/later) event and a position in *A*-time (the present moment). However, granted that Mellor's use of the earlier than relation in the definition of both series is successful in maintaining their distinctiveness, I question whether that same relation can fulfil its task of separating degrees of pastness and futurity. In other words, can the *A*-earlier than relation distinguish different *A*-times *within* the past and future? I argue that it cannot – that whatever is either earlier or later than the present is so *simpliciter*.

Let me begin with how anyone competent in English can make sense of the sentence: 'Hegel's birth is further back in the past than his death'. According to Mellor's definition of the *A*-series this means that both the event of Hegel's birth and the event of his death occurred earlier than the present. This places them in the past. Also, the amount of time between one event (birth) and the present is greater than the amount of time between the other event (death) and the present. This places the birth earlier than the death. From this we are to conclude that the birth has more degrees of pastness than the death. In other words, 'Hegel's birth is further back in the past than his death'. The question, though, is this: how is this amount of *A*-time to be measured?

To measure any distance, there must be recognisable boundary points between which to measure. In this case we are measuring *A*-time and so start with the recognisable position of the present. We then measure back to the times of the two earlier events. To be able to do this the positions in time of the earlier events must also be recognisable. Thus far, only the past position has been recognised – as that which contains both events – since both events are earlier than the present. But we must now ascertain the different positions in *A*-time that are occupied by these past events so that their respective distances from the present are measurable. Only then can we discover which event is further back in the past, or has more degrees of pastness, than the other.

We can only ascertain the respective positions in the past by knowing how much earlier each is than the present. However, we can't know how much earlier they are than the present until we have ascertained their respective positions in the past. In other words, we can only discover the positions in *A*-time of the two events when we know their degrees of pastness.

But we can't know their degrees of pastness until we know their *A*-positions in time. This circle implies that Mellor's *A*-earlier than relation does not allow us to make complete sense of 'Hegel's birth is further back in the past than his death'. Simply put, the only things that measure time are clocks, and the recognisable positions between which clock measurements are taken are 'dates', which are ordered by a *B*-scale not an *A*-scale. Thus, because of its ability to keep separate and distinct the *A*- and *B*-scales (and series), Mellor's definition by this very separation prevents any 'inflation' of the past and future into separate degrees. Mellor's new definition of the *A*-series merely reproduces McTaggart's fundamental *A*-series with just three positions of Past, Present, and Future.

Since temporal distance within the past can't be measured by Mellor's method, the only information that his *A*-scale can provide in this case is that because Hegel's birth and death are both earlier than the present then they are both past. Thus, although Mellor introduces the earlier than relation into the *A*-series in a way that does not collapse that series into the *B*-series, the relation does not deliver the promised degrees of pastness and futurity. That is, it distinguishes no positions in *A*-time from which measurements may be taken that would divide the past and future into far and near. So how do we make sense of the idea of Hegel's birth being further back in the past than his birth?

We can agree with Mellor that since both events are earlier than the present then they are both past. However, to ascertain which event is further back in the past we need to discover which event is earlier than the other. Note, however, that this is how *B*-times are defined, and *B*-times are 'dates' – not degrees of either pastness or futurity. The birth is the earlier of the two because the date of birth is earlier than the date of death. With these recognisable *B*-times, we can now measure the interval between the two events themselves as well as the length of the intervals between each event and the present. And since the distance of the birth from the present is greater than the distance of the death from the present, we know how much earlier each one is than the present. This can translate into how many degrees of pastness separate each one from the present moment; only then are we able to say which one is 'further back in the past'.

These additional *A*-positions, viewed as degrees on the *A*-scale, are thus constructed in thought by importing the *B*-earlier than relation into the *fundamental A*-scale. In making sense of the sentence 'Hegel's birth is further back in the past than his death', we combine

the (fundamental) *A*- and *B*-series in thought. In doing so it appears obvious that if the birth is earlier than the death and both events are earlier than the present, then both are in the past and the birth is further back in the past than the death. We can say that Hegel's birth is earlier than his death (*B*-earlier than relation) and that both events are earlier than the present (Mellor's *A*-earlier than relation). However, there is nothing in Mellor's *A*-earlier than relation *alone* that allows us to say that Hegel's birth is further back in the past than his death. Only the further addition of the *B*-earlier than relation with the consequent representation of *B*-times (dates) as degrees of the pastness and futurity within the *A*-scale can accomplish this.

Thus, Mellor's definition of the *A*-scale by the *A*-earlier than relation defines only three positions in *A*-time – the Past, Present, and Future of McTaggart's fundamental *A*-series. To arrive at McTaggart's expansive *A*-series with an inflated *A*-scale of near and far past and future, we must combine the fundamental *A*-series with the *B*-series. Note that this mirrors the process of 'inflation' undergone by McTaggart's fundamental *A*-series when united with his second order *B*-series.

This analysis exhibits how our everyday temporal speech is imbued with a mixture of the fundamental *A*-scale and the *B*-scale. In thought, we introduce the *B*-scale and the *B*-earlier than relation into the *A*-scale positions of past and future, thus making sense of such notions as near and far past, and near and far future, with their associated degrees of pastness and futurity. Also, we introduce the fundamental *A*-scale into the *B*-scale, thus making sense of a sentence such as: 'The year 2010 is earlier than 2030 and the former is past while the latter is future since 2022 is present'. Again, this result is as it should be, for we (along with McTaggart and Mellor) began with a manifest image of time having (unified) positions in time, before (strictly) separating them into a fundamental *A*-series and a *B*-series (and their respective scales), only to then reunite them into the initial single series of (manifest) time.

Now, with the fundamental *A*-series having only the three positions, the events of Hegel's birth and death just are equally past. Only the *B*-earlier than relation can separate them in time, and that relation is excluded from the fundamental *A*-scale. With this *A*-scale being only the three *A*-times of past, present, and future there can be no difference of degree within these positions. If an event is positioned at the past, then it is past *simpliciter*. Therefore, when Mellor claims that the *A*- and *B*-scales 'put events in the same order and measure time intervals in the same way' he merely expresses the result of uniting the two scales in thought,

either by introducing the *B*-earlier than relation into the fundamental *A*-scale or by introducing the present (as an *A*-position in time) into the *B*-scale. This is indeed how we do measure time, with clocks and calendars, by measuring regular *B*-time intervals in relation to the present. These 'dates' (as indicated by the likes of hour and minute gradations on a clock face as well as days and years on a calendar) allow us to think of the near and distant past as well as the near and far-off future.

The initial manifest scale, of course, jointly holds all positions in time— both earlier/later positions and past, present, future positions – and so allows us to speak of Hegel's birth being further back in the past than his death. However, when relapsing into the initial manifest scale, the fundamental *A*- and *B*-scales become indistinct (conjoined in a 'seemingly seamless union'), thereby forming *the* (expansive) *A*-scale (and hence series). Although, as McTaggart was first to demonstrate, they remain *analytically* distinguishable. Again, this helps explain why the manifest image is so widely held to be solely dynamic. It is only when we disentangle McTaggart's *A*- and *B*-series that we discover that his seemingly dynamic (expansive) *A*-series – the manifest image of time – is a conjunction of the static *B*-series and a dynamic fundamental *A*-series.

Finally, in reference to the claim regarding scientific, notional, and folk time made in 1.6, I can now further claim that the *B*-scale is of instantaneous scientific time, the fundamental *A*-scale is of durational notional time. The union of these two scales in thought constitutes McTaggart's expansive *A*-scale of manifest time, or folk time. In this way instants and durations are included together within the folk category as if in a part-whole relation.

2.5 Should We Care Whether McTaggart's A-Series Is Contradictory?

McTaggart's motivation for introducing his two series of time was to show that the *A*-series is both necessary for time and contradictory; and thus, were he successful in this, he could justly claim that time was unreal. However, I have argued that his expansive *A*-series is merely a description of the structure of the manifest image of time, and as such belongs to the folk category. I have also agreed with Dyke in 1.2 that 'common-sense intuition' of the folk (and of philosophers) bears no evidential weight in metaphysics. Also, I argue in the next chapter that any notional *A*-series is emergent from scientific *B*-time – though it need not so emerge

– and is not necessary for time. I further argue that emergent notional A-series time is equally as real as B-time. However, in this section I examine how McTaggart lays claim to contradiction for the folk (expansive) A-series. Philip Turetzky presents McTaggart’s argument thus:

McTaggart argues that the application of A-series distinctions to reality implies a contradiction. Suppose that all events have real A-characteristics, i.e. that every event is either future, present, or past. *Every future event eventually becomes present, and every present event eventually becomes past (assuming there is no last event). Consequently, every event possesses the A-characteristics future, present, and past.* Future, present, and past, however, are mutually exclusive determinations, if an event has one of these it cannot have the others. Therefore, the supposition that all events have real A-characteristics implies the contradiction that every event must possess all the A-characteristics – future, present, and past – and that since these characteristics are mutually exclusive no event can have them all. Hence the application of A-series distinctions to reality implies a contradiction.
(Turetzky 1998 pp. 123-124, emphasis added)

Of course, there is an enormous amount of discussion in the literature that either agrees or disagrees with the fundamentals of this argument. I have emphasised in the above quote that which I regard as the crux of the matter; and argue that it is open to us to claim that no event can ever possess more than one of the A-characteristics of future, present, and past.

First, though, we need to examine just what allows McTaggart to claim that an event can change from being future to being present to being past, i.e. how does an event change its temporal position? I argued in 2.3 that McTaggart makes unwarranted use of the notion of an event changing its position in time from future to present to past to claim that, unlike B-series positions, A-series positions in time (moments) are not permanent. McTaggart’s claim can seem plausible due to ambiguity in his use of the terms ‘A-series’ and ‘event’.

Following Mellor, we know that positions in A-time make up an A-scale, and that the sequence of events located at those times makes up an A-series. In the folk A-scale the number of moments equals the number of B-scale moments. The permanence of the positions in both scales can be expressed through the between relation. So, if we take any three B-moments, then the moment between the other two will always be so on the B-scale. This permanent order is due to the earlier than relation. And, if we take any three A-moments, then the moment between the other two will always be so on the A-scale. This permanent order is due

to the *B*-earlier than relation being introduced into the fundamental *A*-scale with the resultant expansive *A*-scale.

But McTaggart needs to claim that the moment that is now present, was future and will be past so that an *A*-moment can change its position in *A*-time, or in other words, it can change its position on the *A*-scale. The absurdity inherent in such a notion is revealed when we substitute the synonymous 'A-position in time' for 'A-moment' in the previous sentence. Thus, the claim is that an *A*-position in time can change its *A*-position in time. But of course, *A*-moments are not located at *A*-times from which they can relocate – they just are *A*-times – they are the locations, the times, that are either past, present, or future. A moment can't relocate to a different moment; a future moment can't become a present moment, nor can a present moment become a past moment. Thus, since each moment's position (location) on the *A*-scale is permanent, none can become a different moment.

However, as pointed out in 2.3, the only evidence provided by McTaggart that *A*-positions in time change their *A*-positions is that "an event, which is now present, was future and will be past" (McTaggart 1908 p. 458). The implication is that an *A*-moment changes position when an event changes position. It appears that McTaggart here inextricably links an event to a particular position in time so that, as an event changes from being future to being present to being past, then so must 'its' (inherent) position in time which it 'carries' with it. And yet, a 'ghostly' time (moment) remains behind as a placeholder on the permanent *A*-scale by which the change in location of the 'living' moment may be measured. (Of course, this ghostly time is the *B*-scale as represented within the (expansive) folk series.) The contradiction, therefore, lies in an *A*-moment, at which an event is positioned on the *A*-scale, being both static and dynamic. But, as we saw, no moment can become or be another moment – moments are static on their respective scales. In McTaggart's scenario, though, an event and the moment at which it is located is a unit that can change from the far to near future, then to the present, and on to the recent and distant past. But if *A*-moments cannot change their position in *A*-time then such units cannot change position.

However, there is ambiguity in McTaggart's notion of an event as 'the contents of a position in time' that may allow him to claim that events can change position in time. This phrase can be taken to mean that an 'event' is either content *simpliciter*, that happens to be located at a time, or the *conjunction* of content and position in time. The former sense would allow an

event (as content) to change position in time; the latter implies that any movement of content to a different position in time would dissolve one event (as conjunction) and form a new event. Therefore, McTaggart can only claim that events move from future to present to past on the understanding that events are content *simpliciter*. In this way, dynamic content is independent of static temporal positions and so, if an event just is content, then events can move through time. However, as we saw, McTaggart needs positions in time to change to allow him to claim contradiction, but a dynamic sense of event requires static positions in time.

Which sense of 'event' ought we use to avoid ambiguity? According to McTaggart, 'the events of time, as observed by us, form an A series as well as a B series'. Now, if events were content *simpliciter* then any ordered series formed by them would resemble McTaggart's C-series and so would not be a time series. For events to form a time series they must be *conjuncts* of time and content. Thus, we should take McTaggart's 'event' to be a union of content with moment. But we have already seen that such a unit cannot move through time and so cannot generate contradiction.

However, avoiding contradiction in the A-series has been won at the cost of excluding from it any sense of dynamism, which is supposed to be its special feature, and so it now appears just as static as the B-series. Let's see, though, how McTaggart implicitly recognises this fact of internal stasis in his use of a metaphor of spatial movement to capture time's dynamism:

The movement of time consists in the fact that later and later terms pass into the present, or – which is the same fact expressed in another way – that presentness passes to later and later terms. If we take it the first way, we are taking the B series as sliding along a fixed A series. If we take it the second way, we are taking the A series as sliding along a fixed B series. In the first case time presents itself as movement from future to past. In the second case it presents itself from earlier to later.

(McTaggart 1993 p. 24, n. 1)

Here, time's dynamism has nothing to do with any passage internal to the A-series but is simply the A- and B-series sliding passed each other. However, that sort of 'external' passage would require another time series in which it could occur. That time series, I maintain, is the expansive A-series of the manifest image, that just is the 'seemingly seamless union' in cognition between direct perception of earlier-to-later change and indirect inference of

present-to-past change that gives such spatial metaphors of movement their power when applied to time. This seemingly spatial-type movement of time is now found to be *internal* to an *A-series* after all – but only to the expansive folk *A-series* that is internal to our minds alone. (Note that it is the ‘presentness’ of the fundamental *A-series* that passes (or is passed by) later and later times of the *B-series* that transforms such *B-times* into degrees of pastness and futurity of an expansive *A-series*. This mirrors McTaggart’s original description of the present of the fundamental *A-series* moving along the terms of the *C-series* that results in the *B-series* – with the *C-terms* becoming *B-times*.)

The complaint may be levelled against this manifest image that the clarification of McTaggart’s argument has shown that an *A-series* avoids contradiction when static (which, however, seems to contradict what it is to be an *A-series*) but invites contradiction when dynamic. Therefore, this internally dynamic *A-series* is contradictory for therein ‘time presents itself’ as movement either ‘from future to past’ or ‘from earlier to later’. The first thing to say in response is that if it is contradictory then this contradiction can be viewed as an amazingly useful trick pulled off by our brains. I liken this ‘trick’ to what is experienced when viewing a drawing by M.C. Escher called ‘Waterfall’. We ‘see’ in the picture water cascading over a waterfall, turning a waterwheel, and flowing, yes flowing, back to the top of the waterfall, tumbling over it again, turning the wheel, and flowing back to the top – over, and over again for ever – until we look away. Just as ‘Waterfall’ must be seen to be believed, the manifest image must be experienced to be believed. So, perhaps ‘paradoxical’ is a better (and gentler) term to use to describe the manifest image of time rather than ‘contradictory’. Although, whether a manifest image is contradictory has absolutely no bearing on the metaphysics of time. The *A-series* that metaphysics should be concerned with are the notional (fundamental) *A-series* that are separate (though emergent) from scientific *B-time*.

Now, analytic metaphysics of time, when it engages with scientific time, explores how scientific and folk time are related and how or whether they can be reconciled. This is the root of *A-* and *B-*theories of time as well as hybrids of the two. However, the present study is armed with the added notional category and seeks to apply it to time. Consequently, I pursue a different sort of ‘reconciliation’. I have claimed that the scientific image of time is represented within folk time by the ‘static’ part of the manifest image; and that some form of dynamic time (the ‘notional image’) is represented in the ‘dynamic’ part. Thus, I aim to show that folk

time, the manifest image, just is the ‘reconciliation’ of the scientific image and the notional image of time through their union in thought – having taken this advice from Dennett:

Since at least a large part of philosophy’s task, in my vision of the discipline, consists in negotiating the traffic back and forth between the manifest and scientific images, it is a good idea for philosophers to analyze what they are up against in the way of folk assumptions before launching into their theory-building and theory criticizing. (Dennett 2013 p. 99)

In the next chapter, after using the *A*- and *B*-scales as a heuristic, I set forth ontic (as opposed to analytic) scales of time and demonstrate how they emerge. I also investigate what the physical, dynamic, ‘passage of time’ may mean since we have just seen that the passage of folk time is ultimately a seemingly paradoxical, though extremely useful, psychological ‘trick’.

3. The Emergence of Time II

3.1 Whitehead's Abstractive Sets of Durations

This chapter puts flesh on the skeletal structure of time that was set out in 2.2. The structure of time-atoms and of ontic scales of time are set forth, and the passage of time is subsequently explained as an occurrence solely at the macro-scale of notional time. However, I start by examining the structure of abstractive sets of durations, while giving them a realist interpretation.

In *The Concept of Nature* Alfred North Whitehead sets out his notions of time and space as “abstractions from more concrete elements of nature, namely, from events” (Whitehead 2004 p. 33). In turn, his radical empiricism leads him to view an event as “the ultimate fact for sense-awareness” (Whitehead 2004 p. 15). Although such notions are diametrically opposed to those of this realist thesis, there are still some ideas that can be taken from Whitehead and turned towards a realist perspective with advantage – not least that of abstractive sets of durations. Abstractive sets in general result from Whitehead's ‘method of extensive abstraction’, which he developed as a reliable experiential foundation for abstract concepts of science. One of these ‘abstract concepts’ that particularly concerns us is that of ‘instantaneousness’. In line with his empiricism Whitehead denies concrete existence to instants thus:

Instantaneousness is a complex logical concept of a procedure in thought by which constructed logical entities are produced for the sake of the simple expression in thought of properties of nature. Instantaneousness is the concept of all nature at an instant where an instant is conceived as deprived of all temporal extension. . . There is no such thing as nature at an instant posited by sense-awareness. What sense-awareness delivers over for knowledge is nature through a period. Accordingly nature at an instant, since it is not itself a natural entity, must be defined in terms of natural entities. Unless we do so, our science, which employs the concept of instantaneous nature, must abandon all claim to be founded upon observation. (Whitehead 2004 pp. 56-57)

For Whitehead, the logical construct that is an instant and is so important to science is ultimately grounded in experience through the method of extensive abstraction. In this case,

the idea is that a set of durations has its member durations progressively getting indefinitely smaller and smaller as our thought advances towards the diminutive end of the series, thus converging on an instant that is without extension. Except that crucially there is no end to the series; hence there is no minimum length of duration. Such a set Whitehead calls an 'abstractive set'. Here is how Whitehead defines an abstractive set of durations:

Let it have the following properties: (i) of any two members of the set one contains the other as a part, and (ii) there is no duration which is a common part of every member of the set. Now the relation of whole and part is asymmetrical; and by this I mean that if *A* is part of *B*, then *B* is not part of *A*. Also we have already noted that the relation is transitive. Accordingly we can easily see that the durations of any set with the properties just enumerated must be arranged in a one-dimensional serial order in which as we descend the series we progressively reach durations of smaller and smaller temporal extension. The series may start with any arbitrarily assumed duration of any temporal extension, but in descending the series the temporal extension progressively contracts and the successive durations are packed one within the other like the nest boxes of a Chinese toy. But the set differs from the toy in this particular: the toy has a smallest box which forms the end box of the series; but the set of durations can have no smallest duration nor can it converge towards a duration as its limit. For the parts either of the end duration or of the limit would be parts of all the durations of the set and thus the second condition for the set would be violated.

(Whitehead 2004 pp. 60-61)

However, although such an abstractive set of durations was conceived solely as an aid to thought in anchoring the abstract to the concrete, it can be viewed equally from a realist perspective as the structure of notional extended (durational) time as emergent from scientific punctual (instantaneous) time. Thus, instead of zooming in through smaller and smaller concrete durations that converge on an abstract instant, we zoom out from a concrete instant through larger and larger durations that emerge and diverge from that instant. Of course, such 'zooming' is merely a process of thought that is tied to the perspective taken towards an abstractive set: whether empiricist or empirical (zooming in), or realist (zooming out).

Recall that already in 1.5 it was argued that no 'higher level' time (durations) can emerge from 'lower level' time (instants) *synchronically*, for different levels of time cannot be 'at the same time'. Also, no 'higher level' time can emerge from a 'lower level' time *diachronically*, for any length of time belongs to a single 'level' of time. (Such talk of 'levels' of time is part of

emergence theory and is equivalent to RR's talk of ontological scales.) Therefore, all durations of different length emerge together. There is no sense to be made of a notion such as 'the longer the duration, the longer it takes to emerge'. Surprising as it may seem, a duration of a million years takes the same amount of time to emerge as does that of a millionth of a second – and that is precisely no time at all. Thus, the emergence of time in this case is strictly atemporal.

The smaller durations of an abstractive set converge on an instant but can never 'touch', or coincide with, the instant. These durations approximate the instant, and the smaller the duration the more proximate it is. However, no matter how small, a duration can never coincide with, or be at an instant; in other words, they can never be 'at the same time'. Hence the result that instants belong to a separate ontological scale of time (or 'level') to that of durations, so that one sort of time (durations) emerges from the other (instants). However, recall that in 1.6 it was claimed that folk time just is the combination *in thought* of instants (scientific time) and durations (notional time) – thus viewing them as being on the same level and as belonging to the same category. Hence, from the folk perspective instants are merely parts of durations, and durations consist of instants. (This notion is touched on in the next section when discussing W. H. Newton-Smith.) Thus, when instants and durations are viewed as existing on the same ontic scale, they can and do coincide and hence, in a folk sense, be 'at the same time'.

Whitehead is right to claim that his method of extensive abstraction connects experiential duration with non-experiential instants in such a way that smaller durations converge on a single instant. To the empiricist Whitehead, an instant is simply a "nonentity" (Whitehead 2004 p. 61). For the realist an instant may be viewed as that from which duration emerges. Thus, notional durations are representational real patterns that can be used to locate or 'point to' the extra-representational real patterns that are scientific instants. Specific smaller durations are pointers to specific instants precisely because they are emergent from those instants and hence, because they extend over and 'point to' just that same instant, approximate that specific single instant and no other. Such smaller durations constitute what I call 'time-atoms' and are examined in the next section.

3.2 Time-Atoms as Sets of Durations Covering a Single Instant

My realist approach to abstractive sets of time has it that both instants and durations are concrete, that durations emerge atemporally from instants, and that instants are aspects of spacetime points. Thus, abstractive sets of time constitute notional time. Now, as all instants are equally without extension they belong to the same scale; hence scientific time has just the one ontic scale. However, this is not the case with durations. Not only can their lengths range from the infinitely small to the infinitely large, but also there is a limit or 'cut' at which larger durations belong to a different ontic scale from those that are smaller. These smaller durations are originally identified by Whitehead for epistemic reasons due to their importance for his empiricist project of connecting, in thought, concrete durations with the 'nonentities' known as (mathematical) instants. He notes a crucial difference between those larger durations that cover or extend over two or more instants, and those smaller durations that cover just a single instant. It is only with the latter, smaller durations, that it becomes possible to speak and treat of one instant as being distinct from another. This is how Whitehead introduces this cut within durations (note that here he uses 'moment' as synonymous with 'instant'):

The durations which enter into the composition of a moment all belong to one family. Thus there is one family of moments corresponding to one family of durations. Also if we take two moments of the same family, among the durations which enter into the composition of one moment the smaller durations are completely separated from the smaller durations which enter into the composition of the other moment. Thus the two moments in their intrinsic properties must exhibit the limits of completely different states of nature. In this sense the two moments are completely separated.
(Whitehead 2004 p. 63)

And so, in keeping with his empiricist interpretation, this cut is viewed solely as aiding thought in its need to separate one instant from another, thus providing a physical interpretation to mathematical physics.

However, from a realist perspective this cut can be viewed, not merely as epistemic, but as ontic – as that which divides notional time into two distinct ontic scales. Such a position can be arrived at if we introduce the *A*- and *B*-scales as a heuristic. Recall that what initially kept these two scales distinct is that the positions in time of the *B*-scale are distinguished by the

earlier than relation and the *A*-scale positions are distinguished by past, present and future. We begin with the following suggestion: there are two categories of time that might be assigned to these two scales. Scientific time, as instants, is ordered according to the earlier than relation and so would naturally be assigned to the *B*-scale. Notional time, as durations, is then assigned to the *A*-scale.

Although there appears to be no problem in assigning instants to the *B*-scale, there may be difficulties in assigning durations to the *A*-scale. If we use the 'fundamental' *A*-scale that strictly excludes the earlier than relation, then it is *prima facie* difficult to see how to distinguish past, present, and future durations *qua* past, present, and future. (I explain how to make the distinction in 3.4.1.) It may seem that there is no such difficulty for the 'expansive' *A*-scale, in which the earlier than relation plays a role. According to that scale, past durations would simply be those that are earlier than the present duration, and durations later than the present would be future. However, to be able to do this the present duration itself must already have been determined, and that task throws up two general challenges along with a specific one.

The first general challenge was raised previously in 2.1 and concerns arguments to the effect that the present simply cannot be a duration. Augustine argues that as any duration can be divided into past and future then any posited present duration can be divided into past and future. Hence, what was deemed to be the present duration in fact consists in past and future durations, thus demonstrating that the present cannot be an extended duration but must be an instant. However, assuming this first challenge can be met satisfactorily, the second one asks: if the present is indeed a duration, then how is its length determined? The specific challenge was also raised in 2.1 but only applies to advocates of three-dimensionalism. Recall that Petkov argues that if the present were extended in time, then any object existing in the present would also be extended in time and must therefore be four-dimensional. Thus, any world with an extended present cannot be a three-dimensional world.

Before attempting to meet the general challenges, it is worth asking if adopting the converse assignment, where instants are placed on the *A*-scale and durations on the *B*-scale, would be any less challenging. Now, if we were to use the 'fundamental' *A*-scale, which has only three positions in time, we would have the *A*-scale consisting at most of three instants: a past instant, a present instant, and a future instant. No-one would subscribe to such a bizarre

notion. On the other hand, the 'expansive' A-scale, which allows the earlier than relation to order near and far positions within both the past and future, would allow for an A-scale consisting of an infinite number of instants. Additionally, the present would in that case be an instant, and so all three challenges would not apply. However, in 2.1 I argued that instants are aspects of spacetime points that are ordered by the earlier than relation, and so I have no choice but to assign instants to the B-scale.

I start with the first challenge raised against the A-scale when durations are assigned to it: how can the present possibly be a duration? I argued above that Whitehead's limit or cut that separates larger durations that extend over two or more instants from smaller durations extending over a single instant can be viewed as ontic and not merely as epistemic. Such an ontic cut results in there being smaller durations below the limit that are discrete in the following sense: they are separated from all larger durations above the cut that cover more than one instant and separated from all other smaller durations below the cut that cover other 'separate' instants. Thus, these sets of smaller durations (as subsets of abstractive sets) can be viewed as atomic. Hence, *a time-atom just is a set of smaller durations that extends over a single instant*. Due to ontological emergence, every instant is covered by its own time-atom.

This has the consequence of dividing notional (durational) time itself into two ontic scales, which is problematic for our initial suggestion that assigned durations to the A-scale *tout court*. However, we are here using the A-scale as a heuristic, and it is this very problem that can advance us beyond McTaggart's two series. To see how this is so, we must return to those series. We know that the distinguishing features separating the two series are, for the B-series, the earlier than relation and, for the A-series, past, present, and future. There is no difficulty in applying the earlier than relation to the internal structure of a time-atom. Indeed, it seems to demand it. Recall that abstractive sets of durations are structured as "successive durations packed one within the other like the nest boxes of a Chinese toy" (Whitehead 2004 p. 61), so that larger durations start earlier than and end later than smaller durations nested within them. Hence, it is the earlier than relation that directly constrains the lengths of durations that constitute time-atoms. (In 3.3.3 I show how the earlier than relation indirectly constrains durations larger than those of an atom.)

However, applying past, present, and future to the durations of a time-atom would return us to our initial challenge by ensuring that the present remains without extension after all. This is a consequence of there being no natural cut or limit within the different lengths of durations within an atom that could separate – and keep separate – a present duration *qua* duration from past and future durations. Any such putative cut within an atom would be purely arbitrary; hence the present would shrink to an instant once again. Meanwhile, the outcome of re-designating the present as an instant, while maintaining past and future as durations, would be the present being placed on a separate ontic scale (the *B*-scale) from the past and future and thus ripping apart the *A*-scale itself. This would destroy McTaggart's important initial insight that led him to formulate the two series in the first place.

Thus, maintaining and developing that insight in an ontological direction requires us to hold fast to those distinguishing *B*-features of earlier than and *A*-features of past, present, future. This then requires us to place the internal structure (durations) of atoms outside of the *A*-scale itself; so that there can be no past, present or future durations within time-atoms. (We do this while still designating instants as scientific time and durations as notional time.) We must conclude that if the *A*-scale consists in durations, then those durations are the larger durations that sit above the ontic cut in notional time and thus will be variously located at the past, present, and future. And so, having used McTaggart's two time series as a heuristic, we find that we need to go beyond them: from working with two analytic scales of time we find that we require three ontic scales. The different ontological constituents of these three scales are: (i) instants, (ii) atoms, and (iii) the larger durations that extend over two or more instants or, in other words, aggregates of atoms.

Thus far we have concluded that if the present is to be a duration, then it must be of notional time, that it cannot be located within the structure of an atom at scale (ii), and so any present duration must be located, along with the past and future, at scale (iii). Now, as this scale is constituted by atoms, the smallest possible size of a present duration will be the length of an atom. The answer to the first challenge – how the present can be a duration – is that it is not the case that every duration can be divided into past and future. When a time-atom is 'split' it simply results in earlier and later parts. Hence, if any atom is identified as being the present then there are earlier and later parts that make up that atom – but as these parts are located

at scale (ii) they cannot be classified as either past or future, for past and future are located exclusively at scale (iii).

It is apparent that in answering this first general challenge we are halfway to answering the second, that is, how is the length of a present duration determined? We have just seen that a present duration cannot be less than the length of a time-atom, for lesser lengths fall below the ontic cut in notional time, beneath which the present (along with the past and future) simply does not exist. Thus, we need only ascertain the upper limit to the length of the present to fully answer the second challenge. To do this we use an argument of a similar form to that of Augustine and apply it to scale (iii).

The present, we now know, is at least one atom in length, but can it consist of two atoms? If it did, then that present duration can be divided into a past atom and a future atom, leaving a present without extension. But in that case the present is not a duration after all and so suffers relegation to a different scale from that of the past and future (again ripping it from the A-scale and destroying McTaggart's original insight). Now what if the present were three atoms long? Then it could be divided into a past atom, a present atom, and a future atom; in which case the present is not three atoms long after all but is only one atom long. If this line of argument is repeated each time an atom is added to the previous total so that the present is thought of as four, five, six, etc. atoms long, then we discover that all supposed present durations having even numbers of atoms result in a present that is without extension, and all odd numbers of atoms result in just a single atom being the present. Hence, we can conclude that the longest possible length that the present duration could be is that of one atom, which, of course, is also its shortest length. Thus, the present duration can consist only of a single atom; and, as an atom extends over a single instant, i.e. it approximates an instant, *the present is a duration that is approximately instantaneous*.

This conclusion further allows us to give an answer to the specific challenge that was raised by Petkov against three-dimensionalism: if the present is extended in time, then any object that is present must also be extended in time and so is four-dimensional; in which case, the world cannot be three-dimensional. This is strictly correct, but we can now see that when the extended present is approximately instantaneous then the world can be approximately three-dimensional. Though whether such 'vagueness' of dimensionality would satisfy three-dimensionalists is another matter entirely.

I end this section by emphasising the structure of time-atoms. I mentioned W. H. Newton-Smith at the end of the previous section in connection with what I called the folk perspective of instants being parts of durations. Under the heading of ‘Instants as Parts of Durations’, Newton-Smith writes:

While one can explicate the notion of an instant in terms of that of an interval, one can equally explicate the notion of an interval of time by reference to the notion of an instant. An interval might be construed as a composite object formed from instants. . . The reason for preferring to take intervals as more basic is that we are not as puzzled by intervals of time as we are by instants of time. . . Unlike the notion of an interval, the notion of an instant is not a notion which we apply directly to our experiences.
(Newton-Smith 1980 pp. 134-135)

The reason Newton-Smith can claim instants as parts of durations is that he believes that both instants and durations are abstract entities (Newton-Smith 1980 p. 127). Whereas Whitehead believes that instants, as abstract entities, can only be made sense of by physical science if they are defined by durations as concrete entities. Thus, for Whitehead, there can be no question of an abstract instant being part of a concrete duration. (Of course, I argue that both instants and durations are concrete real patterns, but that the one cannot be part of the other for they are located at separate ontic scales.) However, Newton-Smith and Whitehead – through different methods – arrive at the exact same structure of durations as they ‘approach’ an instant. This structure is, of course, that of nested durations. I have quoted Whitehead to this effect in 3.1. Here is Newton-Smith’s account:

We now proceed informally to define a notion of an instant. . . [A]ny interval has an inner part and that inner part in virtue of being an interval has itself an inner part and so on. Hence we can introduce instants as *infinitely nested sequences of inner parts of intervals*. This means in effect that an instant is an infinite set of Chinese boxes (the intervals). Each box has a finite non-zero size but for any box there is inside it a still smaller box.
(Newton-Smith 1980 p.137, his emphasis)

Remarkably, this image is exactly that of Whitehead’s – although Newton-Smith does not mention Whitehead in the book. This image is arrived at via two different methods employed due to the differently perceived ontological status of instants and durations. On the one hand, Whitehead requires his method of extensive abstraction due to his belief that instants are

abstract and durations concrete entities. On the other hand, as Newton-Smith views both instants and durations as abstract – with instants being parts of durations – he uses Tarski’s version of Lesniewski’s mereology (Newton-Smith 1980 p. 134).

I take their common image of an instant, reject the notion of it being an instant, add the qualification that the largest duration of the ‘box’ extends over only a single instant, and claim it as the image of the structure of a time-atom. Of course, there is no sense to be made of imagining an instant sitting at the centre of this image – like that of the popular image of a nucleus sitting at the centre of electron orbits of a material atom – for instants do not exist at this scale.

3.3 The Emergence of Ontic Scales of Time

3.3.1 The Micro-Scale of Instants

In the previous section, three ontic scales were developed through using McTaggart’s two time series as a heuristic. These scales were simply labelled as (i), (ii), and (iii). However, as ontic scales in RR concern size, whether temporal or spatial, it will be helpful to give these scales names that reflect this fact. Hence, I propose to call the scale of instants (i), the micro-scale; the scale of individual atoms (ii), the meso-scale; and the scale of aggregates of atoms (iii), the macro-scale.

Achim Kempf demonstrates that “there is the possibility that spacetime could be simultaneously continuous and discrete, in the same mathematical way that information can be simultaneously continuous and discrete” (Kempf 2010 p. 3). He does this by applying Shannon’s sampling theorem, which is central to information theory, to the physics of spacetime. He finds that, just as that theorem “provides the crucial equivalence of continuous and discrete representations of information” (Kempf 2010 p. 3), it does the same for spacetime. He concludes his article with:

We have shown that spacetime could be continuous and discrete, in the same way that information can. To this, we considered the cutting off of the spectrum of the Laplacian (or d’Alembertian) at an eigenvalue close to the Planck scale. We found that, in this case, physical theories possess equivalent continuous and discrete representation, and that external symmetries can be preserved.
(Kempf 2010 p. 14)

Thus, although our best current scientific theories (here specifically the Special Theory of Relativity) model time as continuous, it may be the case that we are free to model it as either continuous or discrete. This is how Newton-Smith describes the way in which we do model time as continuous:

We take individual real numbers as denoting instants and project back onto the interval a non-denumerably infinite number of extensionless parts or instants, one corresponding to each real number in the interval. That is, our belief in the continuity of time does not arise from any argument relating to infinite divisibility, it arises from our projecting onto the world the richness that is present in the mathematical system which we have found to date to be essential to the construction of viable physical theories.
(Newton-Smith 1980 p. 118)

My argument concerning the emergence of time stems directly from continuous Minkowski spacetime. Hence, for present purposes, instants, as aspects of spacetime points of this spacetime, may be viewed as continuous. However, if Kempf is right, then we are equally free to view instants as discrete. Either way, all instants, when constituting a series of time, are partially ordered according to the earlier than relation. The micro-scale, at which is located the real patterns we call instants, constitutes scientific time.

3.3.2 The Meso-Scale of the Individual Atom

The first thing to note concerning the notion of time-atom as developed in 3.2 is that, unlike those of the ancient world, they are not indivisible magnitudes. Second, unlike modern chronons (discrete smallest parts of time, whether with or without extension), they are not the smallest parts of time *per se*. Instead, such a time-atom is merely the smallest part of the macro-scale (hence the moniker 'atom') and yet it is infinitely divisible within the meso-scale. Thus, such modern time-atoms are somewhat akin to modern material atoms, which are also divisible, nor are they the smallest parts of matter. This structure avoids what Jean Paul van Bendegem calls the extension problem for chronons. An interval in time has an extension that can be divided into two smaller extended parts, each of which can itself be so divided, and those resultant parts further divided, and so on, with each part having extension. If time is discrete then the number of divisions will be finite. The division must end at the level of

chronons. Such chronons will retain extension. However, having extension implies divisibility, so the division continues and hence they are not chronons since they are not the smallest parts of time after all. Van Bendegem notes that this suggests chronons will have zero extension, which then “raises the problem of how an addition of a finite number of zero extensions can lead to a non-zero extension for an interval” (van Bendegem 2011 p. 148).

These problems do not arise for time-atoms as portrayed here, since they are neither the smallest parts of time nor without extension. Interestingly, van Bendegem’s response to the problem of extension brings him towards the notion of scale relativity of ontology, or emergence, concerning time. He writes that, “the property to have an extension is a *threshold* property: individual chronons do not have the property, but any aggregation of chronons does” (van Bendegem 2011 p. 149, his emphasis).

It is at the meso-scale where we first find duration as emergent from the instantaneous. At this scale the smaller nested durations form the structure of a time-atom. As the meso-scale and atoms emerge together from micro-scale and instants, each instant is covered by ‘its own’ atom. The meso-scale is that of the individual atom. The atom consists in durations that cover a single instant. Thus, the meso-scale is that of the smaller durations of notional time. Now, just as instants are the origin of atoms in that atoms exist through their emergence from instants, so the meso-scale at which atoms are located only exists through this same emergence. Thus, the meso-scale emerges from the micro-scale. Hence, just as atoms are ontologically dependent on instants, so the meso-scale is ontologically dependent on the micro-scale. The meso-scale, at which is located the representational real patterns (durations) of individual atoms, is the lesser of the two ontic scales of notional time.

3.3.3 The Macro-Scale of Aggregates of Atoms

We now arrive at the scale at which we live our lives – the scale that makes experience possible. In 3.2 I argued both that the present must be located at this macro-scale and that it can be neither smaller nor larger than the size of a single time-atom. I also insisted that the present must be found at the same ontic scale as the past and future, thus maintaining the integrity (and insight) of the A-series.

The part of the structure of Minkowski spacetime that concerns us here is absolute-chronological precedence. Thus, spacetime points that lie within or on the surface of the earlier light-cone of a spacetime point p are earlier than p in any reference frame. Also, all points lying within or on the surface of p 's later light-cone are later than p in any frame of reference. Earlier and later light-cones are commonly termed 'past' and 'future' respectively. However, as I argue that past and future emerge at the macro-scale of durational notional time, using such terms for punctual scientific time is not strictly appropriate. (As mentioned previously, Minkowski himself originally used the German equivalents of 'before' and 'after'.) Absolute-chronological precedence is exhibited by instants (as aspects of spacetime points) being partially ordered by the earlier than relation. This ordering is partial in that the relation is reflexive, antisymmetric, and transitive.

Each Instant of Minkowski spacetime that is ordered by the earlier than relation is extended over by a time-atom that is emergent from it. Hence, from the structure of scientific Minkowski spacetime there emerges from its temporal aspect a structure of notional time at the meso-scale. Thus, aggregates of atoms are determined to exhibit a similar structure to that of instants that are structured in order of absolute-chronological precedence by the earlier than relation. Rainforest realism recognises this determining relation as that holding between a second-order representational real pattern (atom) and the real pattern (instant) to which it is second order. Thus, the constraint that holds aggregates of atoms in the positions of a series is that of ontological dependence – and not the earlier than relation *per se*. In terms of the relation of emergence this is viewed as the ontological dependence of the emergent atom on its emergence basis instant.

Time-atoms are constrained to form a time-series that mirrors the sequence of their emergence basis instants, in the sense that, though the instants are directly ordered by the earlier than relation, the positions of the emergent atoms are determined by ontological dependence on those instants. Of course, the mirror metaphor only works for top to bottom reflection, not left to right. Thus, if instants are viewed as constituting a vertical line with the earlier than relation being represented by the lower than relation so that points on the line that are lower than others represent instants that are earlier than others, then its emergent reflection in the 'distorting mirror' of ontological dependence appears as an atomic column.

Since instants are ordered according to the earlier than relation, their corresponding atoms are determined to appear as if ordered by the same relation.

Such determined appearances may be better understood when we recall the compressibility criterion of a real pattern from 1.4. A random mathematical series is incompressible because only the complete verbatim bit map preserves the series. A pattern is compressible if the data is more efficient than the bit map. Keeping with the distorting mirror metaphor, a random distribution of points in space would appear to be reflected as randomly distributed atoms. However, each atom is constrained to be located at a position that is strictly determined by the position held by the point it reflects – although it appears to be just as randomly positioned as its original point. Thus, a random distribution of points is reflected by a non-random, determined, distribution of atoms that appears as completely random. And so, when extra-representational real pattern instants that are serially ordered by the earlier than relation are ‘reflected’ by representational real pattern time-atoms, ontological dependence determines that the atoms are placed at similar relative positions to each other. This results in the appearance of atoms as sequentially ordered by the earlier than relation. Thus, when we view the aggregation of atoms at the macro-scale as forming a series, we observe a series of atoms as sequenced in line with the earlier than relation – so much so that the series appears to be directly constrained by that relation. This, even though, as explained in 3.2, the earlier than relation directly constrains only those smaller durations (of individual atoms) at the meso-scale.

It is important to understand just how atomic the durations of the macro-scale are – that the longest length of an atom at the meso-scale just is the shortest length existing at the macro-scale. Thus, there exists a multitude of macro-durations of varying lengths, but these lengths are strictly atomic and directly determined by the number of atoms that constitute them. According to the scale relativity of ontology, the smaller durations of the meso-scale do not exist at the macro-scale, and *vice versa*. Hence, there are no such things as durations having lengths such as one and a half atoms, or two and three quarters of an atom, etc. Macro-durations, being atomic, are only divisible into atomic lengths. If we ‘split’ an atom, we ‘annihilate’ the macro-scale and ‘instantiate’ the meso-scale. The macro-scale, at which is located consecutive series of time-atoms, is the greater of the two ontic scales of notional time.

I have now shown how time is structured according to the scale relativity of ontology by using the *A*- and *B*-scales heuristically. However, although I have maintained throughout that the *A*-scale of past, present, and future is to be found at the macro-scale, thus far the *A*-scale as such has not been located. The only type of series so far discovered at the macro-scale is a consecutive series of atoms arranged as if by the earlier than relation. Therefore, the past, present, and future do not emerge at the macro-scale in a similar way to that in which van Bendegem envisions extension emerging from extensionless chronons. That is, past, present, and future are not threshold properties that emerge from the aggregation of time-atoms arranged in a series mirroring their original instants' consecutive ordering by the earlier than relation. As we have already seen, such aggregative emergence simply results in series of atoms at the macro-scale that mimic the earlier than relation. And, though this would seem to be a suitable basis from which an *A*-scale might emerge, we have discovered nothing that would naturally anchor the present to one specific atom that could then determine the past and future. This seems puzzling. However, there is a simple explanation.

Recall the analysis from 2.1 that concluded that Minkowski spacetime was in no sense a container and thus had no content that might exist at different ontological scales – not even clocks and rods. Hence, the resultant exposition of the emergent structure of time has been concerned with emergence from a spacetime that is without content, and so the structures of time that we have been dealing with are equally empty of content. This is obviously so when we recall the discussion in 1.4 where composition was viewed as a dynamic, diachronic process so that any content of time is created over time, and of course the emergence of pure time is not diachronic. Therefore, our progress in the analysis of the emergence of time has come to halt at the final emergent structure of pure time. If we want to go further and discover the emergence of the past, present, and future, we need to go beyond pure time and introduce content into the analysis.

B-theorists may object that the present is essentially perspectival and so is easily identified by an observer. Thus, the *A*-series is merely a subjective perspectival construct, and so we identify the present as simply being our temporal perspective on the world at any given time. This present perspective is identified with the *B*-time at which it holds. *B*-theorists may then conclude that this subjective present is *merely* perspectival. There is much to be said for this description of how we, as observers in time, identify our subjective folk present. However, I

am concerned here with identifying an objective notional present that exists independently of consciousness. I would also object to a ‘merely perspectival’ description of the present. When it comes to real patterns, (physically possible) perspective is an essential ingredient in their existing as such. Thus, if the present is (as I argue it is) a real pattern, then its perspectival nature neither reduces its importance nor diminishes its reality in any way.

3.4 The Passage of Time

3.4.1 The Emergence of the A-Scale

I indicated in 3.2 that I would explain in this section how to distinguish past, present, and future durations *qua* past, present, future. Due to strictly withholding the earlier than relation from the (‘fundamental’) notional A-scale, it is not warranted merely to claim – even assuming we can first determine the present – that the past duration is that which is earlier than the present duration, which in turn is earlier than the future duration. However, we have just seen that none of present, past, or future can be determined in a pure, or empty, structure of time; and hence – if the A-scale is real – it must emerge with content at the macro-scale of time.

The composition of the content that is found in notional (durational) time is divided between the meso- and macro-scales of time. The composition of content at these two scales is both separate and different. Meso-composition occurs within meso-scale durations directly constrained by the earlier than relation and for which neither past, present, nor future exist. This composition just is the synchronic emergence of meso-content. This content emerges together with the emergence of time-atoms from instants. In other words, it cannot be the case that there exists pure (empty) time that then somehow gains meso-content. Such a process would be dynamic and diachronic and so requires time’s passage. However, we have already seen that there can be no passage of pure time. Therefore, meso-content either exists/emerges synchronically together with the atemporal emergence of time-atoms in some world or will never exist in a world of pure time. Our world does possess content and so there could have been no time at which time in our world was pure. Content’s ontological dependence on spacetime is examined in 4.2.

On the other hand, macro-composition occurs within a series of atomic macro-scale durations that are correlated with the earlier than relation and is a dynamic process of diachronic emergence. This does require time's passage, which now is made possible by pre-existing meso-content, somehow, having a role in the emergence of content at the macro-scale of time. (This 'somehow', I argue in 5.1.3, is a quantum-mechanical phenomenon.) Thus, 'impure' time can give rise to the passage of time whereas 'pure' time never can. The *A*-scale's three positions are: present, at which events occur; past, at which events have occurred; and future, at which events will occur. With macro-composition of content being an on-going dynamic event, it must occur in the present. At this point we recall the argument in 3.2 that the present must be a single time-atom, a duration that is approximately instantaneous. Content and the present emerge together at the macro-scale. The present, then, is determined by being the location of a single time-atom of a series of macro-durations at which a macro-process of composition occurs.

Having determined the present, we must now determine the past and future durations *qua* past and future. This is done by identifying the relations that exist between those remaining time-atoms in the series in which the present has already been determined. If there are time-atoms that contain content but no process, then, because the process of macro-composition of content is exclusive to the present, they must already have been present and so are now past. On the other hand, if there is within the series a sequence of atoms that contains no content, with one of them adjacent to the present, then they can be neither past nor present and so must be determined as future. Thus, we can now distinguish the future duration (aggregate of time-atoms) as being that part of the *A*-scale that is empty of all macro-content, and the past duration (aggregate of time-atoms) as that part of the *A*-scale that has macro-content but no process. Thus, the past, present, and future durations *qua* past, present, and future are distinguished by either the nature of their content (past without process, present with process) or lack of content (future without content). The emergence of the content of time is the topic of the next two chapters. But what concerns us here is the passage of time. In the next subsection I argue that the continual diachronic emergence of the *A*-scale together with the emergence of content at the macro-scale just is the passage of time.

3.4.2 The Passage of Time

Thus far I have argued that emergence of pure (empty) time is atemporal and so neither synchronic nor diachronic. Here I argue that the emergence of *A*-series time, i.e. the positions of the *A*-scale plus their content, is diachronic. In notional time there is no content to be found at the future, and so there never was a future event that was Hegel's birth. There are no future events, but there is the future position in time. When Hegel's birth was present the content of the present was an ongoing process, when his birth is past the content of the past is without process. The content of the two events is different. Thus, the notional passage of time cannot be of the same content moving from the future to the present and on to the past.

From what has been written so far, we can say that there is no passage in scientific time at the micro-scale. The situation of notional time, being divided between two ontic scales, is more complex. At the meso-scale, there is no passage at all, although in the case of meso-durations that have content there can occur (tenseless) 'anaemic change.' This phrase is borrowed from Bradford Skow (who applies it to a Block Universe). He describes Russellian change as anaemic:

Something is changing if and only if (i) it is currently one way, and
(ii) it was (not long ago) some other, incompatible way.
(Skow 2015 p. 24)

If this idea is expressed in terms of the earlier than relation, so that something changes iff the way it is earlier is incompatible with the way it is later, then such change can apply at the meso-scale. Thus, if there is difference in composition of content within a time-atom, then it qualifies as anaemic change.

However, there are those who may demur to the 'anaemic' label to describe such Russellian change for they believe that *B*-time has a certain dynamism. They hold that events occurring sequentially and directionally from earlier to later along the temporal dimension is sufficient for time's passage. Among their number is Savitt, Deng, and L. Nathan Oaklander. Unlike more traditional *B*-theorists, who regard passage as purely subjective and perspectival, this group believes that such passage is objective and non-perspectival. Oaklander argues that the Russellian 'is earlier than' relation involves dynamicity:

For the Russellian the phenomenology of temporal passage is R-theoretic, that is, temporal passage or the dynamic aspect of time is grounded in a temporal succession or transition from earlier to later temporal items. Thus, an R-theorist should not fear that the words “temporal succession” or “transition” commit them to A-succession or A-transition. Succession is not an A-relation, but it is not a static relation either.

(Oaklander 2012 p. 7)

We can already see from this that the meaning or sense of words appears to be central to such claims. This impression is reinforced when reading the claim by Deng that:

B-theorists can allow our perceptions of succession, including our perception of change and continuity, to be generally veridical, since it acquaints us with tenseless facts about the successive occurrence of events, and . . . (if by ‘dynamicity’ we just mean the continuous happening of things, one after the other), then in this sense, too, we truly experience dynamicity on the B-theory.

(Deng 2013 p. 723)

With terms such as ‘temporal passage’, ‘transition’, and ‘dynamicity’ being used in association with *B*-change, the word ‘anaemic’ may seem out of place. Even more so when ‘becoming’ is added to that list, as when Savitt argues that ‘absolute becoming’ is “a surprising common ground shared by a resolutely anti-passage philosopher like [D. C.] Williams and a stalwart (at least at this period of his life) pro-passage philosopher like [C. D.] Broad” (Savitt 2002 p. 160). In doing so, he juxtaposes quotes from both philosophers, such as this from Williams: “There is passage, but it is nothing extra. It is the mere happening of things, their existence strung along in the manifold” (Williams 1951 p. 165). And this from Broad: “To ‘become present’ is, in fact, just to ‘become’, in an absolute sense; i.e., to ‘come to pass’ in the Biblical phraseology, or, most simply to ‘happen’” (Broad 1938 p. 280). Again, therefore, it is the sense in which these various words are taken that bears the burden of the argument. A distinctly underwhelmed reaction to such a line of argument, which may be shared both by *A*-theorists and more traditional *B*-theorists, is displayed by Earman when he writes:

[I]f a future-inextendible [i.e. eternalist] model is adopted as the model of our world, then the only sense of ‘becoming’ available is a thin yawn-inducing one: by definition, events occur/happen, and the successive occurring/happening of events is becoming.

(Earman 2008 p. 159)

However, I suspect that Savitt points us towards the reason why the objective ‘*B*-passagers’ tend to believe that such *B*-passage is not yawn-inducing, when he writes:

As I understand Broad, he is saying that the happening of events is so fundamental a notion that it cannot be explained in terms of simpler or more basic ideas, and I have considerable sympathy with this claim. . . [A]nd I do think that one has to start somewhere, has to have some primitives.
(Savitt 2002 p. 164)

Therefore, if the ‘happening’ or ‘becoming’ of events is viewed as primitive, then objective *B*-passage may suddenly appear as mysterious and interesting, if not exciting. In this way, by viewing the terms ‘happening’ and ‘becoming’ as synonymous, and perhaps even primitive, then the ‘whoosh and whiz’ normally associated with *A*-passage may seem to be associated with *B*-passage. Even so, Savitt ends the article by questioning whether the very notion of ‘absolute becoming’ can be meaningful in Minkowski (or any relativistic) spacetime. However, there are others, such as Dorato, who argue that there is becoming in spacetime because, “in Minkowski spacetime timelike-separated events are objectively, invariantly timelike-related, and events, *by definition occur or happen*” (Dorato 2006 p.97, his emphasis). I examine Dorato’s argument in 7.2.1 and note again that it ultimately rests on the sense given to words. Thus, as someone who believes that Russellian change is strictly ‘anaemic’, I remain unconvinced that there is any meaningful *B*-passage.

And so, anaemic change occurring at the meso-scale is not sufficient for passage of time. There is no passage because the atomic duration in which composition of content (tenselessly) occurs can neither pass over (or extend over) a different instant from the one it does extend over, nor can it pass into the adjacent atom. Therefore, since any part of the composition of content that is earlier in the duration than another part is ever thus, its time does not pass.

This is not the case with macro-composition. Here composition takes place when the atom that was present becomes past and the adjacent future atom becomes present. In other words, there is passage of time when the *A*-scale appears to leap along a series of time-atoms, one atom at a time, approximately instantaneously. Though, in fact, a new *A*-scale continually emerges with each new atomic emergence of content at the macro-scale. Meanwhile, the *A*-scale positions remain permanent in relation to one another, as the present is ever between

the past and future. Also, the positions of time-atoms relative to one another within the series of macro-durations are equally permanent since they are correlated with instants that are ordered by the earlier than relation.

Passage of time occurs through the diachronic emergence of a macro-process of composition that requires the present to 'move' along a series of time-atoms, seemingly by 'leaps', from one atom that then becomes past to the next atom in the series that was future and now becomes present. Viewed this way, the present position is consecutively filled by time-atoms from the future that were previously empty of content. Each of these time-atoms, when present, (somehow) allows an ingress of content at the macro-scale as emergent from meso-content. This process qualifies as passage of time because one position in time, the present, passes along a series of time-atoms, each of which covers a single instant that in turn is ordered by the earlier than relation. Therefore, while instants and time-atoms are ever held in position by the earlier than relation and ontological dependence respectively, the *A*-scale passes by 'leaps' over the time series 'below' and, in conjunction with the content that it picks up in passing, forms a continually changing *A*-series.

This description of a dynamic notional *A*-series has an obvious similarity to that of the dynamic folk (expansive) *A*-series in 2.5; both utilise a spatial metaphor of movement. However, whereas the folk series' dynamism is expressed in the (fundamental) *A*- and *B*-series sliding passed each other, notional series' dynamism is expressed in the leap of the present from one time-atom to the adjacent future one within the same macro-series of time.

The story of diachronic emergence at the macro-scale may be better understood by using analogous ideas developed by Paul Humphreys in "Synchronic and Diachronic Emergence" (Humphreys 2008). He provides an interesting exposition of diachronic emergence as what he calls "pattern emergence", which is "[a] common type of emergence [that] involves the appearance in a system of novel structure that results from the temporal evolution of the system" (Humphreys 2008 p. 432). Although he is mostly concerned with 'virtual' emergent patterns (like those discussed previously in 1.4) he ends by raising the question of what makes a pattern real. However, what he writes concerning 'patterns' can readily be used at least as a heuristic to better understand the emergence of dynamic real patterns of time. For our purposes, his exposition is applicable to both macro-content emergence and *A*-scale emergence, and so to the continual emergence of an *A*-series.

In what recalls the *A*-scale, Humphreys identifies a type of pattern that emerges from a computational process, which he calls a '*micro-dynamic pattern*' that "consists in the appearance of a non-random pattern and that pattern remains invariant under a specified class of dynamic substitutions of the pattern's constituents" (Humphreys 2008 p. 437). He further identifies three sub-types of such patterns, of which one is especially pertinent here. He calls this subtype of micro-dynamic patterns '*transient autonomy*', in which:

the macro-structure emerges and then persists through substitutions of the same type as the original, a case that applies to standing waves in river flows as well as, in some cases, to the products of social insects such as ants and termites. The standing wave persists even though countless different water molecules move through the three dimensional region that contains the wave. The distinguishing feature of transient autonomy is thus the persistence of a stable structure as the original micro-constituents are replaced by new ones of the same kind, this replacement usually occurring as a result of the dynamics at the micro-level.
(Humphreys 2008 p. 437)

From this we may see how such transient autonomous structure is analogous to the *A*-scale emerging and 'persisting' through continual (re-)emergence as every single present time-atom is serially replaced by individual atoms from the future duration. This is the passage of time, and, combined with the change of content, is the robust objective becoming that block universe theorists such as Skow deny.

3.4.3 The Epistemic Re-entangling of the *A*- and *B*-Series

At the macro-scale we found that there are atomic time-series that mimic the micro-scale series of instants as ordered by the earlier than relation of Minkowski spacetime. Past, present, and future emerge at this macro-scale with the emergence of content. Now, all time-atoms constituting the past and future durations are either equally past or equally future. However, because they are correlated with instants as ordered by the earlier than relation, they are epistemically divisible into degrees of pastness or futurity. The first degree of pastness is the first atom in the series counting from the present in the earlier than direction, the second degree is the second atom of the series in the same direction and so on for the third, the fourth etc. degree. The first degree of futurity is the first atom in the series counting from the present in the opposite, later than, direction, with the second, third, etc. degree of

futurity similarly counted along the series. By such a method we can agree both with Mellor's "obvious fact that pastness and futurity come by degrees" (Mellor 1998 p. 8) and McTaggart's notion that the *A*-series runs from the far future to the near future, through the present and on to the near past and far past. Thus, Mellor's *A*-scale is seen to be an accurate epistemic scale that results from the combination in thought of what is called here the ontic scales of scientific and notional time.

As the degrees of pastness and futurity are viewed as having a one-to-one correspondence with individual time-atoms, they are afforded great precision by the fact that each atom of the *A*-scale holds a unique position in a series due to their emergence from instants that are ordered by the earlier than relation. Hence, when we (epistemically) apply the earlier than relation to the aggregation of time-atoms constituting the *A*-scale we can very sensibly (as folk) believe of two past events that one is further back in the past than the other. Or of two events that may occur in the future that one will be further in the future than the other.

In this way, in both everyday life and special science, we accurately insert all 'dates' of the *B*-scale into the *A*-scale. But this should be understood as a purely imaginary insertion undertaken for strictly practical and epistemic purposes. So, in accord with Mellor's *A*-earlier than relation, the year 1917 is viewed as being further back in the past (or having more degrees of pastness) than 1958, for, though both are equally past, the number of time-atoms that separate 1917 from the present are greater than the number of atoms separating 1958 from the present. And 2066 is said to be further in the future (or has more degrees of futurity) than 2031 because the number of atoms separating the former from the present is greater than the number of atoms separating the latter from the present.

Augustine, then, was quite right to say in Book XI of *The Confessions*:

In ordinary speech, what is easier or more familiar for us to talk about than time?
And we definitely understand it when we speak of it, and we also understand it
when we listen to someone else talking about it.
(Augustine 2016 p. 217)

This general folk knowledge of time, far from being simplistic, is a very considerable achievement in its practical grasp of complex concepts.

4. The Emergence of the Content of Time I

4.1 Content as Structure

At this stage it is as well to re-iterate that from the vantage point of ontic structural realism all content of time and space will be viewed as structure. Thus, when we talk of the emergence of the content of time or space we are, in the final analysis, referring to the emergence of structure within time or space. Additionally, in rainforest realist terms, such structure, as real patterns, exists at various scales of time and space. Thus far, I have argued that spacetime is neither substantival nor relational but is an aspect of the structure of the world; that spacetime does not supervene on spacetime points; that spacetime points are derivative of, or emergent from, scientific 4D spacetime; and that notional 3D space and 1D time emerge respectively from the spatial and temporal aspects of spacetime points.

Also, content was denied to this unitary 4D spacetime, so that any time emerging directly from spacetime is either 'pure', in that it is similarly without content, or 'impure', in that it has meso-content. It was discovered that such pure time is not structured as past, present, and future, but simply as earlier and later; and that any *A*-scale consisting of past, present, and future only emerges with the emergence of content onto the macro-scale of time from content at the meso-scale. Hence, the *A*-scale and its contents dynamically and diachronically emerge together at the macro-scale of time, constituting an *A*-series. The passage of time consists in the continual emergence of content into this macro-series as the present leaps, approximately instantaneously, from one time-atom (which then becomes past) to the next (empty) atom in the future direction of the series. Objective becoming consists in macro-content emerging from meso-content.

The *B*-scale, on the contrary, emerges directly from a spacetime that is devoid of material content. This is the scientific scale of instants as serially ordered by the earlier than relation. Instants, being aspects of contentless spacetime points, are themselves devoid of content. Thus, there is no (scientific) *B*-series at the micro-scale of time. It is important to note that there is no necessity for content to emerge (initially at the meso-scale), for, since there are solutions to the Einstein field equations in which spacetime is 'empty' of matter, GR allows

worlds without content. In such worlds there can still be a pure (empty) time of instants ordered as a *B*-scale, with emergent time-atoms covering the instants. However, as these atoms would have no content, there is no *B*-series (which can only be formed by the conjunction of *B*-scale and content) from which an *A*-scale could emerge. Thus, though there can be both scientific (micro) and notional (meso and macro) time in such worlds, there cannot be past, present, or future. In other words, pure time does not pass.

In our world, however, there is indeed matter as content; and so there exist individual time-atoms whose internal structure ensures that their content is directly arranged according to the earlier than relation. Thus, each such atom with content is its own *B*-series, that (as explained in 3.4.2) has anaemic change but no passage. Strictly speaking, these are the only *B*-series that exist. However, recall that, as aggregates, time-atoms form series at the macro-scale whose order is correlated with the earlier than relation. This order represents the micro-*B*-scale at the macro-scale, and so, when these macro-series have content at the meso-scale, they *may be said* to form a *B*-series. By providing the necessary emergence bases of meso-content and macro-time series, the existence of such (not strictly) macro-*B*-series allows the possibility of the emergence of *A*-series with past, present, and future positions in time, and hence of time's passing. Thus, although there can exist a *B*-scale without a corresponding *B*-series, for an *A*-scale to come into existence there must exist both strictly speaking meso-*B*-series and loosely speaking macro-*B*-series as its emergence bases. Of course, such 'loose speaking' just is the extremely useful *epistemic* re-entangling of the *A*- and *B*-series that was explained in 3.4.3.

There is an ongoing debate in analytic metaphysics concerning the structure of matter: whether it is 'atomic', consisting in partless particles, or 'gunky', being infinitely divisible. Since all contenders continue in the mode of *a priori* reasoning, Ross, Ladyman and Spurrett excoriate this debate on the grounds that it hasn't moved on from that between the pre-Socratic atomists (such as Democritus) and gunkists (such as Anaxagoras). To the contrary, they argue: "Precisely what physics has taught us is that matter in the sense of extended stuff is an emergent phenomenon that has no counterpart in fundamental ontology" (Ladyman *et al.* p. 20). In this chapter I argue that, in our world, emergence of matter occurs either synchronically or diachronically – depending on the scale at which it emerges. Thus, at the meso-scale of time the emergence is from earlier to later and therefore synchronic and non-

dynamic. Whereas at the macro-scale the emergence is from present to past (forming A-series) and so diachronic and dynamic. Before then, however, I want to show how the very notions of ‘empty’ spacetime and its corollary of empty or pure time that are central to the metaphysics of time as developed here may be underpinned by relativistic physics.

4.2 Matter as Ontologically Dependent on Spacetime

Dennis Lehmkuhl wrote an article called “Mass-Energy-Momentum: Only there Because of Spacetime?” that, in his own words, “is grist to the mill of certain structural realists, who think that there are no intrinsic properties whatsoever. . .” (Lehmkuhl 2011 p. 482). This section seeks to show how Lehmkuhl’s exposition of the relation of dependence of mass-energy-momentum on spacetime in relativistic field theory provides support to the metaphysical approach to time taken here. Lehmkuhl cogently argues that a general matter field Φ must have a mass-energy-momentum density tensor $T_{\mu\nu}$ associated with it, and that this tensor density is not viewed in the mathematical sense but that it represents a *physical* density. He further argues that this physical property is not an intrinsic property of matter but a relational property, and that matter having this property is solely due to its relation to (specifically metrical) spacetime structure. Importantly, he argues that, while matter is dependent upon spacetime in this way, there is no reciprocal dependence of spacetime on matter. This asymmetric dependence exhibits the ontological dependence of matter on spacetime.

This is opposed to Mach’s principle which is that the metric field of spacetime is completely constrained and determined by the energy tensor. However, both Einstein’s original gravitational field equations and the later ones (as modified by Einstein himself with the addition of a new cosmological constant λ so as to harmonise them with Mach’s principle) were shown to have non-trivial solutions *in vacuo*, i.e. when the mass-energy-momentum density tensor $T_{\mu\nu} = 0$. Thus, the general theory of relativity (GR) allows matter-free, ‘empty’, Minkowski spacetime as well as various other ‘empty’ spacetime solutions (Lehmkuhl 2011 pp. 455-456).

Lehmkuhl begins by noting how notions of the nature of matter, developed from Descartes as that which is extended and from Newton as that which has inertial mass, evolved to include

electromagnetic fields that have no inertial mass but do have energy and momentum. This inclusive notion of the properties of matter was brought out clearly in the special theory of relativity (SR) so that “it became sensible to regard possession of mass-energy-momentum as the property that qualifies a system as a material system above all else” (Lehmkuhl 2011 p. 458).

Hermann Minkowski first developed the notion of a second rank mass-energy-momentum density tensor $T_{\mu\nu}$ of the electromagnetic field in 4D relativistic electrodynamics, in which could be discerned pre-relativistic energy (current) and momentum (current) densities along with stress. Soon after, Max von Laue showed that of an (old-style) material system such as an extended body or a fluid, its stress and energy can also be viewed as components of a second rank mass-energy-momentum density tensor $T_{\mu\nu}$. It is important to note that the electromagnetic tensor and the (old-style) material tensor have different mathematical forms which represent physical differences. This then results in electromagnetic fields being included with (old-style) material systems as constituting matter in relativistic field theory. With this, the modern concept of a general matter field Φ was introduced so that any field associated with a mass-energy-momentum density tensor (or simply ‘energy tensor’) is seen as a matter field (Lehmkuhl 2011 p. 458-461). From this, Lehmkuhl continues:

But whereas mass density was represented by a simple scalar field in Newtonian physics, relativistic mass-energy-momentum density $T_{\mu\nu}$ is defined *in terms of* the fundamental matter fields associated with the material system. But this is not enough: energy tensors also depend on the metric field $g_{\mu\nu}$!
(Lehmkuhl 2011 p. 463, his emphasis)

He then demonstrates four different kinds of ‘definitional dependence’ and an additional ‘interpretational dependence’ of energy tensors on the spacetime metric. Due to their cumulative importance to this thesis, I briefly describe each one. The first concerns Lagrangian field theory, which derives the field equations – equations of motion – by employing the calculus of variations. A Lagrangian density L , which reveals the system’s dynamics, is assigned to the fields, and if the Lagrangian is known, then, with certain constraints on the variations of the matter fields in place, the equations of motion can be deduced by varying the fields. In general relativistic systems there are two kinds of fields – matter fields Φ and the metric (gravitational) field $g_{\mu\nu}$. Notably, it is not only on matter fields that Lagrangians for

material systems depend; they are also dependent on the metric field $g_{\mu\nu}$. However, the Lagrangian for the metric field itself depends on no other field. More than this, it is only through the dependence of matter Lagrangians on the metric field, Lehmkuhl writes, “that we can derive what *makes* us think of them as matter fields: an associated mass-energy-momentum tensor $T_{\mu\nu}$ ” (Lehmkuhl 2011 pp. 465-466, his emphasis).

This first kind of definitional dependence relation that matter fields Φ have to the metric field $g_{\mu\nu}$ in Lagrangian field theory is specifically that of *direct coupling*. Indirect coupling of fields is where the coupling is via an intermediate field. As there is no indirect coupling relation holding between a matter field and the metric field, there can be no intermediate fields between any matter field and the metric field. As Lehmkuhl notes:

[O]nly *direct* coupling of a matter field Φ is a *necessary* condition to define an energy tensor for this field. For example, imagine the matter Lagrangian were $L_M = L_{M1}(g_{\mu\nu}, F_{\mu\nu}) + L_{M2}(\phi, F_{\mu\nu})$, [where $F_{\mu\nu}$ is the electromagnetic field and ϕ is the scalar field] i.e. we have direct coupling of the matter fields ϕ and $F_{\mu\nu}$ to each other, direct coupling of $F_{\mu\nu}$ to the metric field $g_{\mu\nu}$, but only indirect coupling of ϕ to the metric. In this case, the variational derivative of L_M with respect to $g_{\mu\nu}$ gives *the same* energy tensor as if L_M had been identical to $L_{M1}(g_{\mu\nu}, F_{\mu\nu})$. In other words, we would get the energy tensor of only the electromagnetic field, for the lack of direct coupling between $g_{\mu\nu}$ and ϕ stops ϕ from having mass-energy-momentum. Thus, *direct coupling* between the metric field and the fields representing a material system results in the latter having an energy tensor! (Lehmkuhl 2011 p. 468, his emphasis)

However, Lehmkuhl recognises that not every system can (yet) be given a Lagrangian formulation, so he moves on to a second definitional dependence that is independent of that formulation. This is dependence on the metric at the level of the matter fields themselves. The argument here is that there are cases in which the very formation of the energy tensor of a material system requires that the matter fields possess certain properties, and that these matter fields can only possess the properties in question if either conformal or metric spacetime structure, or both, is in place. For instance, all kinds of fluids’ energy tensors need certain kinds of velocity vectors – and such vectors need conformal and/or metric structure. Concerning these different structures, Lehmkuhl writes that “metric structure means that spacetime is endowed with a unique metric tensor field $g_{\mu\nu}$, conformal structure demands

only that it is endowed with an *equivalence class* $[g_{\mu\nu}]$ of such metrics” (Lehmkuhl 2011 p. 471, his emphasis).

As examples, Lehmkuhl takes the simplest fluid systems: ‘normal dust’, representing a batch of non-colliding particles, and ‘null dust’ that represents a collection of light rays that do not directly interact. The energy tensor of both includes a velocity vector. Normal dust requires a velocity vector that is time-like, so that it represents material particles moving at less than the speed of light; null dust on the other hand requires a velocity vector that is light-like – as it represents objects (light rays) moving at the speed of light. However, distinguishing time-like and light-like velocity vectors as such, requires that spacetime possesses (at least) conformal structure in the case of null dust and metric structure in the normal dust case. It being the light-cones of conformal structure that lets us distinguish time-like (as well as light-like and space-like) curves in the first instance, conformal structure suffices to define the energy tensor for null dust. However, in the case of normal dust velocity vectors are normalised, and this requires a metric. Metric structure always has conformal structure but further allows a unique length to be assigned to a curve or vector. Similarly, for the matter fields of more complex material systems to possess the required properties, their energy tensors often need metric and not only conformal structure (Lehmkuhl 2011 pp. 471-472).

A third kind of definitional dependence is at the level of conditions of the energy tensor itself. There are two conditions referred to and both are required to be fulfilled for any system to qualify as an actual material system. The first, ‘weak energy condition’, is that in relativistic field theory, for any observer the mass-energy density must be non-negative in any frame of reference. The second, the ‘conservation condition’, is that mass-energy-momentum is only transferrable and can be neither created nor destroyed. Lehmkuhl shows that the first condition not only needs a conformal structure to spacetime but cannot be formulated without metric structure. He argues that the second condition needs a uniquely defined metric for it to hold (Lehmkuhl 2011 pp. 473-474).

Fourth is an abstract definitional dependence in that, in the most abstract manner, we view the energy tensor as a map from pairs of unit time-like vectors to energy densities, $T : T_pM \times T_pM \rightarrow \Theta$. Here T_pM is the tangent space of a future-directed unit time-like vector at a given point of spacetime; Θ is the set of all possible mass-energy densities. The vector needs to be time-like in order to represent the motion of an observer at less than the speed of light. Also,

to allow us to distinguish observers having various states of motion, the time-like vector must be of definite magnitude. Again, in order to define the vector as time-like only conformal structure is needed; however, metric structure is needed to determine its length. Lehmkuhl explains:

This is where a definitional dependence of $T_{\mu\nu}$ on metric structure comes in yet again, this time in as general a fashion as possible. If we did not have a metric tensor field $g_{\mu\nu}$, then the map $T : T_pM \times T_pM \rightarrow \Theta$ would not allow us to distinguish between the mass-energy density as measured by different observers. One could say that we need *abstract definitional dependence* of $T_{\mu\nu}$ on $g_{\mu\nu}$ if we do not want to have to give up pursuing relativity theory altogether!
(Lehmkuhl 2001 p. 475, his emphasis)

In addition to these four definitional dependence relations, Lehmkuhl identifies a fifth kind of dependence of tensor fields on the metric field which he terms 'interpretational dependence'. This dependence is demonstrated by the fact that to even interpret tensor fields as representing physical densities we need a metric field. The only way we can make sense of $T_{\mu\nu}$ as a *density* is if we speak of density in a specific volume. For, without a volume element, we could neither speak of different amounts of mass-energy being in different parts of a system nor even compare different material systems by the amounts of mass-energy-momentum they possess. Lehmkuhl notes that it is only with the integration of density over volume that the amount of mass-energy-momentum of a material system is obtained, and crucially it is only through a metric tensor that the natural volume element of spacetime is defined (Lehmkuhl 2011 p. 475). After presenting the case for the dependence of energy tensors on the metric field in these five ways, Lehmkuhl continues:

I pointed out that the only thing that would really answer the question of which was more fundamental, matter or spacetime structure, would be if one was a requirement for the existence of the other but not vice versa. But the tensor field that is supposed to represent *the* main properties of matter, the mass-energy-momentum tensor $T_{\mu\nu}$ is a non-fundamental field, *and* it does require *both* the metric field $g_{\mu\nu}$ and the matter fields Φ in order to have some of its crucial properties.
(Lehmkuhl 2011 p. 477, his emphasis)

In a detour into metaphysics Lehmkuhl discusses what it is for an object to have properties, whether essentially or accidentally. Accidental properties are those properties possessed by an object so that were it to lose them the object would still exist. Whereas properties that an

object must possess in order to exist are essential properties. He further notes concerning essential properties that they need not be fundamental properties, which is important due to mass-energy-momentum density not being a fundamental property. For he argues that, in relativity theory, all the objects we think of as material – electromagnetic fields, particles, extended bodies, and fluids – have their properties encoded by mass-energy-momentum density tensors $T_{\mu\nu}$. Thus, to qualify as a material object, an object must have mass-energy-momentum, i.e. as an essential property. And so Lehmkuhl concludes: “An object might lack the property $T_{\mu\nu}$ and still exist – but it cannot lack $T_{\mu\nu}$ and still count as a *material* object” (Lehmkuhl 2011 p. 462, his emphasis).

When this essential, but non-fundamental, property of matter is seen to be dependent on spacetime, without spacetime being dependent on it, then this lends support to core ideas utilised by this thesis – that matter is emergent and that its emergence depends on spacetime. In other words, matter is ontologically dependent on spacetime. From the asymmetric dependence on its relation to spacetime, Lehmkuhl argues that “the energy tensor $T_{\mu\nu}$ must be seen as corresponding to an *extrinsic* property of material systems” (Lehmkuhl 2011 p. 478, his emphasis), and in doing so makes explicit how his article is indeed grist to the mill of the structural realist.

The claim of the ontological priority of spacetime over matter lends support to the argument that the time that emerges from an ‘empty’ spacetime can itself be either without content (pure) or with content (impure). In turn, this allows for emergent matter to exist in a temporal world either solely at the meso-scale of time having anaemic change, or to additionally exist (and become) at the macro-scale while undergoing robust change.

Of course, I happily acknowledge that these arguments will fail to sway those, such as Julian Barbour, who take the opposite view concerning Mach’s principle. Thus, Barbour writes in his fascinating book *The End of Time*:

In my opinion, general relativity is actually as Machian as it could be. What is more, it is the Machian structure that has such dramatic consequences when one tries to reconcile the theory with quantum mechanics. If, as I believe, the quantum universe is timeless, it is so because of the Machian structure of general relativity.
(Barbour 2000 pp. 66-67)

As his title shows, Barbour's quest is opposite to mine. For him, time is an illusion that he seeks to explain away.

4.3 Content at the Macro-Scale of Time

4.3.1 Content as Particles in the 'Quantum Realm'

It is important to note straightaway that the microscopic realm of standard quantum mechanics (QM) is not situated at the micro-scale of time, which ought not be surprising as I have repeatedly said that instants have no content. However, nor are elementary particles found at the meso-scale. In this subsection, I argue that microscopic particles that are commonly thought of as belonging to the 'quantum realm' are nonetheless situated wholly at the macro-scale of time. As argued in 3.4.1, macro-composition is a dynamic, diachronic process that progresses by (time-)atomic leaps along a series of macro-durations and so belongs to the A-series. Thus, even elementary particles have a past.

Quantum mechanics may be thought of as essentially a mathematical formalism that can be interpreted in various physical ways – though this is disputed by such as David Wallace (Wallace 2012) and David Deutsch (Deutsch 2011) for both of whom Everettianism is not an interpretation but is to be found within the formalism itself. The structuralist interpretation of the elementary particles of QM as presented in this subsection is due to Steven French.

Recall from 1.3 that the structure of the world is inherently modal and that both French and Ladyman take as modal the laws and symmetries of physics. French maintains that "law statements express the network of relations, 'held together' by the symmetry principles which represent what is invariant in the network" (French 2014 p. 264). Symmetry principles can be viewed either as constraints on laws or as by-products of laws. However, there is a third view favoured by French which is "the Cassirerian line that there is a kind of 'reciprocal interweaving and bonding' between laws and symmetries and that it is this that yields those entities formerly known as objects" (French 2014 p. 264). French shows how laws and symmetries in fundamental physics result in the constitution of kinds of elementary particles thus:

Kinds of (putative) objects are given to us by the relevant symmetries in terms of what Chakravarty calls 'sociable' clusters of properties. Thus, beginning with the fundamental (or close to fundamental) kinds associated with quantum statistics, namely bosons and fermions, this 'natural' distinction is cashed out structurally, in terms of the symmetry features of the relevant wave-functions. These are encoded group-theoretically in the principle of Permutation Invariance (PI) [which] might be conceived as a kind of initial condition, imposed on the structure of Hilbert space, or as a consequence of global Hamiltonian symmetry given the group structure of the particle permutations.

(French 2014 pp. 264-265)

This Permutation Invariance is one of three Symmetries embraced by the Standard Model of particle physics. A second is that of Minkowski spacetime whereby properties such as mass, charge and spin are conferred upon bosons and fermions via the symmetries of Minkowski spacetime that are associated with the Poincaré group. This both challenges the metaphysical view that such properties are 'intrinsic' (French 2014 p. 265) and reinforces Lehmkuhl's argument for the dependence of matter on spacetime. From this symmetry, Eugene Wigner showed that all elementary particles can be classified according to their mass and spin. A third symmetry is gauge symmetry, which is an expression of the way in which the Lagrangian of a system, which reveals the system's dynamics – and as such is an important part of Lehmkuhl's case, is invariant under a continuous group of local transformations. Concerning this symmetry French writes:

The generator of this group of transformations represents a field and when such a field is quantised, we get certain gauge bosons that 'carry' the interaction. Thus in the case of electrodynamics, the relevant gauge symmetry group associated with the property of charge is $U(1)$ and the requirement of gauge invariance yields the photon. Thus, particles like the photon also 'drop out' of the imposition of this symmetry.

(French 2019 p. 164)

Thus, the properties of elementary particles are viewed as resulting from the modal structure of the world as found in the reciprocal interweaving and bonding between the laws and symmetries of physics. Indeed, as French insists, "one cannot attribute the properties without attributing the laws and symmetries" (French 2014 p. 275).

Modality inherent in structure at this scale is further teased out by French. Permutation Invariance, in addition to being central to the kind distinction of bosons and fermions, also

encodes “all the possible kinds of particles (at this level of the kinds hierarchy)” (French 2014 p. 265). This is seen in the particle statistics that arise from the action of the permutation group on Hilbert space. The resulting division gives sub-spaces with their corresponding irreducible representations. These representations of the group include not only the symmetric bosonic and anti-symmetric fermionic representations but also large numbers of paraparticle representations. It is precisely in the paraparticle representations that “the presence of possibility lies” (French 2014 p. 265). Out of all these possible particle kinds, it seems that only bosons and fermions are actualised in our world.

Modality and symmetry are also intertwined in spontaneous symmetry breaking (SSB). Katherine Brading, Elena Castellani, and Nicholas Teh illustrate SSB by using an example from classical physics. They ask us to consider

a linear vertical stick with a compression force applied on the top and directed along its axis. The physical description is obviously invariant for all rotations around the axis. As long as the applied force is mild enough, the stick does not bend and the equilibrium configuration (the lowest energy configuration) is invariant under this symmetry. When the force reaches a critical value, the symmetric equilibrium configuration becomes unstable and an infinite number of equivalent lowest energy stable states appear, which are no longer rotationally symmetric but are related to each other by rotation. The actual breaking of the symmetry may then easily occur by effect of a (however small) external asymmetric cause, and the stick bends until it reaches one of the infinite possible stable asymmetric equilibrium configurations. (Brading *et al.* 2017)

This example of SSB describes a physical system that displays both a symmetrical state (the vertical stick) and an asymmetrical state (the collapsed stick). In this way, “SSB allows symmetric theories to describe asymmetric reality. In short, SSB provides a way of understanding the complexity of nature without renouncing fundamental symmetries” (Brading *et al.* 2017). As French notes, the breaking of symmetry need not mean that symmetry is lost. Instead, it can be understood as a phenomenon that results in a ‘lower’ symmetry than the unbroken symmetry (French 2014 p. 313). This approach brings out the modal aspect of SSB. Referring to the example of the compressed vertical stick French writes that

we need to consider the ‘possibility space’ covered by all the post-collapse orientations of the stick in our explanation. From the SSB perspective . . . the

representations represent the post-break situation, and the symmetry – which the structuralist will want to focus on – is preserved across all of these possibilities.
(French 2014 p. 319)

The actuality of the phenomenon of the stick collapsing thus emerges from these infinite possibilities. Returning to the scale of elementary particles, the actual particles ‘observed’ in our world – bosons and fermions – may be understood as emerging through SSB alongside the other irreducible paraparticle representations that remain as mere possibilities. Together, they maintain symmetry at a ‘lower’ level.

SSB also helps us understand how mass arises in our world. Arianna Borrelli quotes several examples from textbooks whereby physicists explain how particles gain mass through the spontaneous breakdown of electroweak symmetry (Borrelli 2019 Section 6). She notes that they all “describe how massless particles are transformed into massive ones in a time-based process which is characterised as a “mechanism”” (Borrelli 2019 Section 6). Physicists call this specific example of spontaneous symmetry breaking the Higgs mechanism or Higgs phenomenon. Borrelli concludes from a comparison of these quotes that

although the wording may vary, all quoted statements convey the same message: masses are not an inborn, invariable property of particles, but are rather the result of a “generation” going hand in hand with a spontaneous breakdown of gauge symmetry. The whole terminology is time-based: symmetry is not already broken, but breaks down, mass is generated or acquired, and massless particles disappear or are eaten by other particles.
(Borrelli 2019 Section 6)

Borrelli characterises her investigation into SSB as ‘historical-epistemological’, and explicitly dissociates it from ontology. Thus, she writes that “spontaneous symmetry breaking provides a ‘growing explanation’ of particle masses, because it relates how they emerge in a (fictive or real) time” (Borrelli 2019 Section 1). However, I end this subsection by arguing from an ontological point of view that the emergence associated with instances of SSB occurs in (very) real time.

Up to now, I have discussed emergence of particle kinds and of mass: we still need to understand the emergence of particles as ‘individual objects’. This is done by introducing “observable quantities such as position and momentum and thus move from kinds to

individual objects by supplementing the group-theoretic account” (French 2014 p. 158). In other words, ‘individuation’ of particles as ‘objects’ is via their spatiotemporal locations. Importantly, spatiotemporal location is not just a means to identify (or re-identify) an individual particle – it is part of the essential properties that *constitute* the particle as an ‘individual’.

French’s putative ‘individual objects’ here – ‘individual’ bosons and fermions as nodes of structure – are viewed as real patterns in the ontology of rainforest realism. Thus, Ladyman and Ross can write concerning the question: are there really protons?

[T]he answer is ‘Yes’, because theories in which protons are elements characterize real structure; but it does not follow from this that the world is partly composed out of individual pieces that intrinsically bear properties corresponding to predicates of the word ‘proton’ as it occurs in mathematical physics.

(Ladyman and Ross 2013 p. 127)

Thus, the elementary particles of the Standard Model are real patterns (or nodes of structure) that have no intrinsic properties – which fully agrees with Lehmkuh’s analysis in the previous section. And in further agreement with Lehmkuhl, these particles, with their extrinsic and essential properties, are dependent on spacetime for their existence. However, they exist not ‘in’ scientific spacetime but in notional time and space, which are themselves emergent from spacetime.

In this way I offer an addition to French’s argument and claim that the ‘interweaving and bonding’ of symmetries and laws *at this scale*, which results in ‘observable’ content as individual particles, is a dynamic, diachronic process that occurs at the macro-scale of time. In other words, the dynamic structure that is ‘observed’ as individual particles is emergent structure that is composed as content emerges in the present and moves into the past.

4.3.2 Content as Material Objects in the ‘Classical Realm’

The first thing to note is that there is no sharp distinction between the quantum and classical worlds. Lars Q. English writes: “Usually, the quantum world is confined to scales substantially below a micrometer (the size of a typical bacteria)” (English 2017 p. 23). However, this is after informing us that the suspended 10 kg mirrors that were used to detect gravitational waves,

when cooled to near absolute zero, displayed quantum behaviour. I argue that this vague boundary between the so-called 'quantum scale' and the 'classical scale' is at least partly due to both microscopic and macroscopic objects being found at the same ontic (macro-)scale of time.

Although populating the same ontic scale of time, microscopic and macroscopic objects are still distinguished by the different length scales of macro time (as well as the different length scales of space) and hence by different energy scales at which they exist. There exist no sharp boundaries between these 'internal' scales that can clearly separate objects ontologically. Nevertheless, however vague they may be, there are still boundaries that do allow us to differentiate such objects – as real patterns. Thus, Ross, Ladyman, and Collier write:

[W]e are sanguine about ontological vagueness in the sense that . . . we think it makes no sense to ask questions about cats over very short timescales or about mountains over very short-length scales. There is no fact of the matter about the exact boundary of Mount Everest because it is not a real pattern at all length scales. (Ladyman *et al.* 2007 pp. 253-254)

Of course, the corollary to this is that asking questions concerning cats and mountains does make sense when referring to the scales at which they (as real patterns) exist. And so, when we combine this notion with the quote from Ladyman and Ross at the end of the previous subsection, we understand how neither cats nor mountains – nor any other macroscopic objects – can be instantaneous mereological compositions from microscopic particles. For, of course, such particles themselves only exist – are being composed – dynamically and diachronically. Again, this just is an expression of the scale relativity of ontology. We saw in 1.4 how composition is a dynamic, diachronic process so that “in science the part/whole relation is shorthand for a process” (Ladyman 2017 p. 157).

When it comes to the emergence of macroscopic objects, we must investigate the quantum/classical transition. However, I leave this to the next chapter. For now, I discuss the emergence of macroscopic objects (or properties) from microscopic objects (or properties) in relation to condensed-matter physics. This is how English describes his own field of condensed-matter physics:

Whereas elementary particle physics is concerned only with the “parts”, meaning with the smallest constituents of matter, condensed-matter physics wrestles with both “parts” and “whole”, with both atoms and their aggregation into macroscopic matter. It looks in detail at phase transitions where matter reorganizes itself on the macro-scale and in the process redefines the relations between the constituent parts and often even of their essential nature.

(English 2017 p. 64)

English shows how at critical points during these phase transitions in such varied systems as ferromagnets, fluids, super-conductors, and metal alloys – that have widely differing micro-components – the systems exhibit the same macro-behaviour (English 2017 p. 86-91). We can compare for instance the phase transition in the gas sulphur hexafluoride (SF_6) with that of magnetism in iron.

When a pressure cell with a viewing port is gradually filled with SF_6 then the rising pressure will reach the threshold for condensation at which droplets of liquid SF_6 can be seen falling to the floor of the cell. When the content is half liquid and half gas the supply of gas is cut off and the cell sealed. The cell is then heated so that the vapour pressure increases until the substance goes completely black. This is known as critical opalescence and shows that the critical point has been reached at which the distinction between liquid and gas has broken down. When the critical point has been passed the blackness clears and the line between liquid and gas has disappeared, as the transition temperature has been exceeded. The phase transition is demonstrated by the absence of any such dividing line.

The explanation of blackness is the interesting part. Before the critical point is reached, bubbles can be seen to form in both the liquid and the gas. In the liquid are gas bubbles, in the gas the bubbles are droplets of liquid. When these bubbles remain quite large, they allow light to pass through the substance. However, bubbles of many different sizes start to develop together as the critical temperature draws near. Now, in general, when waves interact with objects or perturbations on the order of their wavelength then the waves are scattered. This happens here with light and the bubbles, so that when the bubbles – as fluctuations in density – are at a scale on the order of the wavelength of light then the light is scattered by the bubbles. Thus, the blackness, being due to the scattering of all wavelengths (or colours) of light, shows that there are density fluctuations at all length scales. English goes on to write concerning this:

In the lingo of the field, the correlation length [i.e. the average distance over which the behaviour of bubbles in one degree of freedom or microscopic variable is correlated] of the fluid/gas goes to infinity at the critical temperature. This is technically not correct, as the sample is not infinite. But compared to the separation of atoms in the liquid it might as well be considered infinite. . . So another way to think of it is to say that fluctuations range from the atomic scale all the way to the size of the sample (here, the cell size).
(English 2017 p. 89)

This 'going to infinity' is therefore a mathematical idealisation that is associated with the thermodynamic limit – i.e. a system's number of particles approaches infinity. The idealisation "is essential for the explanation", Robert W. Batterman informs us,

because for a finite number of particles the statistical mechanical analogs of the thermodynamic functions cannot exhibit the nonanalytic behavior necessary to represent the qualitatively distinct behaviors we observe.
(Batterman 2011 p. 1037)

In the case of ferromagnets the phase transition occurs at precisely 1043 Kelvin (approximately 1418° F), which is known as the Curie temperature. Thus, when a piece of iron is heated to this temperature it stops being a magnet. The iron remains a solid throughout this transition – with the same crystalline structure – so that, unlike in the SF₆ case, the loss of magnetism is not due to any sort of bubbling; rather, it is due to the change in orientation of electron spins. When the iron is a magnet there is alignment of spins. However, at the phase transition, just like in the SF₆ case, there are again fluctuations – though here it happens to spin orientation. Importantly, the correlation length again goes to infinity with these spin fluctuations occurring at all length scales. English emphasises the strangeness of this situation:

If I went in and physically manipulated one particular spin (on one atom in the lattice), perhaps wiggling it back and forth, I cannot say that the effect would be confined to just a certain vicinity around that spin. Even though spins can physically interact with other spins only within close range (spin interactions extend only to nearest neighbors and perhaps to next-nearest neighbors), nevertheless my little manipulation would be felt as far away as you want to consider – as far as a 100 million spin sites away. My little jigging would be transmitted down the line from spin to spin, all the way out without diminishing. But only at the critical temperature.
(English 2017 p. 90)

All phase transitions, no matter the underlying micro-components, have this going off to infinity (or divergence of the correlation length) in common. Through experiment there were discovered constants – dimensionless numbers called ‘critical exponents’ – that characterise the behaviour of systems as they approach their own critical points. Different types of quantities in phase transitions have their own critical exponents that are denoted by Greek letters. The surprising thing is that in both the liquid/gas case and the magnet case the critical exponent β is found to be the same, which is 0.33. Also, many other phase transitions such as order-disorder in other systems like alloys have this same 0.33 for its β constant. After calling this “weird”, English goes on to write concerning these same systems:

Not only that, but the other critical exponents also mysteriously match up. For instance, the constant ν which described how fast the correlation length diverges was measured at 0.63 for phase transitions in a whole range of disparate systems. Physicists knew this couldn’t be a coincidence, and they termed the phenomenon *universality*. Not all systems undergoing a phase transition share the same set of critical exponents, but there are only a small number of “variation on the theme” – a few sets of values also called *universality classes*.
(English 2017 p.91, his emphasis)

Batterman finds that there are two general features in this universality in physics. One is that details of micro-structure are not relevant to descriptions of the behaviour of the macro-system. The other is that many diverse systems with different micro-structures share the same critical exponent because their behaviours are identical. From this he argues that, since these features are found in many examples of what in philosophy is known as multiple realisability, universality can be viewed as an instance of multiple realisability (Batterman 2000 p. 123).

The universality (multiple realisability) of phase transition, being experimentally established, is held to be non-reductively emergent by both physicist English and philosopher Batterman and to be physically explicable by renormalisation group (RG) theory. As the correlation length diverges, the large number of microscopics, or degrees of freedom, makes calculations intractable. Employing the RG makes them tractable. This is done by reducing the number of parameters through coarse-graining and preserving the macroscopic behaviour by renormalising. This requires transforming the intractable problem into an analysis of the topological structure of the space of Hamiltonians. Thus, Batterman writes:

One introduces a transformation on this space that changes an initial physical Hamiltonian describing a real system into another Hamiltonian in the space. The transformation preserves, to some extent, the form of the original Hamiltonian so that when the thermodynamic parameters are properly adjusted (renormalized) the new renormalized Hamiltonian describes a system exhibiting similar behaviour. Most importantly, however, the transformation effects a reduction in the number of coupled components or degrees of freedom within the correlation length.
(Batterman 2000 p. 127)

The initial problem becomes more tractable each time this renormalization group transformation is repeated. The sequence of Hamiltonians that results from such iteration is found to describe a trajectory in the space of Hamiltonians that terminates at a fixed point as the number of RG transformations goes to infinity. As mentioned previously, different types of physical systems (i.e. with different microstructures) share the same critical exponent and this is now explained by the trajectories of Hamiltonians in RG transformations ‘flowing’ towards the same fixed point at criticality. As English says, the “weird” fact that experimental observation reveals critical exponents with the same value being shared by systems with different microstructures or interaction laws “is now an actual prediction of the theory” (English 2017 p. 108). Meanwhile, Batterman further writes:

The RG type of analysis illuminates those physical features that *are* relevant for the upper level universal behavior, *and at the same time demonstrates that all of the other details which distinguish the systems from one another are irrelevant.*
(Batterman 2000 p. 128, his emphasis)

In other words, there is no question of the relation between the ‘lower’ and ‘upper level’ being that of supervenience. Thus, the importance of such a physical explanation of universality, for naturalised metaphysics in general and for rainforest realism in particular, is expressed by Ross, Ladyman, and Collier in this way:

The existence of the physical explanations for the universalities must, for a naturalist, block any temptation to try to reduce away the emergent kinds and properties through the introduction of ‘metaphysical hidden variables’. Thus, by Batterman’s argument universalities are real patterns and his emergentism is ontological rather than merely epistemological. Now, the universalities on which he focuses would be invisible to inquirers who confined their attention to the scale on which microproperties (relative to them) are measured. Thus Batterman’s ‘emergentism’ . . . is a special case of scale relativity of ontology.
(Ladyman *et al.* 2007 p. 204)

According to R. B. Laughlin and David Pines such emergentism results in what they call 'protectorates'. A protectorate is "a stable state of matter whose generic low-energy properties are determined by a higher organizing principle and nothing else" (Laughlin and Pines 2000 p. 29). However, Batterman's description of protectorates, as "stable states of matter that are in effect decoupled and largely independent of physics at shorter length/higher energy scales" (Batterman 2010 p. 1040), better captures the notion as scale relativity of ontology.

Karen Crowther points out that the RG explanation of emergence is not dynamical. This lack could be overlooked in that a dynamical term such as 'flowing' is often used to describe the trajectory of Hamiltonians towards the same fixed point. As Crowther writes:

Although the RG is often said to "induce a flow" in the parameters of a system, this way of speaking is misleading, as the RG is not something that can properly be said to act. The parameters that "flow" are those whose values are seen to differ in the space of all Hamiltonians as we change (by hand) the energy at which we view the system.
(Crowther 2016 p. 119)

Thus, the RG allows us to explain real patterns at different scales but does not give a dynamical account of emergence itself. Margaret Morrison argues that such an account must look to symmetry breaking to be successful. She agrees with Batterman that RG "illustrates and explains the ontological and epistemic independence between different energy levels – the defining features of emergent phenomena" (Morrison 2012 p.158). However, realising that RG is not a dynamical account, she writes that "it does not give us the kind of physical dynamics required for the production of emergent phenomena. For that we need symmetry breaking and the accompanying phase transitions" (Morrison 2012 p.157).

Morrison, as an example, details the spontaneous symmetry breaking of electromagnetic gauge invariance that results in exact properties of superconductivity that are the same for all superconductors (Morrison 2012 pp. 151-156). She emphasises both the universality and the general principles that are important for emergence. Thus, she maintains that the exactness of the results "must follow from general principles rather than simply be derived using approximations" (Morrison 2012 p. 151). Here is how Morrison describes the

importance of symmetry breaking and phase transition to what I have called the dynamic, diachronic emergence of content as structure at the macro-scale of time:

I refer to symmetry breaking as a “structural/dynamical feature of physical systems” because of the way order and structure emerge as a result of the phase transitions associated with symmetry breaking. . . Spontaneous symmetry breaking (SSB) is manifest in, among other things, the acquisition of rigidity and the existence of low-energy excitations in condensed matter physics; superconductivity incorporates symmetry breaking via Cooper pairing as a basic feature in the Bardeen-Cooper-Schrieffer (BCS) theory. Particle masses in high-energy physics are also thought to be generated by SSB. In each of these cases we have dynamical processes that produce specific effects.

(Morrison 2012 pp. 149-150)

While agreeing with this, Crowther notes that both Morrison’s and Batterman’s conception of emergence is of limited scope as it applies only to critical phenomena. Their concept thus leaves out all non-critical thermodynamic phenomena – which Crowther is keen to classify as emergent. Thus, she widens its scope to include non-critical as well as critical systems so that “we can understand condensed matter physics as emergent from particle physics in general” (Crowther 2016 p. 120). Morrison and Batterman maintain that emergence is confined to critical systems, and further maintain that universality can only apply if there are several other examples of systems with different high-energy physics having the same (emergent) low-energy physics – as holds in the case of critical systems.

However, Crowther provides a modal argument that expands the scope of universality to include non-critical systems. In the case of non-critical systems, there may be no real examples of other systems with the same low-energy physics having different high-energy physics. And yet, Crowther writes:

Even though the observed low-energy physics is such that it would be consistent with a number of high-energy theories, it may well be that not all of these potential micro-theories actually correspond to existing systems. Hence, in many cases we have “unrealised” multiple-realizability; or, in other words, “universality”, but with only a single member of the universality class.

(Crowther 2016 p. 122)

The advantage of this modal approach is that, unlike those of Morrison and Batterman, any individual system (whether critical or non-critical) may be classified as emergent (Crowther

2016 p. 122). It also meshes nicely with French's modal approach to SSB as described in the previous subsection. Now, if we agree with Crowther that condensed-matter physics is indeed emergent from particle physics in general, then we can claim in RR terms that any 'universality', whether its universality class has several members or just a single member, is a real pattern. Hence, Crowther's 'emergence' here, just like Batterman's 'emergentism', is a case of scale relativity of ontology.

5. The Emergence of the Content of Time II

5.1 The Transition from Quantum to Classical

5.1.1 Environmental Decoherence and Superselection

The difficulty in explaining the transition from quantum to classical stems from the deterministic, linear (time-dependent) Schrödinger equation. With time evolution being linear, if any system with superpositions of possible states interacts with any other system then this system will itself evolve into a superposition of possible states. A quantum superposition is the combination of different wavefunctions. Experiment confirms this deterministic evolution of the wavefunction ψ . When it is assumed that the wavefunction ψ has universal application, that it can indeed describe every dynamical system, including macroscopic objects, then we ought to witness superpositions of states in our classical world. But, of course, we never do. We seem to live in a classical world where all measurements have unique outcomes; and this experience appears to contradict the QM description of the world.

The very notion of a transition from quantum to classical may be problematic for, as Wojciech H. Zurek writes, “there is no indication of a border between quantum and classical at which [the Schrödinger] Equation would fail” (Zurek 2002 p. 4). The universality of quantum theory seems to preclude there being a border across which there could be transition. Zurek goes on:

In the absence of a crisp criterion to distinguish between quantum and classical, an identification of the classical with the macroscopic has often been tentatively accepted. The inadequacy of this approach has become apparent as a result of relatively recent developments: a cryogenic version of the Weber bar – a gravity-wave detector – must be treated as a quantum harmonic oscillator even though it may weigh a ton . . .

(Zurek 2002 p. 4)

Niels Bohr famously provided his Copenhagen Interpretation as a description of how a unique outcome emerges from the multitude of possible states. Concerning this interpretation, Zurek tells us that Bohr “insisted that a classical apparatus is necessary to carry out measurements.

Thus, quantum theory was not to be universal. The key feature of the Copenhagen interpretation is the dividing line between quantum and classical” (Zurek 2002 p. 4). However, Kristian Camilleri and Maximilian Schlosshauer provide a cogent argument against such a reading of Bohr that I discuss in the next subsection on the quantum measurement problem. First, though, I examine the importance of environmental decoherence and superselection to the problem of the transition from quantum to classical.

In QM, interference is the degree of coherence that holds together states in superposition; and so decoherence is that which ‘separates’ them by reducing the level of interference. Zurek claims that environmental decoherence is key to the transition from quantum to classical:

Macroscopic systems are never isolated from their environments. Therefore . . . they should not be expected to follow Schrödinger’s equation, which is applicable to a closed system. As a result, systems usually regarded as classical suffer (or benefit) from the natural loss of quantum coherence, which “leaks out” into the environment.
(Zurek 2002 p. 5)

A coherent, or pure, state is describable only by QM. A mixed state includes both quantum and statistical mechanics (as exemplified by Schrödinger’s notorious cat thought experiment). Through the process of decoherence a coherent state becomes a mixed state. Schlosshauer informs us that though the decoherence process is one of local interaction, “the *states* that can be generated by these local interactions are distinctly *nonlocal*” (Schlosshauer 2007 p. 4, his emphasis). In play here is quantum entanglement, in which two systems are entangled to the extent that they can be described only by a single quantum state. The quantum correlations exhibited by the entangled state between the two original systems (now subsystems) can display physical properties that were absent from either of the individual systems. In this case, physical properties at least partly reside in the nonlocal quantum correlations. From this Schlosshauer proceeds:

Thus, in the quantum picture, the (local) interactions between a system and its environment now have the power to play a much greater role than in classical physics. They will typically lead to entanglement between the two interacting partners and thus change the nature of the object itself, in the sense of fundamentally altering what we may observe at the level of the system . . . [T]he coupling to the environment now *defines* the observable physical properties of the

system. At the same time, quantum *coherence*, a measure for the “quantumness” of the system, is delocalized into the entangled system-environment state, which effectively removes it from our observation.
(Schlosshauer 2007 p. 5, his emphasis)

The import of this practically irreversible process of environmental decoherence is that classical properties and behaviours that we observe all around us are a result of entanglement – i.e. a quantum-mechanical phenomenon. Thus, Schlosshauer writes: “We may therefore understand our deeply rooted notion of “classicality” as an *emergent concept*, as something that is not contradicted but rather justified by the peculiar features of quantum mechanics” (Schlosshauer 2007 p.9, his emphasis).

Decoherence is not the only important consequence of a quantum system’s interaction with the environment; another is environment-induced superselection. This concerns the preferred basis question: How are the states that result from the suppression of interference selected from the range of possible bases? Schlosshauer, following Zurek, answers:

The *preferred states* of the system emerge dynamically as those states that are the least sensitive, or the most *robust*, to the interaction with the environment, in the sense that they become least entangled with the environment in the course of the evolution and are thus most immune to decoherence. This is commonly referred to as the *stability criterion* for the selection of preferred states . . .
(Schlosshauer 2007 p.73, his emphasis)

Thus, the physical quantities of a quantum system that can be observed are limited, or ‘selected’, by the interaction with the environment. With robustness being integral to states in classical physics, preferred, or pointer, states represent quasiclassical states. These quasiclassical states emerge dynamically through the quantum system’s interaction with the environment. Schlosshauer writes that “environment-induced superselection represents *effective* superselection rules that dynamically emerge from the (structure of the) system-environment interaction” (Schlosshauer 2007 p. 73, his emphasis). Guido Bacciagoluppi explains these quantum effective superselection rules by using an analogy with classical superselection rules thus:

The concept of a (strict) superselection rule means that there are some observables – called classical in technical terminology – that commute with all observables. . . Intuitively, these observables are infinitely robust, since no possible interaction can

disturb them (at least as long as the Hamiltonian is considered to be an observable). By an *effective* superselection rule one means, analogously, that certain observables (e.g. chirality) will not be disturbed by the interactions that actually take place. (Bacciagaluppi 2012 Section 1.1)

Among the limited few observable robust quasiclassical states are position and momentum. Importantly, these are, as explained in 4.3.1, the essential ‘classical’ observable properties that ‘individuate’ particles.

Decoherence is very much a process that happens over time. However, the time taken depends on the size of the system that is coupled to the environment. Thus, Crowther writes:

A large system comprising many degrees of freedom is more strongly coupled to its environment than a small system with fewer degrees of freedom, and so decoherence occurs much faster for larger systems. Since macroscopic objects (being systems with a large number of degrees of freedom) are difficult to isolate from their environments, decoherence tells us that the interference effects rapidly “leak” out as the system goes from being in a pure state to a mixed state with its environment. (Crowther 2016 p. 24)

Schlosshauer provides the following table of comparison between the estimates of decoherence timescales, in seconds, for the localisation (or suppression of spatial interference) of a 10^{-3} cm dust grain and of a large 10^{-6} cm molecule over the distances that are equal to their respective sizes (Schlosshauer 2007 p. 135):

<u>Environment</u>	<u>Dust grain</u>	<u>Large molecule</u>
Cosmic background radiation	1	10^{24}
Photons at room temperature	10^{-18}	10^6
Best laboratory vacuum	10^{-14}	10^{-2}
Air at normal pressure	10^{-31}	10^{-19}

This table illustrates three issues concerning decoherence. First, the bigger the system the faster the decoherence. Second, just how fast decoherence can be. Third, how the nature of the immediate environment affects the rate of decoherence. All of these have implications

for the scale relativity of ontology. To see this, let us return to Eddington's 'two tables' – the solid everyday table at which he sits, and the scientific table made up of mostly empty space and various particles. I repeat here the quote from Ross, Ladyman, and Collier concerning this claim, previously presented in 2.1:

The everyday table is probably a real pattern. Strictly speaking *there is no scientific table at all* because there is no single candidate aggregate of real microscopic patterns that is best suited to be the reductive base of the everyday table. We deny that everyday or special science real patterns must be mereological compositions of physical real patterns, and we deny the local supervenience of the table on a real pattern described by physics.

(Ladyman *et al.* 2007 p. 253, emphasis added)

Decoherence throws this counterclaim into sharp relief. The everyday, macroscopic, table – with its large number of degrees of freedom – will decohere at a vastly faster rate than the particles that allegedly make it up. Indeed, as we can see from Schlosshauer's table, even the dust that may 'lie on the surface' of an everyday table decoheres at a much faster rate than the largest of the molecules that allegedly make up that table. This fully supports Ladyman's and Ross's application of the scale relativity of ontology. At the spatiotemporal scale at which everyday tables exist there simply are no molecules, or even smaller particles, that can 'make up' such a table. Not only are such particles located at different spatial length-scales than everyday tables, but they are also situated at different temporal length-scales – although all these objects reside at the same ontic (i.e. macro-) scale of time.

5.1.2 The Quantum Measurement Problem

Schlosshauer informs us that the term 'measurement problem' was chosen "in the context of a quantum-mechanical description of a measuring apparatus interacting with a system" (Schlosshauer 2007 p. 49). He maintains that the problem has three parts, and so is better seen as measurement problems. These three problems are: of the preferred basis; of the non-observability of interference; and that of outcomes. He notes that the first two are operational and have been resolved within the standard formalism of QM through environmental superselection and decoherence respectively (as explained in the previous subsection). Thus, he writes that

many interactions between physical systems can be viewed as measurement-like interactions. For example, light scattering off an object carries away information about the position of the object, and it is in this sense that we thus may view these incident photons as a “measuring device”. Such ubiquitous measurement-like interactions lie at the heart of the explanation of the quantum-to-classical transition by means of decoherence.
(Schlosshauer 2007 p. 49)

By contrast, the problem of outcomes of measurement “is almost inextricably linked to the choice of a specific interpretation of quantum mechanics (which mostly boils down to a matter of personal preference)” (Schlosshauer 2007 p. 50). Of course, there are several interpretations of QM, with differing approaches to this measurement problem. These include various Copenhagen interpretations, relative-state (Everettian), modal, physical collapse theories, and Bohmian mechanics.

Each of these interpretations accounts for outcomes of measurement in various ways and while each is consistent with observation, as Wayne Myrvold writes:

Mere consistency, however, is not enough; the rules for connecting quantum theory with experimental results typically involve nontrivial (that is, not equal to zero or one) probabilities assigned to experimental outcomes. These calculated probabilities are confronted with empirical evidence in the form of statistical data from repeated experiments. . . [A]mong the major lines of approach, none is favoured in a straightforward way by the empirical evidence. If one is to make a decision as to which, if any, one should accept, it is to be made on other grounds.
(Myrvold 2016 Sect. 4.4)

And, as we have just seen, Schlosshauer claims that these grounds will be mostly those of personal preferences. These preferences concern each person’s metaphysical inclinations. And so, confronted with various consistent physical interpretations of the quantum formalism that are not ruled out by empirical evidence, any favouring of one interpretation over all others would usually be due to that interpretation having the best fit with prior metaphysical beliefs. Although, as mentioned in 4.3.1, Everettians such as Deutsch and Wallace deny that Everettianism is an interpretation and claim instead that it resides within the formalism itself. However, this claim is rejected by Ladyman and Ross, for even “the Everett interpretation, while not revisionary physics, is (naturalistic) *metaphysics*, in that it unifies theories

indispensable for predictive success, but contributes no novel predictions itself” (Ladyman and Ross 2013 p. 138, their emphasis).

Although Ladyman and Ross have previously claimed “that some form of Everettian QM is the most natural for us to adopt. . .”, in line with their strict version of naturalism and because no interpretation is yet globally empirically adequate, they still denied that *any* interpretation is “the last word in metaphysics” (Ladyman *et al.* 2007 p.181). However, they have since developed a rainforest realist interpretation that uses an Everettian multiverse interpretation as a foil. I discuss this later interpretation briefly in 5.1.3.

For now, I examine their challenge to the very context in which the measurement problem is framed – i.e. the description of the measuring apparatus in quantum-mechanical terms. Therein, the apparatus, due to the common belief that it is composed of very many quantum particles, is seen as a quantum state represented by a ket vector. Ladyman and Ross counter this notion by invoking scale relativity of ontology:

[O]n the view of higher-order ontology . . . there is no reason to regard the measuring device as something that exists at all from a microscopic perspective. We have also made clear our hostility to the idea that macroscopic objects are fundamentally made of microscopic ones. Hence, the application of the quantum formalism to macroscopic objects is not necessarily justified, especially if those objects are importantly different from microscopic objects, as indeed they are, in not being carefully isolated from the environment . . . Rather, [measuring devices] are real patterns and their states are legitimate posits of science in so far as they enable us to keep track of the phenomena.
(Ladyman *et al.* 2007 p. 182)

This may be viewed as a suggested dissolution of the measurement problem. (Some years later they write that, in practice, QM has been getting along “very successfully despite the lack of a viable solution to the measurement problem” (Ladyman and Ross 2013 p. 135)). However, we need to be careful with this approach. Firstly, there is the claim that an important difference between microscopic and macroscopic objects is that the latter are not carefully isolated from the environment. This describes experimental settings where care is indeed taken to isolate the microscopic object from the environment. However, the very fact that such care is required illustrates that the environment can (and does) interact also with the microscopic, and so isolation from the environment does not serve to differentiate

microscopic from macroscopic objects. (We saw in the previous subsection that what does differentiate microscopic from macroscopic objects is their differing *rates* of decoherence.) Secondly, the point that macroscopic objects are not isolated from the environment is an implicit acknowledgement that decoherence applies to them and, since decoherence is part of quantum formalism, this undermines the claim that applying this formalism to macroscopic objects is not necessarily justified.

In 4.3.2 the discussion concerned the emergence of macroscopic objects from microscopic objects in the context of condensed-matter physics. What concerns us here, however, is the emergence of the classical from the quantum. When examining the measurement problem, confusion of the separate notions of the quantum-to-classical transition and the microscopic-macroscopic transition can result from a failure to distinguish between ontological and epistemological approaches. Camilleri and Schlosshauer counter this source of confusion through their examination of Bohr's doctrine of classical concepts and its relation to the later development of environmental decoherence.

Camilleri and Schlosshauer contrast Bohr's with Heisenberg's views on the mathematical representation of the measurement process in which a dividing line is drawn between the measuring apparatus and the object being measured or observed. For Heisenberg this division was construed as a 'cut' between an object (the apparatus) "described in classical concepts" and an object (being observed) "whose behaviour is represented by a wave function" (Heisenberg 1952 p. 49). There is a widely held view that Bohr endorsed this description of the cut by Heisenberg. However, Camilleri and Schlosshauer return to Bohr's own writings and show that this is not the case. They note that in any construal such as Heisenberg's the problem arises of how two systems can interact when one is described by classical theory and the other is described by quantum theory – "given that such an interaction does not appear to be subsumed under either classical or quantum theory" (Camilleri and Schlosshauer 2015 p. 77). This problem was avoided by Bohr in his description of the cut. As Camilleri and Schlosshauer write:

Put simply, Bohr never described the measurement interaction between the quantum object and the apparatus as an interaction between an object described by a wave function in configuration space and a measuring instrument described by

classical dynamical laws in ordinary three-dimensional space. . . Bohr insisted that the concepts of classical physics must be used on *both* sides of the dividing line. (Camilleri and Schlosshauer 2015 p. 77, their emphasis)

It is worth emphasising that it is the *concepts* of classical physics that Bohr insists must be used on either side of the cut. Camilleri and Schlosshauer argue that this insistence was because “Bohr’s primary concern was to articulate an epistemology of experiment not an epistemology of quantum theory” (Camilleri and Schlosshauer 2015 pp. 74-75). In support, they quote this reply Bohr gave to Schrödinger’s request that he give his reasons for insisting on the need for classical terms to interpret any observations:

My emphasis of the point that the classical description of experiments is unavoidable amounts merely to *the seemingly obvious fact that the description of any measuring arrangements must, in an essential manner, involve the arrangement of the instruments in space and their functioning in time, if we shall be able to state anything at all about the phenomena.*
(Bohr 1996 p. 511, his emphasis)

Here, Bohr’s empirical need for classical concepts when describing quantum experiments is reminiscent of Whitehead’s empirical need for sets of extensive abstraction in order to make any sort of physical sense of the points and instants of mathematical physics. As for the results of quantum measurement, its empirical object (far from being Heisenberg’s wavefunction in configuration space) must be described classically. Thus, for Bohr,

the appropriate physical interpretation of the symbolic quantum-mechanical formalism amounts only to predictions, of determinate or statistical character, pertaining to individual phenomena appearing under conditions defined by classical physical concepts.
(Bohr 1949 p. 238)

Alongside the need for classical concepts to describe what lies on both sides of the cut, Bohr insisted that any interaction between such separate systems must further be described using concepts of classical physics (Camilleri and Schlosshauer 2015 p. 76). Such blanket need for classical concepts to describe experiments was insisted upon by Bohr even while he “acknowledged that measuring instruments, like all systems, macroscopic or microscopic, are strictly speaking subject to the laws of quantum mechanics” (Camilleri and Schlosshauer 2015

p. 79). This is because, for Bohr, the interaction between the apparatus and the object to be observed, when viewed quantum-mechanically, becomes paradoxical. This paradoxical situation is explained by Camilleri and Schlosshauer thus:

On the one hand, in order to observe something about an electron – say, its momentum – we must *assume* that the electron possesses an independent dynamical state (momentum), which is in principle distinguishable from the state of the instrument with which it interacts. On the other hand, such an interaction, if treated quantum-mechanically, destroys the separability of the object and the instrument, since the resulting entanglement between the two partners means that they must be described by a single composite nonseparable quantum state. (Camilleri and Schlosshauer 2015 pp. 75-76, their emphasis)

In other words, viewed quantum-mechanically there is no cut between two objects, instead there is interaction as entanglement; and such entanglement leads inexorably to John von Neumann's infinite regress. I come back to this chain of entanglement and the resulting paradoxical situation shortly.

Another important difference between Bohr and Heisenberg, brought out by Camilleri and Schlosshauer, is in their approaches to the movability of the cut. For Heisenberg, because the cut was between one object described in classical concepts and another object represented by a wave function, "there must, within certain limits, exist complete freedom in choosing the dividing line" (Heisenberg 1952 p. 49). Against the commonly held belief that Bohr held a similar view, Camilleri and Schlosshauer write:

In Bohr's view, once the aims of the experiment had been decided upon and the experimental apparatus has been set up accordingly, the "cut" was effectively fixed. It could not be moved around arbitrarily. To this extent, Bohr argued that the cut corresponded to something "objective" in the sense that the object-instrument distinction was essentially fixed by the *functional-epistemological* considerations dictated by the choice of the particular experimental arrangement. (Camilleri and Schlosshauer 2015 p. 78, their emphasis)

Taking this view together with Bohr's other view that classical concepts are needed on both sides of the cut leads Schlosshauer to conclude that "for Bohr the quantum-classical distinction did not exactly coincide with the object-instrument distinction, whereas this appears to have been precisely the case for Heisenberg" (Schlosshauer 2007 p. 335 n. 5). These *epistemological* views of Bohr, with the resultant decoupling of the quantum-classical

distinction from the object-instrument distinction, when taken with his *ontological* view that all systems are subject to the laws of quantum mechanics, do not conflict with von Neumann's chain of measurements. Unlike that of Bohr's, other Copenhagen interpretations postulate measurement instruments that are intrinsically classical and to which the laws of quantum mechanics do not apply. It was in reaction to these views that von Neumann set out to describe the quantum measurement interaction in solely quantum-mechanical terms (Schosshauer 2015 p. 51).

Von Neumann's ideal quantum measurement scheme treats not only the system being measured but also the measuring instrument (and ultimately the observer) as quantum mechanical. Therefore, if the system being measured is in a superposition of basis states then the linear time-dependent Schrödinger equation implies that any measuring device interacting with it will evolve into a state of superpositions. The result of interaction is then described as a system-instrument combination being in an entangled state. A second instrument used to measure this composite system suffers a similar fate to the first – it becomes entangled through interaction – thus forming a larger combination. In this way, with each interaction, the von Neumann chain gains added links with no end in sight. Furthermore, since any observer interacting with the entangled system will also become entangled according to this never-ending quantum-mechanical scheme, no measurement is ever completed.

This quantum state of lack of completion of measurement is known as 'premeasurement'. In turn the proposed actual completion of a measurement is termed 'objectification'. Objectification only occurs when an instrument indicates a definite eigenvalue. The problem is that premeasurement cannot conclude in the realisation of a completed measurement, for premeasurement precludes objectification. In response to this deficiency in QM, von Neumann introduced the 'projection postulate'. And so, in the standard interpretation of QM the projection, or collapse, postulate allows completion of measurement ('objectification') to occur via the eigenvalue-eigenstate link.

The physicist and Kantian structuralist Sunny Y. Auyang, informs us that "eigenvalues can be the direct result of experiments. The explicit stipulation of some quantities that can be measured justifies the name *observable*. . ." (Auyang 1995 p. 19, her emphasis). She describes completion thus:

Abstractly, the eigenvalues of an observable can be regarded as labels of the eigenstates, which are the axes of a coordinate system in the state space that enables us to determine definite amplitudes. Physically, the labels are realized in classical objects we can measure. How they are realized *no one knows*. . . Practically, an indicator is somehow triggered in measurements and experiments. (Auyang 1995 p.79, emphasis added)

However, such practical completion or ‘objectification’ as realised in classical objects evokes the quantum measurement problem, which is that quantum-mechanical explanations stop at ‘premeasurement’. Quantum theory cannot explain (or even recognise) completed measurement. Hence, the measurement problem is also called the ‘problem of objectification’. This grounds Bohr’s ‘paradoxical’ situation where both the system observed and the measuring device used are viewed as subject to the laws of QM, except that these very laws do not allow for any ‘cut’ to exist between (entangled) ‘separate objects’ in the first place. As shown above, Bohr avoided this problem by focussing on formulating an epistemology of experiment (rather than of quantum theory) that is concerned with the ‘practical’ part of the Auyang quote.

Recall that Bohr explained both how the ‘cut’ was fixed once an experiment’s apparatus was set up and how classical concepts must be used on both sides of that cut to make empirical sense of the experiment. Consequently, when the interaction at the heart of measurement is itself viewed classically then nothing appears paradoxical. Thus, in practice, there occurs ‘objectification’ as obtained outcome. Of course, successful practice in QM, combined with Bohr’s (I believe) successful epistemology of experiment, still leaves the ontological problem of objectification untouched by quantum theory. Before examining this problem from a metaphysical point of view within RR, I show how it may divide approaches within OSR itself.

5.1.3 The Quantum Measurement Problem and ‘the Collapse Problem’ in OSR

The ‘collapse’ referred to in the heading is not the putative ‘collapse of the wavefunction’ of standard quantum mechanics, but the threatened collapse of the physical into the mathematical that confronts ontic structural realism. French sardonically coined the label ‘the collapse problem’ to refer to this threat. He views it thus:

The argument, put briefly, is that if only the structure of mathematical theories is relevant to ontology in mathematics, and only structural aspects of the mathematical formalism of physical theories are relevant to ontology in physics, then there is nothing to distinguish physical and mathematical structure. Hence, the concern runs, the structural realist must conclude that the world is a mathematical structure.

(French 2014 p. 193)

Max Tegmark views this as unproblematic. He embraces this conclusion and advances his Mathematical Universe Hypothesis in support of the idea that the world just is a mathematical structure. He argues that “our external physical reality is a mathematical structure, which is by definition an abstract, immutable entity existing outside of space and time” (Tegmark 2015 p. 274). Following this, he notes that “change” and the “flow of time” are both “illusions” (Tegmark 2015 p. 276). He adheres to the Everettian multiverse interpretation of QM, in which all possible (measurement) outcomes are realised. In this interpretation, there is no measurement problem since the wavefunction never collapses and no add-ons from outside quantum theory are required. For Tegmark, the modal structure of a mathematical world is clearly displayed in a multiverse where whatever can happen does happen.

The opposite approach is to deny that physical structure collapses into mathematical structure and to not only accept that there is a measurement problem but to welcome its existence. This approach is described by Roland Omnès when writing

that the inability of the quantum theory to offer an explanation, a mechanism, or a cause for actualization is in some sense a mark of its achievement. This is because it would otherwise reduce reality to bare mathematics and would correspondingly suppress the existence of time.

(Omnès 1994 p. 494)

I should make clear that Tegmark denies only the existence of time’s passage and not of time *per se*. For him, time just is the fourth dimension of spacetime, and “[s]ince spacetime is static and unchanging, no parts of it can change their reality status, and all parts must be equally real” (Tegmark 2015 p. 276). Thus, he upholds the idea of a Block Universe. A Block Universe is precisely what Omnès questions; the notion of ‘time’ that Omnès is referring to is not the ‘fourth dimension of spacetime’ but is that of an A-series. This is made clear in the following

passage where he describes quantum measurement, or objectification, as being outside of quantum theory:

The existence of actual facts can be added to the [quantum] theory from outside as a supplementary condition issued from empirical observation. The structure of time must then be modified accordingly. Time must be split into a past, a present, and a future having very different qualities. Present and past are uniquely defined while the future must remain potential and subject to probabilistic expectations. This structure of time, so obvious from the standpoint of observation, turns out to be necessary from a theoretical standpoint.
(Omnès 1994 p 508)

As I have tried to show, one need not be an A-theorist of time to agree with Omnès here; anyone holding a theory of time that views the A-series as real can do so. However, I suspect few structural realists are willing to go down the route of embracing the reality of the A-series and of objective becoming. Equally, there are few structural realists willing to follow Tegmark down the Pythagorean route. Hence, most will be found somewhere between these two extremes of dealing with the ‘collapse problem’ – due to their rejection both of a wholly mathematical universe and of objective becoming. I end this section with a brief look at Ladyman’s and Ross’s proposed rainforest realist solution to the collapse problem in OSR and conclude that the metaphysical theory of time espoused in the present thesis – because it is an ideal fit with Omnès’ views here – is only partially reconcilable with it.

The title of the article, “The World in the Data”, by Ladyman and Ross gives some indication of their solution, which is this:

The fundamental empirical structure of the world is not mathematical but statistical. *And there is no such thing as pure formal statistics.* The ‘principles’ of statistics are simply whatever dynamics emerge from our collective exploration of, and discovery of patterns in, data. Applied scientists are continually reminded of this in their day-to-day work, especially as our new technological capacity at last realizes the potential for limitlessly evolving of co-adaptive growth of new techniques for discerning real patterns and new demand for statistical innovation arising from the discovery of new possible patterns.
(Ladyman and Ross 2013 p. 114, their emphasis)

Before detailing where I come to diverge from Ladyman and Ross, let me agree with this statement as it stands. The *empirical* structure of the world is described correctly here.

Further, their route to this conclusion is impeccable. They name-check Batterman and his contribution to anti-reductionism (as outlined in 4.3.2) that shows the non-redundancy of higher-order real patterns; and write: “Most of these non-redundant non-reducible patterns are also irreducibly statistical, in the sense that they are generated by stochastic processes” (Ladyman and Ross 2013 p. 147).

Also, they argue against one of Deutsch’s reasons for holding an Everettian interpretation of quantum measurement. They note that, in the debate between Bohr and Einstein over the measurement problem, Deutsch sides with Einstein “in the sense of holding that unreduced stochastic generalizations indicate incomplete explanation” (Ladyman and Ross 2013 p. 126). Against this Ladyman and Ross argue that the probabilities of outcomes in quantum measurement should be viewed “as basic properties of the external world that constitute its structure” (Ladyman and Ross 2013 p. 146). And in this regard, they praise C. S. Peirce’s “naturalistic embrace of the probabilistic modal structure he found in some science, and defend the claim that the world is fundamentally statistical” (Ladyman and Ross 2013 p. 114).

However, my disagreement begins with this last claim. Ladyman and Ross are basically saying that ‘it’s statistics all the way down’; whereas I am claiming that the non-deterministic statistics, as expressed in the modal structure of the empirical world, emerge from that part of the structure of the world represented by the deterministic, linear, time-dependent Schrödinger equation. In other words, only the *empirical* structure of the world – as discovered in the A-series at the macro-scale of time – is what Ladyman and Ross call “the totality of non-redundant statistics” (Ladyman and Ross 2013 p. 147).

The structure of the world at the meso-scale of time has no A-scale and is (viewed classically) seemingly ordered by the earlier than relation. At this scale, the structure is not statistical but is either purely mathematical or is represented mathematically. To many structural realists, this claim will merely reproduce the collapse problem: if the structure at this scale is thought to be physical and only represented mathematically, then what prevents this ‘physical’ structure from collapsing into a mathematical structure at the micro-scale of time? After all, I argued in 4.2 that matter is ontologically dependent on spacetime – and spacetime (with its scientific micro-scale of time) may be a purely mathematical structure just as Tegmark maintains.

However, to someone who happily endorses the approach to the measurement problem in quantum theory as set out by Omnès above, this outcome is of no great concern. That is because the ‘measurement problem’ of quantum theory, when believed not to have any solution in principle, can be viewed as a solution to the ‘collapse problem’ of OSR. So that, the question of whether structure at either the meso- or micro-scale is mathematical has no bearing on the physicality of content (as structure) at the macro-scale of time. Of course, as Omnès makes clear, this interpretation of QM is strictly metaphysical – as is its rival from the other ‘extreme’: the Everettian interpretation that may lead to the mathematical universe. These two extremes are motivated by the different stances taken towards the question of whether quantum theory and reality agree in everything (Everettian) or in everything except the uniqueness of phenomena (Bohrian). Thus, the Everettian “assumes essentially that reality must comply to theory and be as multitudinous as the theoretical possibilities” (Omnès 1995 p. 621). Whereas, Omnès writes that, the Bohrian “says that reality is unique”, and continues:

As for theory, it is the best one can have and it fits every detail of physical reality, except for its uniqueness, its essence, beyond which reality and theory would become identical or at least interchangeable. In Heidegger’s philosophy, this final gap between reality and theory would indicate a limit in the “cartesian program”, i.e., the compliance of reality to a mathematical theory. If this were so, the last remaining problem of quantum mechanics would indicate a triumph rather than a failure, as so many people, who believe uncritically in the cartesian program, consider it.
(Omnès 1995 p. 621)

When OSR is added to the mix, so that ‘theory’ is viewed as mathematical structure and ‘reality’ as physical structure, then the two extreme approaches to the collapse problem come sharply into focus. The Everettian structuralist may be led to embrace the collapse into the mathematical in order to maintain the ‘cartesian program’; the Bohrian may be led to abandon the ‘cartesian program’ in order to remain living in a physical world. It is worth emphasising again that these are purely metaphysical choices that current physical theory allows (as well as other choices). When it comes to the modal structure of the world, the difference in these two extreme pictures is stark. The Everettian structuralist accepts a world where all possibilities are actualised; the Bohrian structuralist embraces a world where there is real time, unique, actualisation of potentiality as we ‘advance into the future’.

If the Bohrian approach is right, then, as Omnès says, the physical nature of the empirical world in which we have our being would be guaranteed. That such a physical world might somehow be constrained by mathematical structure may not surprise too many people; that it could emerge from mathematical structure may be more surprising but need not be cause for alarm. Indeed, at an earlier time before Ladyman and Ross had developed their stochastic approach to the collapse problem, Ross, Ladyman, and Collier exhibited a very sanguine attitude towards the whole question of mathematical or physical structure, by writing:

One distinct, and very interesting, possibility is that as we become truly used to thinking of the stuff of the physical universe as being patterns rather than little things, the traditional gulf between Platonistic realism about mathematics and naturalistic realism about physics will shrink or even vanish. The new wave of structuralism in the philosophy of mathematics, which has a number of supporting arguments in common with OSR . . . adds substance to this speculation.
(Ladyman *et al.* 2007 p. 237)

Finally on the measurement problem, although I took issue with some of the comments of Ladyman and Ross quoted near the beginning of 5.1.2, I was careful not to reject their general approach towards the measurement problem, dependent as it is on the scale relativity of ontology. The key phrase from the quote given there is that “there is no reason to regard the measuring device as something that exists at all from a microscopic perspective” (Ladyman *et al.* 2007 p. 182). In which case we may appear to have something analogous to Heisenberg’s measurement interaction problem; for how can a (macroscopic) measuring device interact with a (microscopic) object when they exist on separate ontological scales? Recall that the problem confronting Heisenberg was due to his construal of the measurement interaction as being between a classically described measuring apparatus and a quantum object whose behaviour is represented by a wavefunction. However, RR not only accommodates the existence of both microscopic and macroscopic objects as real patterns that exist at different ontological scales; it also maintains that any connection existing between such patterns, ‘across the scales’ as it were, is that of ontological dependence.

5.2 Content at the Meso-Scale of Time

5.2.1 Quantum Entanglement as Content

The previous chapter partly dealt with the emergence of macroscopic from microscopic real patterns in condensed-matter physics. From that perspective macroscopic measuring devices belong to what, in 4.3.2, was called ‘protectorates’, i.e. stable states of matter existing at a longer length/lower energy scale than the shorter length/higher energy scales from which they emerge. The emergence of elementary particles was dealt with in 4.3.1 where it was argued that these particles as ‘objects’ also exist (emerge) at the macro-scale of time. In this chapter we have seen the importance of decoherence for the quantum-to-classical transition occurring at all those ontological scales that reside at the macro-scale of time. Thus, both the measuring device and the object to be measured suffer decoherence – though at different rates. And yet, decoherence is no solution to the problem of outcomes in quantum measurement. Schlosshauer poses the problem of outcomes as: “Why do measurements have outcomes at all, and what selects a particular outcome among the different possibilities described by the quantum probability distribution?” (Schlosshauer 2007 p. 50).

However, not only does decoherence not solve the problem of outcomes but, as Bacciagaluppi shows, there is reason to believe that it may exacerbate the problem. He states that since, according to decoherence theory, the environment (independently of us) carries out lots of approximate position measurements on both microscopic and macroscopic objects, the domain to which the measurement problem applies ought to be expanded to include “these spontaneously occurring measurements” (Bacciagaluppi 2012 p. Section 2.2). The expansion of this domain would then cast doubt on the ability of QM to account for the emergence of our classical world *tout court*. This is how Bacciagaluppi concludes his argument:

Given that everyday macroscopic objects are particularly subject to decoherence interactions, this raises the question of whether quantum mechanics can account for the appearance of the everyday world even apart from the measurement problem in the strict sense. To put it crudely: if everything is in interaction with everything else, everything is generically entangled with everything else, and that is a worse problem than measuring apparatuses being entangled with the measured systems. (Bacciagaluppi 2012 Section 2.2)

Bacciagaluppi's point will be well taken by those of us who concur with Omnès' view of QM in relation to time and the physical; so that, rather than being a 'worse problem', such 'generic entanglement' can be regarded as a further contributory factor in QM exhibiting that 'mark of achievement' in allowing for the existence of both physical structure and A-series time. Additionally, it can motivate us to apply Bohr's central insight in his epistemology of experiment to that of epistemology of quantum theory.

Recall from 5.1.2 how Bohr insisted that classical concepts must be used to describe both sides of the 'cut' in order to overcome the 'paradoxical situation' where the interaction between the measuring device and the object to be observed is viewed quantum-mechanically as a single nonseparable quantum state. Also, the classical concepts central to such descriptions are identified as space and time. Thus, by accepting both Bohr's epistemology of experiment and Bacciagaluppi's generic entanglement through 'measurement', we are led to the conclusion that to make sense of a now universal 'paradoxical situation' classical concepts must be used in any interpretation of quantum theory. This is especially important for the discussion of content at the meso-scale of time.

What, then, can be said of content at the meso-scale of time? Meso-content just is generic quantum entanglement. This content can be represented in two ways: formally through mathematics, or informally through classical concepts. The latter is an interpretation, or rather are interpretations, of the former. Any choice made between these interpretations, such as Everettian or Bohrian, as argued for in 5.1.2, is bound up with the metaphysical inclinations of the person making the choice.

The metaphysical interpretation I offer unites Bacciagaluppi's generic quantum entanglement, which we can only make some sort of (empirical) sense of by using classical concepts of time and space, with the theory of ontic scales of time. Thus, the nonseparable state of generic entanglement that just is meso-content is viewed classically as entanglement interactions that are ordered from earlier to later at the meso-scale of time. These interactions constitute the process of meso-composition as discussed in 3.4.2 and so are understood as strictly anaemic changes.

In Chapter 6, the different types of content existing at the meso- and macro-scales are brought together to explain how objective becoming occurs in our world. Next, however, I

examine a challenge to the very notion of a time-atom that comes from the Special Theory of Relativity. This challenge threatens to render all talk of meso-content empty.

5.2.2 Time-Atoms and Doubly Special Relativity

In my examination of content at the macro-scale of time, I observed the distinction between the microscopic-macroscopic transition and the quantum-classical transition. However, when it comes to content at the meso-scale of time there are no such transitions; interactions are there viewed as links in von Neumann's chain of measurement. Even so, in line with Bohr's epistemology, I argue that classical concepts are needed to make descriptive sense of such meso-content. Thus, while maintaining that quantum theory is universal, so that it applies at all scales, I argue that the 'cut' between the ontic scales of notional time, i.e. between the meso- and macro-scales, ensures the difference in content at the two scales. Recall from 3.4.1 that meso-content is synchronically emergent and suffers no passage of time. The change-as-composition is 'anaemic' change, which occurs (tenselessly) in line with the earlier than relation. Whatever meso-content may be, it has no past, present, or future. However, the very concept of time-atoms appears to be ruled out by Einstein's Special Theory of Relativity (SR). Therefore, having discussed meso-content at the scale of the individual time-atom, it behoves me to show that time-atoms can be accommodated within relativity theory. This is made possible by the revision to SR known as Doubly (or Deformed) Special Relativity (DSR).

The challenge posed to the notion of time-atoms by SR is both stark and simple. The physics literature usually puts this challenge in terms of a challenge to the notion of the (spatial) Planck length being the shortest observable length. However, since the Planck length just is the distance covered by light in a vacuum over one unit of Planck time, while the Planck unit of time just is the time required for light to travel a Planck length in a vacuum, we can see that the Planck length and the Planck unit of time are mutually implicative. Thus, any challenge to one is a challenge to both. Equally, the vindication of either vindicates both. I therefore follow the literature and discuss the challenge to, and any vindication of, the Planck length.

Giovanni Amelino-Camelia is one of the originators of DSR and in an early article provides arguments for the consistency of the very idea of DSR. Its title announces this idea as:

“Relativity in space-times with short-distance structure governed by an observer-independent (Planckian) length scale” (Amelino-Camelia 2000). In other words, the idea proposes a modification to the standard rules of SR according to which measurements of time and space are strictly observer dependent. According to SR the length of an object, for instance a metre rule, will be observed differently by an observer who is stationary relative to the object than by an observer who is in motion relative to it. The stationary observer observes the object to be a metre long; for the moving observer, the rule is observed to be less than a metre long. The faster the relative motion, the shorter is the object observed. This is SR’s phenomenon of length contraction. This phenomenon poses a seemingly insurmountable problem for any notion of a shortest observable length that all observers can agree on. For, as Lee Smolin writes,

this implies that there cannot *be* such a thing as a “shortest length”. No matter how short something is, you can always make it shorter by moving relative to it very close to the speed of light. Thus there appears to be a contradiction between the idea of the Planck length and special relativity.
(Smolin 2008 p. 227, his emphasis)

Amelino-Camelia surmounts this problem through an addition to the postulates of SR. One of the two postulates fundamental to SR is that of the relativity principle (i.e. the laws of physics do not vary for observers in different inertial frames); the other is the constancy of the speed of light c , irrespective of the speed of either its source or an observer. The former postulate ensures that it is a theory of relativity, while the latter is what makes Einstein’s theory ‘special’. Amelino-Camelia adds a third postulate, thus making it ‘doubly special’. This new postulate states that for any observer, irrespective of their speed, nothing can be smaller than the Planck length L_p . In this way, the apparent contradiction between L_p as the shortest length and SR is overcome in a similar manner to that of the apparent contradiction existing between two observers moving at different speeds relative to each other, who measure the speed of the same photon and find the same result c . From this, Amelino-Camelia concludes: “The laws of physics involve a fundamental velocity scale c and a fundamental length scale L_p ” (Amelino-Camelia 2000 p. 4). Now, as argued previously, this implies that the theory of Doubly Special Relativity also allows a shortest observable unit of time, here the Planck time T_p , that does not conflict with the relativity principle. The consistency of the theory, logically argued for in Amelino-Camelia’s article, was soon proven to be consistent mathematically in a paper by Lee

Smolin, Laurent Friedel, and Jerzy Kowalski-Glikman (Friedel *et al.* 2004). Referring to this paper, Smolin writes:

The consistency of DSR was shown by demonstrating that there is a possible universe in which it would be true. The possible universe is like our own, with one difference, which is that space has only two dimensions. It was discovered in the 1980s that quantum gravity can be precisely defined in a world with only two spatial dimensions. We call this $2 + 1$ quantum gravity, for two dimensions of space and one of time. Moreover, if there is no matter, the theory can be exactly solved – that is, one can find exact mathematical expressions that answer any question that can be asked about the theory the world describes.

(Smolin 2008 p. 234, his emphasis)

He then immediately informs us that DSR has now also been proven consistent in a $2 + 1$ quantum gravity world with matter. These results demonstrate that claims for the possible existence of time-atoms, either with content or without, is indeed consistent with the principle of relativity.

However, Sabine Hossenfelder warns against accepting the Planck length *per se* as the shortest length. This is because in string theory with extra dimensions there are models in which the minimum length turns out to be much larger than the Planck length. Hossenfelder notes:

That such possibilities exist means, whether or not the models with extra dimensions are realized in nature, that we should, in principle, consider the minimum length a free parameter that has to be constrained by experiment.

(Hossenfelder 2013 p.23)

Thus, although string theory may predict a different minimum length from that of DSR, it still demonstrates the consistency of the very idea of such a length and hence of the possibility of a time-atom. Hossenfelder's advice is well taken: the size of a time-atom, if it is to be known at all, is to be discovered through experiment. Of course, this means that (if we regard the 'empirical world' as that which is directly accessible to experiment) the empirical world is sandwiched between the constancy of the speed of light c and the minimum length scale (whether Planck or larger). Thus, content at the meso-scale of time is not directly accessible to experiment; and so, anything said about it can only be inferred. It is precisely this lack of direct experimental access that ensures the observer-independent nature of a time-atom.

Such observer independence can now be seen to have two aspects. One is that the size of a time-atom will be universally agreed to by all observers; the other is that the content of any time-atom is inaccessible to all direct observation. Thus, as Hossenfelder writes in relation to DSR and its minimum Planck length:

To actually determine a distance in some reference frame one has to perform a measurement. Thus for the observer independence of a minimum length, it is sufficient if there is no operational procedure that allows one to resolve structures to a precision better than the Planck length.
(Hossenfelder 2013 p. 47)

Of course, should the minimum length be discovered to be larger than the Planck length, the general point still applies. In which case no structure will be experimentally resolvable at a lower scale than this minimum length. This brings into focus the fact that it is important to remember that any 'minimum length' (as time-atom) being discussed here is not absolute. It is relative to the macro-scale of time alone. There is an infinite number of shorter lengths within each time-atom or 'minimum length'. Thus, as Hossenfelder writes, it is better to speak of a minimum length scale rather than a minimum length as such:

We have already discussed that there are various possibilities for a minimum length scale to make itself noticeable, and this does not necessarily mean that it appears as a lower bound on the spatial resolution. We could instead merely have a bound on products of spatial and temporal extensions. So in this sense there might not be a minimum length, just a minimum length scale.
(Hossenfelder 2013 p. 67)

All processes of experiment, as observation, take place at the macro-scale of time, which is experienced as the expansive, folk *A*-scale. Its minimum length is the atom of the present. Any lengths shorter than this scale reside at the meso-scale and hence are beyond observation. Our minimum length scale is one of the two limits to the empirical world (the other being the speed of light).

6. Dynamic Composition

6.1 Content of the Past, Present, and 'Future'

If what exists are real patterns, then what constitutes the content of the past will simply be real patterns. As was stated in 1.4, real patterns are termed in everyday (folk) discourse: 'objects', 'properties', 'processes', and 'events'. Most A-series real patterns will be wholly past in that the processes forming them are complete. However, there are also those real patterns that are presently in the process of becoming. These real patterns are partly past and partly present. Their past grows as once present time-atoms sequentially become past along with their macro-scale content. What makes for their dynamism (as growth) is this very connection to the present which is denied to wholly past patterns. Thus, once they have wholly become, their being is complete and the present ceases to add content to them. However, wholly past real patterns do not thereby cease to have a bearing on the present. Starlight hitting our retinas from a long dead star being an extreme case in point. This demonstrates how information about the past affects the nature of the becoming of real patterns in the present, and so is intimately involved in the creation of new real patterns. Self-creating, or self-organising, real patterns are constituted through their past parts impressing a specific future direction onto their present part. The present continually receives information about the past that is then used to create more (past) being as real patterns. Real patterns are, of course, subject to the scale relativity of ontology so that different patterns exist at different scales of time and space, or energy scales.

We have just seen that information about the past is a major constituent of the content of a present time-atom *qua* present (i.e. at the macro-scale). Also, as we saw in the previous chapter, a major constituent of the content of a (present) time-atom *qua* time-atom (i.e. at the meso-scale) is a nonseparable state of quantum entanglement that is viewed classically as content undergoing anaemic change from earlier to later. Robust change happens at the macro-scale when a present time-atom becomes past, and its content has objectively become. The process of objective becoming that takes place at the present time-atom is that process of 'objectification' or 'quantum measurement' that quantum theory does not

recognise. This is the process that Omnès views as modifying the structure of time by splitting it into “a past, a present, and a future having very different qualities” (Omnès 1994 p. 508). My only disagreement with Omnès here is in my claim, as set out in 3.4.1, that the structure of time (as earlier-later at both the micro- and meso-scale) undergoes no modification. Rather, the *A*-scale of past-present-future emerges with the emergence of content onto an already existent macro-scale of time through that very process of objectification. An *A*-scale, together with ‘objectified’ past content, ‘objectifying’ present content, and a future that is empty of content, constitutes an *A*-series. Thus, past-present-future is not a modification of the structure of time, it is an *addition* to the structure of time that emerges dynamically and diachronically from a pre- (and post-) existent temporal structure. The present time-atom, then, is the location of a process of objective becoming that just is the interaction between meso-scale content and macro-scale content (as information about the past). In other words, this is the interaction between quantum content and classical content that was described at the end of 5.1.3 as a quantum measurement interaction.

This section’s heading may seem somewhat strange, as it comes after having previously written that what constitutes the future just are those serially-ordered empty time-atoms at the macro-scale of time – beginning with the empty atom that is adjacent to the present atom. This is strictly true. However, here the term ‘future’ appears in scare-quotes to indicate that it is being used in the folk sense: as being those ‘times that are later than the present’. In which case, atoms that are empty when viewed at the macro-scale can still have content at the meso-scale of time. Thus, although the future *qua* future is indeed empty, the time-atoms that constitute the future part of the *A*-scale can yet have meso-content; and such content just is a nonseparable state of quantum entanglement. Therefore, there may indeed be content at ‘times later than the present’, but since this content would be wholly meso-scale content, the future itself is strictly devoid of content. Even so, any meso-content that is ‘later than the present’ can have a bearing on the constitution of any macro-content if or when ‘objectification’ or ‘quantum measurement’ occurs at those later time-atoms as they become present; so that what can emerge there will be constrained by the nature of that meso-content. This sort of folk discourse concerning time is examined in the next chapter.

6.2 The Present

The default way in which positions in analytic philosophy of time are expressed is through Newtonian spacetime, in which the present is viewed as a hypersurface (three-dimensional slice of Euclidean space) of that 4D spacetime. This slice, of course, is known as an instant, and so the present just is such an instant. (Recall the different notion in 2.1 where a hypersurface is viewed as a set of achronal instants and termed ‘moment’.) This picture then allows for an easier understanding of presentism, possibilism (the growing block), and eternalism. Presentism holds that the content of only a single slice (the present) exists; possibilism holds that the present slice plus all earlier slices with their content exist, and that this block grows as each new slice with its content is added; and eternalism holds that all slices together with their content exist (as in a block universe).

The picture gets more complicated when Einstein’s theory of relativity is introduced. Flat Minkowski spacetime (developed from the special theory) still allows for a foliation of spacetime whereby the present may be viewed as an instantaneous slice. But now there is the added difficulty that, due to the relativity of simultaneity, the present can differ according to which inertial frame is chosen; and so, there is an infinite number of slices that may be viewed as present. Thus, the eternalist Balashov claims: “Since the geometry of Minkowski spacetime does not support a frame-invariant notion of simultaneity, it does not allow one to define the concept of *the present*” (Balashov 2010 p. 2). However, he recognises there are both presentists and possibilists who claim that absolute simultaneity and an absolute present are compatible with SR and Minkowski spacetime, hence he writes:

The idea is that one could accept all the empirical consequences of this theory [SR] (including length contraction, time dilation, and so on) and yet insist that there is a privileged inertial reference frame, in which meter sticks *really* have the length they do and time intervals between events refer to the *real* time. Associated with this reference frame would be a set of hyperplanes uniquely foliating spacetime into equivalence classes of absolutely simultaneous points. Such a privileged reference frame would not be distinguished in any empirical sense and would not be identifiable in any real experience.
(Balashov 2010 p. 3, his emphasis)

Here, all three sides to the debate – eternalists, possibilists, and presentists – can agree in as much as a meaningful concept of ‘present’ can be a frame-dependent notion. And yet,

General Relativity provides a further challenge to such a notion of present, in that there are solutions to the Einstein field equations that provide models of spacetime in which global foliations resulting in such worldwide slices are not possible.

Stein takes issue with this interpretation of a world-wide slice of spacetime – the time coordinate of an inertial frame with its accompanying (relative) simultaneity – as being the present. He argues that the mathematical facts about the structure of Minkowski spacetime “have at most a tenuous connection with anything like an ‘experience’ or ‘intuition’ of an instantaneous present” (Stein 1991 p. 155). Thus, he writes elsewhere:

[W]hat Einstein’s arguments showed was that *a certain procedure of measurement singles out a time axis and gives numerical time differences dependent upon that distinguished axis*; not that an observer’s state of motion imposes upon him a special view of the world’s structure. This illegitimate metaphysical interpretation of the time coordinate appears perhaps most plainly in Rietdijk’s phrase describing *C* and *A*, when at rest with respect to one another, as “experiencing the same ‘present’” [(Rietdijk 1966)]; there is of course no such “experience”: the fact that there is no experience of the presentness of remote events was one of Einstein’s basic starting points.

(Stein 1968 p. 16, n. 15, his emphasis)

Stein puts forward an alternative to the idea of the present as frame-dependent coordinate time that stems from Robb (mentioned in 2.1) and which confines the present to a spacetime point – the punctual present. Thus, Stein writes that, “in the theory of relativity, the only reasonable notion of ‘present to a spacetime point’ is that of the mere identity-relation: present to a given point is that point alone – *literally* “here-now”” (Stein 1991 p. 159, his emphasis). However, Stein recognises that the punctual present throws up a problem in connection with experience – awareness seems to require a non-punctual temporal duration known as the ‘specious present’. I examine the specious present in relation to experience in the next chapter.

While these two approaches to the idea of the present – frame-dependent and punctual – differ in the spatial extent of the present they both agree that its temporal extent is zero. Recall from 2.1, Petkov’s argument that the presentist’s three-dimensional world must exist at a single moment of time, otherwise an extended present would entail presently existing objects being extended in time, and hence would be four-dimensional. Also in 2.1, having

followed Robb in confining an instant to the 'now' of a single 'here-now' spacetime point, I disavowed his notion of a 'present instant', claiming that this is a category mistake. I then explained in 3.2 how the present is notional (durational) and not scientific (instantaneous), and there arrived at the idea of the present as a time-atom extending over a single instant. An instant, being the temporal aspect of a 'here-now' spacetime point, is always joined by the spatial point that is the spatial aspect of that particular 'here-now'; while this spatial point is extended over by a space-atom. Therefore, the 'spatial extension' of a time-atom is merely the length of the space-atom extending over the same spacetime point. Thus, the present has neither the spatial extent of an inertial reference frame (as required by presentists and possibilists) nor the extensionless-ness of a 'here-now' point (as claimed by Robb and Stein). Instead, the spatial extent of the present is that of the space-atom with which it is linked via the spacetime point over which they both extend. Thus, the present is *approximately* punctual regarding both (notional) time and (notional) space.

Now, the brief overview given in 6.1 of the composition of A-series content is greatly simplified; not least in the way that the term 'the present' is used. Thus far, I have deliberately kept discussion of the present to the simple formula of existing in a single A-series so as not to unnecessarily complicate the initial exposition of a temporal structure that is considerably more complex than usually thought. (This strategy may be comparable to that of analytic metaphysics making use of the (simpler) Newtonian default positions of eternalism, possibilism, and presentism.) However, if an instant is the temporal aspect of a single spacetime point rather than a hypersurface (three-dimensional slice) of spacetime, and the (notional) present is a time-atom covering one such instant, then the present would seem to have very little connection with what we, as folk, commonly refer to as 'the present' – for this folk present seems to have a large (if not infinite) spatial extent. In the rest of this chapter, I want to demonstrate how dynamic composition takes place 'in the (notional) present' – and how this present can refer to a multitude of present time-atoms belonging to a multitude of A-series, at a multitude of different ontological scales. What these different A-series consist in will become clear as the discussion advances. I begin with an examination of different rates of the passage of time.

6.3 Measuring Objective Time Lapse

6.3.1 Coordinate Time and Proper Time

Richard T.W. Arthur is one of those who argue that there is becoming (as the occurrence of successive events) in Minkowski spacetime. Although I ultimately disagree with this conclusion, I find that some arguments he makes from relativity theory are of great use – particularly those concerning coordinate (relative) time and proper time in relation to becoming and the present. Thus, he writes of coordinate time and proper time:

In SR the becoming of events in succession, the rate of process or the rate at which a thing ages, is tracked by *proper time*; the synchronicity of distant events is tracked by the *time-coordinate function*. This separation of these two different aspects of time into two different time concepts τ and t is characteristic not only of SR, but of all relativistic physics, where every timelike curve represents a possible process, whose rate of evolution is parametrized by proper time. This connection of becoming or process with proper time as opposed to coordinate time is masked, so I argue, by the way many physicists and philosophers talk about proper time as if it is simply the *relative time of an observer in his or her own rest frame*.
(Arthur 2008 p. 208, his emphasis)

What Arthur emphasises here can be used in support of both the robust A-series becoming and the ontology of spacetime that I have been arguing for. In 2.1 I used RR's scale relativity of ontology to argue that Minkowski spacetime was without content, and in 4.2 I used arguments from Lehmkuhl in support of the claim that matter is ontologically dependent on spacetime. Now, if neither becoming nor content is applicable to Minkowski spacetime then there can be no proper time existing there as there is neither process nor ageing content to which a rate can be given. Thus, "every timelike curve represents a possible process" is an apt description when emphasis is placed on "possible", for such curves represent processes that, if they did occur, would have happened in A-series of notional time and not at instants of scientific time, and hence not in Minkowski spacetime. Therefore, although processes, as proper time lapse, may be informatively represented by timelike curves on a spacetime diagram, these curves should not be understood as representing an existent within Minkowski spacetime itself. And so, I go this far with Arthur when he writes: "Events 'exist all at once' in a spacetime manifold only in the sense that one represents them all at once as belonging to the same manifold"; but then strongly disagree with his: "But one precisely

represents them as occurring at different times, or different spacetime locations, and if one did not, one would have denied temporal succession” (Arthur 2006 pp. 136-137). I disagree with the meaning he appears to give to ‘occurring’ in this passage, which (I believe illegitimately) implies a notion of robust becoming. I criticise this use of ‘occurrence’ in connection with Minkowski spacetime in 7.2.1.

This claim, that actual proper time does not exist within Minkowski spacetime but can be represented as the path of a timelike curve within a spacetime diagram, is further supported by an observation Stein makes in a mild correction to David Malament regarding the question of a distinguished time-orientation in spacetime:

To obtain Malament’s conclusion for the (stronger) structure of space-time with a time-orientation, one has to strengthen somewhat the constraints he imposes on the relation of simultaneity; it suffices, for instance, to make that relation . . . relative to a *state of motion* (i.e. a time-like *direction*), rather than – as in Malament’s paper – to an *inertial observer* (i.e., a time-like *line*).
(Stein 1991 p. 153 n. 1, his emphasis)

Thus, the relative simultaneity of events in SR is relative to a time-like direction (or state of motion), so that “events are ‘simultaneous relative to’ such a direction if and only if the vector they determine is orthogonal to that direction” (Stein 1991 pp. 153-154). Since anything having a time-like vector moves at a slower rate than the speed of light, c , it will be represented in a spacetime diagram as being within the interior of a light-cone; and since only massive objects can have velocity less than c , then only massive objects, by their state of motion, can be used to distinguish time-orientation in spacetime. Also, as Arthur states, the rate of evolution of this motion is “parametrized by proper time.” In relativity theory, a non-zero proper time is only applicable to physical systems having velocity less than c . Andrew Holster makes clear the connection between mass, velocity, and proper time so

the rate of proper time for a system varies with its velocity, or motion through space. The relationship is very simple: the faster a system travels through space, the slower its internal processes go. At the maximum possible speed, the speed of light, c , the internal processes in a physical system would stop completely. Indeed, for light itself, the rate of proper time is zero: there is no ‘internal process’ occurring in light. It is as if light is ‘frozen’ in a specific internal state. . . For radioactive systems, the rate of radioactive decay is a measure of proper time. . . For light, treated as a quantum mechanical particle (the photon), the rate of proper time is zero, and this is because it has no mass. But for quantum mechanical particles with mass, there is always a

finite 'intrinsic' proper time rate, represented by the 'phase' of the quantum wave which is responsible for quantum interference effects and other non-classical 'wave-like' behavior.
(Holster 2021 Section1)

We can say, then, that any material real pattern belonging to an A-series qualifies as such due to its possessing mass, velocity, and proper time. Hence these are essential properties of all A-series material content. Coordinate times that can be applied to these real patterns are merely accidental – dependent as they are on the chosen frame of reference. Again, it is important to note (as in 4.2) that essential properties need not be fundamental – which they clearly are not in this case.

Arthur takes great pains to ensure that others may fully grasp the important nature of the difference between proper time and coordinate time. Thus, after informing us that Minkowski introduced the concept of proper time in 1908 he writes of it:

If at any point $P(x,y,z,t)$ in spacetime we imagine a worldline running through that point, the magnitude corresponding to the timelike vector dx, dy, dz, dt laid off along the line is

$$d\tau = \sqrt{c^2 dt^2 - dx^2 - dy^2 - dz^2} / c$$

Proper time is now defined as the integral of this quantity along the worldline in question [thus, proper time $\tau = \int d\tau$]. . . x, y, z, t – the components of the vector OP , where O is the origin – are considered as functions of the proper time τ , and the first derivative of the components of this vector with respect to the proper time, $dx/d\tau, dy/d\tau, dz/d\tau$ and $dt/d\tau$, are those of the *velocity vector* at P .
(Arthur 2008 p. 218, his emphasis)

And, of course, it is a velocity vector such as this that, when timelike, indicates the time-orientation of a spacetime. Whereas light, with velocity c , having a lightlike spacetime interval rather than the required timelike interval, has zero rate of proper time and hence, being 'frozen', cannot indicate a time-orientation in spacetime.

The time-coordinate function, t , allows us to determine which distant events are simultaneous; and so, if the present were a world-wide 'now' it would allow us to say which distant events were present with us. However, in SR there is relativity of simultaneity due to different inertial frames having different events as simultaneous. This would then mean that there are different world-wide 'nows' that are dependent on the inertial frames chosen.

According to Hilary Putnam (1967) and C. W. Rietdijk (1966) such frame-dependence also means that the future is fixed, since (so the argument goes) what is future for one observer is (already) present for another simply due to them 'inhabiting' different inertial frames. Of course, this argument has no effect on those who, like me, reject the initial premise that the present is frame dependent and world-wide.

For those who believe that time lapse is measured in coordinate time, Arthur writes that "the time lapse between, for instance, two events in anyone's life history is given by the difference in the values of the time co-ordinate function in some particular inertial reference frame" (Arthur 2008 p. 210). In other words, time lapse is here viewed as the interval between one (world-wide) 'now' and a later 'now' according to some one inertial frame, and this interval is measured by the time-coordinate function. And, of course, were it measured from different inertial frames, the difference in values would vary accordingly. Time lapse in this view is therefore both variant and frame dependent. This is precisely the notion of time lapse that Arthur argues against.

He does this by using the famous Twin Paradox from SR. This paradox demonstrates that twins who are naturally the same age, will come to have different ages when their worldlines diverge. This divergence is demonstrated by a thought experiment where one twin remains on earth while the other speeds off in a spaceship for several years before returning to earth. At their reunion it is discovered that the earthbound twin is some years older than the space-travelling sibling. Arthur cogently argues against the common belief that the difference in ages is explained by the travelling twin's change of inertial frame due to the acceleration and turnaround involved in the journey. However, while Arthur concedes that the space traveller's acceleration "is a necessary condition for [the twins] taking different paths through spacetime", he insists that "the time dilation is due to the different paths, not an effect of the acceleration itself" (Arthur 2008 p. 216).

Arthur uses his modified version of the Paradox, in which both twins are in inertial motion relative to an inertial point near the earth, to show that the difference between the ages of the twins in the original thought experiment cannot be due to one twin being in inertial motion while the other is not. Rather, he writes:

It is the time elapsing along a particular path in spacetime that measures how fast the processes traversing that path are going, how fast the people or things undergoing them are aging, how fast they are becoming. . . It follows that it can't be said, as one often reads, that the duration processes in relativity theory is relative to an inertial frame. In the sense of time lapse that is relevant to the twin paradox – how much time elapses for each twin – *it is simply false that time lapse is frame-dependent*, i.e. depends on the inertial frame adopted. Indeed, the duration of each twin's journey through spacetime is an invariant measure: it is the same in all inertial reference frames.

(Arthur 2008 p. 217, his emphasis)

And, of course, this invariant measure of the duration “through spacetime” just is proper time.

Jean-Pierre Luminet describes a variant of the Twin Paradox with a topological twist. In this thought experiment, there are quadruplets who inhabit the surface of a torus (dough-ring) shaped spacetime. The torus is initially formed from a rectangular section of flat spacetime by firstly rolling it lengthwise and joining the two long edges, so forming a tube; then bringing the open ends of the tube together to form the dough-ring shape. Quad 1 remains at home, while the other three depart on their various travels. Quad 2 takes a round trip similar to that of the travelling twin in the original version of the Paradox – i.e. with acceleration and a turnaround that results in change of inertial frame. Quad 3 loops around the handle of the torus, while quad 4 loops around the hole. Both the third and fourth quads travel in straight lines at constant speed, so there is no change to their respective inertial frames throughout the journeys. However, due to the topology, both straight lines traversed by quads 3 and 4 ‘circle back’ so that all three travellers end up back where they started. Furthermore, the three travellers depart at the same time and return at the same time. At the four quads’ ‘reunion’, it is discovered that all have aged at different rates. The stay-at-home quad (here quad 1) is always the oldest – no matter the speed or routes the travellers might take (Luminet 2011 pp. 539-544).

Now, I expect Arthur would say that the example of the third and fourth quads conclusively demonstrates that, since there is neither acceleration nor turnaround involved in either of their trips and hence no change of inertial frame, the only explanation for both the difference in their ages and them being younger than the stay-at-home quad is the different measures of proper time due to their different paths ‘through’ spacetime. Further, since the difference

in paths is sufficient to explain the difference in ages in this case, so it is also sufficient to explain the difference in ages between quads 1 and 2. The only thing common to both cases in this respect is the difference in spacetime paths of the quads in each case; though, of course, this difference has different causes: acceleration and turnaround in one case, spacetime topology in the other. Thus, the difference is measured in both cases by proper time that is directly due to the objects' (here the quads') different worldlines. Hence, inertial frames are incidental to the proceedings.

However, in his discussion of Luminet's quadruplets, Rickles maintains that inertial frames have a role to play in the explanation. He first gives the standard (Twin Paradox) response to the difference in age of quads 1 and 2 as that "the symmetry between their perspectives about 'who was really in motion' will be broken because of the second quad's switching between different inertial frames" (Rickles 2016 p. 67). Luminet's response to this case differs somewhat in that, while he agrees that the two quads "are not symmetrical because only [quad] 1 stays in an inertial frame. Here the asymmetry is due to acceleration" (Luminet 2011 p. 541). It seems to me, however, that if acceleration is the cause of the asymmetry, then it is also the cause of the change in inertial frame of quad 2; and so inertial frame change (or lack thereof), rather than causing or explaining the breaking of symmetry, is itself an effect of, and is explained by, the asymmetry due to acceleration.

Rickles then explains the breaking of the perspectival symmetry that results in the age difference between quads 3 and 4 thus:

If the symmetry is broken in this case, what breaks it? It cannot be a *change* in frames since they move inertially throughout their journeys. While not a change of frames as such, there is a difference in their frames caused by the non-simply connected topology. . . So here is an asymmetry: there are non-trivial (topological) differences in the quads' trajectories. This causes differences in their frames and is already enough to dissolve the paradox.
(Rickles 2016 pp. 67-68, his emphasis)

But again, if the difference in the worldlines is the cause of differences in inertial frames, and is sufficient to "dissolve the paradox", then "difference" in inertial frames does no explanatory work. It would be much simpler to accept that inertial frames are just along for the ride, and that the explanation for any difference in lapse of time lies with the difference

in length of spacetime paths that determines the different measures of proper time. However, simplicity is not the only reason to adopt the world-line/proper time explanation; there is also a crucial difference between proper time and the time-coordinate function. While the time-coordinate function quantity varies with the inertial frame chosen, the proper time quantity is *invariant*, so that its value remains the same whatever the frame chosen. It is this invariance, this sign of objectivity, that leads Arthur to claim that only proper time measures the objective lapse of time. The importance of invariance to physics is expressed by Max Born thus: “The feature which suggests reality is always some kind of invariance of a structure independent of the aspect, the projection” (Born 1953 p. 149).

Luminet informs us of another invariant involved in his Quad Paradox, a topological invariant called the ‘winding index’, and writes of it:

In the case of a torus, the winding index is a couple (m,n) of integers where m and n respectively count the numbers of times the loop goes around the hole and the handle. In our example, 1 and 2 have the same winding index $(0,0)$, whereas 3 and 4 have winding indices of $(0,1)$ and $(1,0)$ respectively. The winding index is a topological invariant for each traveller: neither change of coordinates nor of reference frame can change its value.
(Luminet 2011 p. 541)

Hence, we now have two invariants with a connection to time lapse: proper time and winding index.

In a lecture given by Minkowski, in which he introduced to the public the notions of a 4D spacetime (that now bears his name) and proper time, there appears this famous passage:

The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.
(Minkowski 1923 p. 75)

The reasoning behind this claim has to do with the idea that objectivity in physics is revealed by invariant structures. Minkowski demonstrates that both the cone-like structure and the intervals between spacetime points are invariant in his 4D spacetime unity. These invariant spacetime intervals, however, appear in different guises depending on from which inertial

frame they are measured. This difference, of course, is an expression of the length contraction, time dilation, and relativity of simultaneity of SR. Thus, lengths of space and time, as separate measures, vary with inertial frame. On the understanding of the invariance of spacetime and the variance of both space and time, Minkowski concluded that spacetime was objective and hence possessed of an “independent reality”, whereas space and time by themselves were lacking such objectivity and so were mere shades.

However, the difference between coordinate time and proper time, which Minkowski himself introduced, can be used to undermine his argument. As we saw in 6.3.1, proper time is also an invariant quantity – being independent of choice of inertial frame – and hence possesses an objectivity that is lacking in coordinate time. Thus, proper time may also qualify as maintaining a sort of “independent reality”, in which case *A-series* processes (as measured by proper time) would qualify as objectively physical, not merely subjective, occurrences.

There is an important difference to be drawn between what can be called ‘actual’ proper time and ‘possible’ proper time. In a Minkowski spacetime diagram, any timelike worldline can be drawn inside any light-cone one chooses. The mathematical proper time of this spacetime path is calculated by integration (as per Minkowski’s definition of proper time above). This is a possible proper time, i.e. what would have been the proper time had a real process taken place as represented by that worldline. An actual proper time is that of a real process that either is still in progress or is complete. In other words, there can be no actual proper time in any future part of an *A-series*. Only possible proper time belongs to ‘empty’ Minkowski spacetime; actual proper time belongs to the actual (general relativistic) world in which we live. In our world, any possible spacetime path of a massive body can be represented by a timelike curve in a spacetime diagram. In which case possible proper time will be integral to that representation. Stein lays bare the intimate connection between (actual) proper time and material processes thus:

Proper time is not a quantity attached to space-time points or to pairs of space-time points; it is in this respect a notion utterly different from the quantity “time” or “time interval” of pre-relativistic theory. Instead, proper time is associated with each timelike . . . *line segment* in spacetime. As attached to such line segments, it is of the nature of a *length*. . . The fundamental physical role of proper time comes from the principle (here stated roughly) that whenever a process takes place along a well-defined line of space-time (“world-line”), the time rates in the dynamical principles that govern that process are to be understood in terms of the proper time along that

line (and not in terms of a “time coordinate” . . .) According to this principle, for example, a clock beats proper time.
(Stein 1968 p. 11 n. 6, his emphasis)

However, Stein (like Arthur) seeks to demonstrate a form of becoming from earlier to later instants of time within Minkowski spacetime itself. The reason Stein believes that there can be becoming in Minkowski spacetime in the first place seems to be due to an acceptance of the idea that tense can apply to spacetime points. Just as Robb equates the ‘now’ aspect of a ‘here-now’ spacetime point with ‘present instant’, so Stein writes that “in Einstein-Minkowski spacetime *an event’s present is constituted by itself alone*. In this theory, therefore, the present tense can *never* be applied directly to ‘foreign’ objects” (Stein 1968 p.15, his emphasis). It is this common entangling of tensed and tenseless time series, i.e. the use of folk time, that allows Stein to claim becoming for Minkowski spacetime. This is how he epitomises such ‘becoming’: “For an event . . . at a space-time point a , those events, and only those, *have already become* (real or determinate), which occur at points in the topological closure of the past of a ” (Stein 1968 p. 14, his emphasis). The use of tensed ‘have already become’ in conjunction with tenseless ‘occur’ (like all good folk usage) does make sense.

However, it is this very (folk) sense that misleads some into believing that tense can be applied to scientific time. The way to avoid this is by disentangling and keeping separate in analysis *B*-tenseless and *A*-tensed language. Thus, although I agree with Stein that the only simultaneous event in Minkowski spacetime is the single spacetime point alone as ‘here-now’, I disagree with his designation of what he calls the “‘chronological perspective’ of each spacetime point” (Stein 1968 p. 16). For Stein this ‘chronological perspective’ faces backwards to the past, as demonstrated in his notion of becoming. For me, however, the chronological perspective of a spacetime point is solipsistic – it just is ‘here-now’ and has no perspective of ‘there-then’ (whether forwards or backwards). Of course, this does not imply that spacetime points are isolated ‘individuals’ in any sense, for I have maintained throughout that spacetime points are merely derivative of 4D spacetime and the earlier than relation. I return to this theme in 7.2.1 where I discuss Dorato’s notion of becoming in Minkowski spacetime as the successive occurrence of events.

Contrary to this, I have argued that an objective lapse of time is purely tensed and that it can only occur as the passage of time in an *A*-series belonging to durational notional time, i.e. when objective becoming of content in the present duration ceases and becomes content of the past. Since both passage (as lapse of time) and process (as ageing of content in the present) emerge together to form an *A*-series, their rate of change is identical – and objectively measured by proper time.

6.3.2 How Fast Does Time Pass?

The question How fast does time pass? is often (sceptically) asked of those who believe that the passage of time is a real phenomenon in the world, with many of the enquirers (ironically) holding that the question does not even make sense. While Skow meticulously demonstrates that the question is indeed sensible (Skow 2015 pp. 101-105), he makes a further demand of those who would agree with an answer given by Arthur Prior. Thus, he writes of Prior in relation to the question ‘How fast does time pass?’:

In one place he identifies this question with the question “How fast do I get older?” and says that the “obvious” answer is one year per year, one time-unit per time-unit (“Time After Time”, p. 244). This (perfectly fine) answer to the question “How fast do I get older?” is an answer that a believer in the block universe could give. But a believer in . . . objective becoming . . . should deny that the only thing “How fast does time pass?” can mean is this question about the rate at which one ages. They should want it to also have a more robust meaning.
(Skow 2015 p. 127)

If Skow is referring to analytic *A*-theorists, then his injunction may make some sense. However, it makes little sense according to the naturalised metaphysics of time developed here. The investigation of the previous subsection appears to vindicate Prior’s identification of the rate of time’s passage with the rate of ageing. There, ageing was viewed as a process that is only undergone by massive objects moving at velocity less than the speed of light, *c*. This ageing process is measured invariantly across inertial frames by proper time as “one time-unit per one time-unit”, which ultimately, in terms of the present thesis, is grounded on the smallest time-unit of the macro-scale of time – the time-atom.

Furthermore, since there is no passage of time at the meso- and micro-scales, neither ageing nor proper time is to be found there. However, Skow seems to think a believer in objective becoming should not be satisfied with such an answer since it is not robust enough. He borrows the idea of what a more robust becoming would look like from Ned Markosian, who writes of “the pure passage of time” (Markosian 1993 p. 842). However, since the rate of Markosian’s preferred measure of “pure passage” is shown to be variable, Skow expects that a believer in objective becoming will seek a definition that forbids, or at least suppresses, any variation in the rate of such passage. He then writes that “many believers in objective becoming will want to say that pure passage of time goes on, and goes on at some rate, even if nothing else changes” (Skow 2015 p. 129).

Again, as someone who believes in objective becoming, I am not one of the “many” as portrayed by Skow – for two reasons. First, the previous subsection shows (and welcomes the fact) that the passage of time can and does vary greatly in rate. Second, any notion of “pure passage” was demonstrated to be a non-starter in 3.3 and 3.4, where it was argued that pure time – i.e. time without content – does not change. There are two requirements for passage of time to occur. First, there must be content at the meso-scale; second, there must be (becoming of) content at the macro-scale. When these are in place, passage is initiated by present content becoming past, thereby inaugurating a changing *A*-series. Hence, only ‘impure’ time can pass.

Thus, I agree with Prior on this question. The elements required to answer it in more detail are provided in the previous subsection, they need only be brought together. Each entity in *A*-time, as process, is its own clock. Each clock registers its own age according to its spacetime path, and the rate of ageing is its rate of proper time. A change in rate of passage can be brought about in two ways. One (from SR) is due to change in velocity. The other (from GR) is due to change in curvature of spacetime, as when a clock is closer to or further from a massive body. As is well known, even the difference in velocity between a clock being flown in a jet plane and one remaining on the ground has a measurable difference on their rates of passage. As does the difference between a clock sitting atop a mountain and one at sea level.

From this we can conclude that every entity (real pattern), being its own clock, is/creates its very own *A*-series. Its past can be represented in a spacetime diagram as a worldline. As it continues to ‘tick’ in the present, the representation will need to be extended as the ticks

become past. Thus, any representation of a presently existing entity in a spacetime diagram would require continual updating. Any difference in the rate of proper time just is a difference in the rate of creation of the past, i.e. the rate of ageing. Nothing that is present, or partly present, can escape this passage of time. Only when it is wholly past – has ceased to become – only then is it without time’s passage. For, as I have argued contra McTaggart and Mellor, the past has no scale of ‘near’ or ‘far’ along which a ‘dead fact’ can be conveyed. Thus, ageing is a process that occurs in the present, not in the past. Such wholly past entities are, like photons in relation to proper time, ‘frozen’ in time. They remain fully in existence, just as the past parts of entities that are still in the process of becoming in the present are fully existent. Thus, presently existing entities that possess past parts are wholly real, spread as they are across present and past.

There is a multitude of *A*-series, or clocks, found in the world with their own rates of passage; and these different *A*-series (as real patterns) can be found distributed across different ontological scales that reside at the macro-scale of time. These clocks are actual illustrations not only of the vast array of possible different rates of proper time as per SR and GR, but also of the different rates of decoherence in QM according to the size, or number of degrees of freedom, of entities, previously examined in 5.1.1.

6.4 Composition of A-Series Real Patterns

6.4.1 Notional Causation and Notional Coherence

When it comes to understanding the composition of *A*-series real patterns we are immediately confronted with the need to understand causation. In this regard I reproduce a quote from Ladyman, previously given in 1.4:

Roughly speaking, chemistry says that atoms compose molecules when there are (relatively enduring) chemical bonds between them, and economics says that agents compose a market when there are financial transactions between them. In both cases, the systems in question are considered over time, and composition is a result of interactions between the parts of the whole. Hence, the answers that science gives to the special composition question make reference to causal processes, not to instantaneous facts about, for example, how close things are to each other. (Ladyman 2017 p. 157)

Ladyman and Ross always insist that their approach to metaphysics is careful not to take sides in the debate about the nature of time; whether it is 'static' or 'dynamic', 'tenseless' or 'tensed'. Thus, according to them, the nature of the interaction "between the parts and the whole" could be (what I call, following Skow) either anaemic or robust. However, this thesis argues that anaemic interaction applies strictly to the generic nonseparable entangled state at the meso-scale of time; whereas robust interaction, being part of the process of becoming of an A-series, is confined to the macro-scale. Therefore, interactions that compose 'things' as real patterns are robust and may be either quantum or classical. With the process of composition on the macro-scale of time being causal, we need to examine the concept of causation in rainforest realism. Recall from 1.6 that Ladyman and Ross hold that causation is both a notional and a folk concept, while leaving open the possibility that fundamental physics may in future develop a scientific concept of causation. These notional and folk concepts of causation are useful to special science and everyday living respectively. Ross, Ladyman, and Spurrett identify the following three core features of the content of the folk concept of causation:

First, it construes causal relations as centred on some agent of change (animate or otherwise), thereby distinguishing agents and patients. Second, it postulates various transformative principles (often conceived as 'forces') proceeding *out from* an agent *to* the recipient of causal influence. . . Third, the core folk notion of causation incorporates assumptions about time-asymmetry: causal influences flow from the past into the future.

(Ladyman *et al.* pp. 268-269, their emphasis)

In relation to the present thesis, the most important feature is the time-asymmetric one, which, as is to be expected, fits well with the folk concept of time. When it comes to the notional concept, Ross, Ladyman, and Spurrett note that when special scientists talk of causes, they are talking of causal explanation, and that each science usually has its own set of causal relations rather than there being just one set applicable to all. Causal explanation may be sought in different 'mechanisms', as identified by different sciences, for transmitting the same asymmetric influence-flow found in the folk concept. They hold that these various (successfully identified) causal relations are objective, and that "those relations should be explicated in terms of processes" (Ladyman *et al.* p. 274). It can be seen from this that there is no conflict between the notional and folk concepts of causation. Ross, Ladyman, and

Spurrett put this down to the thin-ness of the folk concept's core features. This allows them to leave

the folk concept of causation intact (as our view of the concept of things leaves that concept intact, rather than claiming like Eddington that it applies to electrons but not to tables). . . [Thus] the core folk concept of causation need not conflict with naturalistic philosophy of science or naturalistic metaphysics. (Ladyman *et al.* p. 274).

This idea of notional concepts not clashing with their folk counterparts may appear as slightly odd to some. Ladyman and Ross can often be found criticising analytic metaphysics for “domesticating scientific discoveries” (Ladyman *et al.* p. 1). But the accommodation of (some) folk concepts with notional concepts has nothing to do with the domestication of science but may have much to do with the non-reductive unity of science. The ontology of rainforest realism, as Ross, Ladyman, and Collier write, “makes room for everyday objects and treats them on a par with the objects of the special sciences” (Ladyman *et al.* p. 254), i.e. they are ‘individuated’ as real patterns not as metaphysical individuals.

I claim to have demonstrated that the manifest image of time, far from clashing with the scientific image, just is the union in thought of scientific and notional time. And now we can see that the manifest image of ‘things’ is dependent on causation, which itself is dependent on the time-asymmetry of notional time. Also, causation (it is claimed) is notional and folk only, but time is both these plus scientific. With special sciences being housed in notional worlds, the claim can be made that the non-reductive unity of science is achievable because time (and with it, space) belongs to all three categories of scientific, notional, and folk. Now, to restate part of a Ross, Ladyman, and Spurrett quotation from 1.6:

[T]he PPC at least requires that such time-asymmetry as appears to be characteristic of our region of the universe be compatible with fundamental physics and the ubiquity of such time-asymmetry would in turn explain the value of the ‘causation’ locator in special sciences. (Ladyman *et al.* p. 277)

Complying with this requirement we have (notional) time-asymmetry being compatible with fundamental physics due to it being ontologically emergent from (and constrained by) scientific time; causation, which assumes time-asymmetry, is an indispensable concept to the

time-asymmetric notional worlds of special science; and ‘things’ that populate both special science and our everyday world are composed by causal processes over time.

There is another notional concept that plays a crucial role in the special sciences; one that enables the identity of specific processes of composition as individuated ‘things’. This is the concept of ‘cohesion’. Since projectibility – the modal notion of information-carrying possibility – grounds the existence claims for any real pattern, Ross, Ladyman, and Collier write:

Induction is therefore part of the manifest and scientific images in the sense that we individuate objects in the light of inductive knowledge of what is relatively invariant. The objects that we identify are ontologically secondary to the modal structure of the world. . . Induction is any form of reasoning that proceeds from claims about observed phenomena to claims about unobserved phenomena.
(Ladyman *et al.* p. 255)

The relative invariance that allows us to individuate objects and upon which inductive knowledge is built is an expression of their cohesion. This idea of cohesion was developed by E.O. Wiley (Wiley 1981) in the context of phylogeny so to understand how species cohere. John Collier further developed the notion by generalising it so to help analyse individuality (Collier 2004). Ross, Ladyman, and Collier now identify ‘coherence’ as a strictly notional concept, having neither scientific nor folk counterparts. For them, an object coheres “if there are propensities of forces and flows that show statistical distribution in space and time . . . such that propensities of centripetal forces and flows are favoured over propensities of centrifugal ones” (Ladyman *et al.* p. 247). It is important to realise that, as coherence is solely a notional concept, such ‘centripetal’ and ‘centrifugal’ forces are not found in fundamental physics. Nor is it a folk concept, for its role is scientific, so

the key conceptual job performed by cohesion is that it is an equivalence relation that partitions sets of dynamical particulars into unified and distinct entities. . . Cohesion is this unity relation for dynamical objects and their properties. It does not apply to things that are not taken to be unified by internal dynamical relations, for example rainbows or uncontained gases. It is invariant under conditions that do not destroy it, so that breaking the cohesion of a thing is equivalent to destroying its status as a thing. When a star explodes it ceases to be that star. When a species splits into distinct descendent species there are no longer any members of the original species.
(Ladyman *et al.* p. 248)

The notional concepts of causation and coherence are crucial to explaining the composition and individuation of *A*-series real patterns, and, as we shall see next, they are also central to real patterns being found at different ontological scales.

6.4.2 Composition of Real Patterns at Different Ontological Scales

Most of this subject has already been covered in Chapters 4 and 5 with the emergence of content at the macro-scale of time. There, emergence was examined from both a quantum and a condensed-matter physics perspective. The causal and coherence processes that compose real patterns of the *A*-series will differ according to which science they fall under. So, for instance, there is emergence due to decoherence, spontaneous symmetry breaking, and the universality (multiple realisability) of phase transitions, that results in stable states of matter (protectorates). In this way, real patterns as ‘processes’ compose, dynamically and diachronically, real patterns as ‘things’. Emergence and composition at the macro-scale just is the same process, and this process occurs in the present of an *A*-series.

Such processes-as-things can occur at different spatial and temporal ontological scales. For example, atoms, molecules, and tables belong to different ontological scales – though all are found at the macro-scale of time as different *A*-series or ‘clocks’. Hence, the definitive process of composition at this scale is the interaction of content from the meso-scale of a present time-atom with the macro-content that can consist in both specific information about the past of that *A*-series ‘clock’ and general information about its environment. To conform with SR, the availability of all such information is constrained in a way that, when represented in a spacetime diagram, only information about events on or within the past light-cone of the instant covered by the present time-atom is allowed. This interaction between the content of meso- and macro-scales is the ubiquitous quantum measurement, or objectification, of quantum mechanics, which gives rise to the ‘quantum measurement problem’. That is, the interaction is inexplicable within quantum theory itself. However, from a metaphysical perspective, as explained in 5.1.3, this ‘problem’ can be hailed as a triumph – as being the guarantor of the physicality, uniqueness, and time-asymmetric structure of the empirical world.

This reinforces the claim of compliance with the PPC made in the previous subsection, for metaphysics here is not dictating what physics ought to be telling us but is merely (so to speak) filling a vacuum in our understanding left by physics through its (believed) inability to pronounce on the matter. And of course, in operation alongside causation in the composition of A-series real patterns is cohesion in their individuation. As Ladyman and Ross write: “cohesion and causation are precisely *not* scientific ideas: they are metaphysical ones. Science, including special sciences as full, first-class, citizens, tells us to banish them from our first-order ontology” (Ladyman *et al.* 2007 p. 300, their emphasis).

Thus, the very lack of a scientific explanation for quantum measurement, or objectification, provides the opportunity for a metaphysical explanation. In this sense, we can say that quantum measurement, or objectification, is the causal ‘mechanism’ that (somehow) transfers information from the meso- to the macro-scale of time, which information can then mingle with macro-information about the past. Whenever intermingling of the differently sourced information results in the composition of real patterns, then this is (notional) cohesion in action. Now, as Ross, Ladyman, and Collier inform us, cohesion is a tool for locating real patterns and “location is irreducibly pragmatic and perspective dependent” (Ladyman *et al.* p. 249). Here is where scale relativity of ontology becomes obvious (at least to the rainforest realist) – which real patterns we discover depends on which perspective is taken in whatever science and at whatever energy or spatial and/or temporal scale.

7. The Language and Experience of Time

7.1 Folk Discourse

7.1.1 The Scope of 'Now'

When it comes to discussing time, the folk category is particularly useful. However, when doing metaphysics, unless we understand that the concepts being used at any time are folk concepts then misunderstanding will inevitably follow. The most elastic term to be found in the temporal lexicon is that of 'now'. Its referents can range from the extensionless instant of a 'here-now' point of four-dimensional spacetime, to a present time-atom, through a specious present and on up to a duration of infinite length, including all points (as instants) and durations in between. For example, we can say: "It is now 4 o' clock", "It is now Thursday", "It is now May", "It is now 2021", "It is now the 21st Century", "It is now the 3rd Millenium", "It is now the time of the universe". In the first example 'now' refers to an instant, whereas in the final example 'now' refers to the duration through which the universe exists – however long that may be. In the other examples, 'now' refers respectively to durations of the lengths of one day, one month, one year, one hundred years, and one thousand years.

This term 'now' can be categorised according to the rainforest realist schema: 'now' as instant will be scientific; as duration, notional; and, as a combination of instants and durations, it will be found in the folk category. The scientific 'now' applies to any, and all instants as the temporal aspect of 'here-now' spacetime points and, since the present only comes into existence with the emergence of content at the macro-scale, the scientific 'now' recognises no present time. All instants, 'individually' and 'collectively', are/exist together as 'now'. This is obviously so when we recall that OSR has instants as derivative relata of the earlier than relation, that just is the temporal aspect of spacetime. In other words, the earlier than relation ensures that all instants as relata exist 'Individually and collectively' now. Thus, when we say that "spacetime exists now", we do not nonsensically imply that spacetime exists in time but simply that the temporal aspect of spacetime just is (scientific) now.

The present, for the same reason, is also absent from individual time-atoms at the meso-scale as well as aggregates of empty time-atoms at the macro-scale of notional time. Therefore,

notional 'now' can have two types of referents. One is the sempiternal durational 'now' that, existing in a world without macro-content, covers or extends over the instants that constitute the scientific 'now', and is without passage. This sempiternal duration is the aggregation of all time-atoms viewed from the perspective of an empty macro-scale. The term 'sempiternal' is used here to indicate that the duration covers, or extends over, all instants of the 'eternal' *B*-scale. The other type of durational 'now' exists in a world with macro-content, and hence with an *A*-series. This 'now' can refer to any length of duration of the *A*-scale that *includes a present time-atom*.

When we use the word 'now' in a folk sense, we combine scientific and notional nows in thought and so include 'the present' as an integral part of its meaning. Also, the sempiternal duration may be divided into any length that thought can imagine; and provided the present is thought to be part of any such length, then the folk 'now' can equate to any length. Thus, some of the 'now-times' given earlier will mean: "It is presently 4 o' clock", "It is presently Thursday", and "It is presently the time of the universe". Note that the first phrase (strictly scientifically and notionally false, though approximately true) designates an instant as present. 'Now' is the quintessential (temporal) folk term, for it ultimately encompasses all time at all scales. This folk now bears comparison with Mellor's take on 'present':

In 1943, World War II stretched four years into the past and two years into the future. Yet it was certainly present then . . . So it's *A*-time, a six year *A*-interval including the present moment, should, despite its length, count as present. Similarly we should call any *A*-time 'present', however long it is, if and only if it includes the present moment. That makes *this century* as present an *A*-time as *today* or *this moment*. And so it should, since a centenarian whose *A*-time it is will obviously be present throughout it.
(Mellor 1998 p. 9, his emphasis)

Mellor's term 'present' here is very close to what I have described as the folk now. Thus, Mellor's 'present' can stretch from an instant as 'the present moment' to a sempiternal duration "if and only if it includes the present moment". However, for the *B*-theorist Mellor, real time just is scientific '*B*-time'; and so, what he is describing here is a folk (or manifest image of) time that has no objective reality – although he does recognise that it is of great practical value as a purely subjective indexical. Whereas, I have argued that, not only are there three ontic scales of time that are objectively real, but so too is the *A*-scale that emerges

(together with content) at the macro-scale. For me, it is the objective reality of the A-scale that ensures the practical usefulness of this folk now – because it anchors our subjective experience of ‘now’ (as the specious present) to specific time-atoms that are objectively present. This is examined in 7.3.

7.1.2 All Content at the Meso-Scale of Time Exists Now

We saw at the end of 6.1 that there can exist now, meso-content at time-atoms that are later than now. The two uses of the word ‘now’ in the previous sentence must have two different referents if it is to make sense. The first refers to the notional now as a sempiternal duration. The second, of course, refers to the present. There also exists now, meso-content at both the present time-atom and past time-atoms (using the folk sense of past as earlier than the present). In other words, all content at the meso-scale of time exists now (sempiternal duration). Consequently, we appear to have arrived at a Block Universe! In fact, far from arriving at such a universe, this thesis seeks to demonstrate that we (along with all the ‘furniture’ of our empirical world) *have emerged/are emerging from* this ‘Block’, and that the universe, or world, is considerably more than just this ‘Block’.

There is another very small but very important difference between this ‘Block’ and the standard Block Universe that is favoured by many physicists and philosophers. The content of this ‘Block’ is not located at instants, but is located solely within time-atoms, i.e. it is durational and not instantaneous. Another difference concerns the nature of the content itself. ‘Meso-Block’ content just is a nonseparable state of quantum entanglement, whereas the standard Block Universe may be populated by all sorts of classical entities as individuals. Thus, Balashov writes:

To be sure, if one is an eternalist one must admit that there is a basic sense in which *all* inhabitants of spacetime – those which we call (in our unreflective moments) past, present, and future – coexist with each other, simply because all such entities – including dinosaurs, Nebuchadnezzar, Napoleon, Nicolas Sarkozy, future human outposts on Mars, and Gorbachev’s great great grandson – *exist*, at their respective spacetime locations.
(Balashov 2010 p. 131, his emphasis)

However, there are two things that these two 'Blocks' may be said to have in common. One is that both of their respective contents exist now. However, the Meso-Block 'now' is in the notional sense of a sempiternal duration without an *A*-scale, whereas the standard Block 'now' is in the scientific sense of a block of instantaneous three-dimensional slices. The other thing found in common is that becoming is found in neither block, hence neither recognises an *A*-series. Sometimes though, Block Universe eternalists, when using the folk category (e.g. Balashov's 'unreflective moments'), say that the past, present, and future are equally real. This is a folk interpretation of their view that all times and their content exist (scientific) now.

7.1.3 All Past and Future Times Exist Now

If I begin by asserting that the above heading is a folk phrase, then, from what has just been written, it should be clear that it need not be affirming eternalism or a Block Universe. Recall from 3.4.3 the extraordinary usefulness of the epistemic entangling of the *A*- and *B*-series that was praised as a great achievement of folk knowledge of time. This entanglement creates in thought the idea of degrees of pastness and futurity that Mellor designates (with the present) as the *A*-scale of time. It is these ideal (folk) degrees of pastness and futurity that are being referred to as past and future *times* in the heading. For, as I have argued, the real (notional) past and future positions on the *A*-scale have neither degrees nor internal divisions. Instead, past and future are simply two of the three single positions (the other being the present) that constitute the entire *A*-scale. Thus, folk 'past times' refers to those serially ordered time-atoms that have content at the macro-scale of time and constitute the past of an *A*-series. Whereas 'future times' of that *A*-series refer to the serially ordered time-atoms that are contentless at the macro-scale and constitute the future of the series.

Each atom in the series is then assigned a 'time', i.e. a position (or degree of pastness or futurity) on the ideal *A*-scale, reflecting the earlier than relation that has the appearance of constraining the order of the macro-scale series. Note that the 'now' referred to in the heading is not the notional now of a sempiternal duration that was referred to in the previous subsection heading. Here, a folk now that includes macro-content is being used. This folk now allows both the 'past', as that part of the duration that is earlier than the present, and the 'future', as the part later than the present, to be divided into different 'times'. Therefore, the

folk heading, in referring to this folk now, is in no way making the absurd claim that all past and future times exist in the notional present (as time-atom) or at the folk present time (as instant) or exist simultaneously.

7.2 Metaphysical discourse

7.2.1 Making Sense of Eternalism

Like Stein and Arthur, Dorato also argues that there is becoming in Minkowski spacetime and that this form of becoming consists in the successive occurrence of events from earlier to later times. I have argued against this view being applied to the 'Meso-Block' as I agree with Skow that, at most, merely anaemic change exists from earlier to later in any four-dimensional Block and that such change does not qualify as a form of becoming. Nevertheless, it is worth engaging with some of Dorato's ideas as expressed in "The Irrelevance of the Presentist/Eternalist Debate for the Ontology of Minkowski Spacetime" (Dorato 2006), for it allows me to clarify my position in relation to those of analytic metaphysics of time. Of course, I agree with the sentiment behind Dorato's title. However, I disagree with his reasoning behind it.

Dorato seeks to show both that there is no substantive difference between eternalism and presentism, and that there is becoming in Minkowski spacetime. However, as stated in 2.1, I claim that Minkowski spacetime is 'empty' of content. Also, since there are no objects 'within' that spacetime, both eternalism and presentism are mistaken in their common claim that objects are located, or exist, at instants. (I disregard those presentists who claim that the present is a duration, for I fail to see how Augustine's argument against this notion can be avoided other than by invoking different ontic scales of time (as I have done) – but that is simply not possible if 'only the present exists'.) Here is Theodore Sider's brief ontological description of eternalism and presentism (part of which is quoted by Dorato):

According to *eternalism*, past and future objects and times are just as real as currently existing ones. Just as distant places are no less real for being spatially distant, distant times are no less real for being temporally distant; the ontological significance of distance is thus a respect in which time is spacelike. Reality consists of a four-dimensional spatiotemporal manifold of events and objects – the so-called 'block universe'. In the block universe, dinosaurs, computers, and future human outposts on

mars are all equally real. According to *presentism*, on the other hand, only currently existing objects are real. Computers, but not dinosaurs or Mars outposts, exist. (Sider 2001 p. 11, his emphasis)

The description of eternalism is especially helpful because it considers the ontological status of times and not just that of the more oft mentioned objects. (Also, I trust that it is clear by now that this is a respectable *folk* description.) It seems to me that Sider captures the nub of eternalism. Thus, if “past and future objects and times are just as real as currently existing ones”, then they must be equally as existent as ‘current’ existents; and so, in some (folk) sense, past and future objects and times must exist together. Yet this is precisely what Dorato argues against, and in doing so claims that events successively (tenselessly) become. Thus, he writes:

No sensible eternalist will argue that the events along the temporal dimension of the universe are all simultaneous with each other (as in a *Totum Simul*), because otherwise such events could not occur, as they actually do, in temporal succession. But if events occur in succession, then there is [a] form of becoming consisting of such successive occurrence, and events cannot coexist simultaneously as they do in space.

(Dorato 2006 p. 97, his emphasis)

I explained in the previous subsection how the claim that all (ideal) past and future times exist now can make perfect sense; so that, when recognised as a folk statement, it clearly does not imply that the past and future exist simultaneously. Although Dorato is here referring to *B*-times, not *A*-times, my argument still applies – for ‘past times’ and ‘future times’ just are folk expressions that refer to time-atoms ordered “along the temporal direction of the universe” in such a way that they strictly mimic *B*-times. As explained in 7.1.1, *B*-times as instants exist together, i.e. they coexist – as do all time-atoms. Even though instants are ordered by the earlier than relation, this in no way implies that there is some sort of successive *occurrence* of different times. The *B*-scale exists now (scientific category). This means that coexistence does not imply simultaneity. Recall from 2.1 that I endorse Robb’s claim that no instant can be simultaneous with any other. Yet, they are coexistent as (derivative of) aspects of a real spacetime that exists now, i.e. no part of it is in any sense becoming.

Unfortunately, Dorato (as do many others) conflates coexistence with simultaneity; so that for him, if successive events were to coexist then they must be simultaneous – something which we can agree with Dorato to be absurd. No two events can be both successive in time and simultaneous. As Dorato rightly says, no sensible eternalist makes any such claim. The only way that a *B*-scale can exist *qua* scale is if all *B*-times exist together in the scientific now. Thus, all *B*-times forming a *B*-scale must exist together within the same scale; and since different times are merely different positions that mark off the scale, they cannot be at the same position in time (or simultaneous). They coexist as that scale.

However, Dorato uses the conflation of coexistence with simultaneity to argue that the occurrence of a temporal succession of events, in conjunction with the impossibility of successive events coexisting simultaneously, implies a “form of becoming”. The notion that bears most of the weight of the argument for Dorato’s becoming is ‘occurrence’, for he writes:

[I]n Minkowski spacetime timelike-separated events are objectively, invariantly timelike-related, and events, *by definition, occur or happen*. They do so, so to speak, *a priori*. If any two events *are* tenselessly timelike-separated, and a reasonable arrow of time can be assumed, one event will happen after the other, and this suffices to assume the mind-independence of (tenseless) becoming.
(Dorato 2006 p. 97, his emphasis)

The problem with this approach to metaphysics is that other philosophers may disagree with such a definition. Take, for instance, William G. Lycan when he writes concerning his semantic theory of conditionals:

‘Event’ here is used in a slightly uncommon way, as being roughly equivalent to ‘case’ or ‘circumstance’ or ‘situation’. Events are not things that *happen* or occur, rather they *obtain* or materialize.
(Lycan 2001 p. 17, his emphasis)

Of course, both definitions may be right within their different contexts. However, Dorato claims too much for his definition. Even were his definition the one most commonly used, that would not validate the claim that an event “so to speak, *a priori*” occurs or happens. Rather than strengthening Dorato’s metaphysical case, such word usage appears to beg the question. It may be argued that Dorato’s usage is correct in the context of events as relata of the causal relation; and since the causal relation is to be found within the light-cone structure

of Minkowski spacetime then such causally related events, by definition, do indeed 'happen' within Minkowski spacetime.

However, such a context does not apply in rainforest realism with its scale relativity of ontology. Recall from 6.4.1 that causation is a notional concept (not applicable to scientific spacetime), and from 6.4.2 that notional causation emerges at the macro-scale of time with the emergence of macro-content. Thus, the (quantum) events that belong to the meso-scale of time do not 'happen' or 'occur' in Dorato's sense because they are *not* related to the causal relation. They are the basis from which the causal relation emerges through quantum measurement, or objectification. These non-causal meso-events are viewed classically as ordered by the earlier than relation, which orders the light-cone structure of spacetime.

Thus, it is Lycan's definition of 'event' which is applicable in the context of scientific spacetime. Dorato's dynamic definition of 'event' as 'happening' or 'occurring' applies in the context of non-scientific, notional, macro-time – with the emergence of dynamic, notional causation along with strictly A-series real patterns of both dynamic time and its content. From a rainforest realist perspective, then, Sider's description of eternalism, with past, present, and future times and objects being equally existent and equally real – thus ruling out any form of becoming – makes more sense than the notion held by those like Dorato who view Minkowski spacetime as being compatible with (tenseless) becoming.

It is worth noting that, ironically, Dorato's notion of eternalism seems to contrast nicely with a version of presentism that is due to Quentin Smith (Smith 2002) called 'degree presentism'. Whereas Dorato's eternalism has past, present, and future as somehow equally real but not equally existent, Smith's presentism has degrees of pastness and futurity that, *qua* degrees, are equally existent, but not equally real. For Smith, only the present is fully real while past and future degrees of reality are proportional to their distance from the present. So, the closer to the present, the more real the degrees of pastness and futurity; the further from the present the less real they are. Having said that, the presentist Craig Bourne writes that "degree presentism does not count as a genuine variety of presentism [since] . . . times other than the present do exist; it is just that they are less real" (Bourne 2006 p. 24).

To be clear, then, I agree with 'sensible' eternalism to the extent that all past, present, and future *times* (as per folk category) are equally existent and equally real. Where I disagree is

that, while I hold that all content at the meso-scale of time is equally real (i.e. there exists meso-content both earlier than and later than now), there is no macro-content existing at the future position of the *A*-scale. This position may at first blush appear similar to that of a Growing Block Universe. But a little reflection shows this not to be the case. I argue for: a fully existent 4D spacetime, not a growing one; a fully existent Meso-Block, not a growing one; a fully existent (though empty of any content) future *time*, not a non-existent one; a durational present, not an instantaneous one; and a past that is a single position in (*A*-)time, not one that consists in (*B*-)instantaneous slices of 4D spacetime.

7.2.2 Is the Tensed-Tenseless Debate Substantial?

Eternalism is known as a tenseless theory of time. Other theories such as the moving spotlight, the growing block, and presentism are known as tensed theories. Whereas Dorato argues against a substantive difference between eternalism and presentism on ontological grounds, others argue the same case on linguistic grounds. Thus, Bourne (himself keen to keep the distinction substantial) writes:

It is often argued that there is no substance to the tensed-tenseless debate – that once we recognize the confusion over tensed and tenseless readings of various quantifiers and copulas, the tenseless theorist’s ‘does exist in the past’ is not substantially different from the tense theorist’s ‘existed’ – they are the same theory under different descriptions.
(Bourne 2006 p. 66)

Such an approach is signalled in the title of Savitt’s article, “Presentism and Eternalism in Perspective” (Savitt 2006), in which he argues that these ‘isms’ are different perspectives, or descriptions, on the same underlying reality. Savitt attacks the use made of “the formal similarity between presentism/eternalism and actualism/possibilism [that is] supposed to help in formulating a non-trivial presentism/eternalism distinction” (Savitt 2006 p. 117). He notes that a central notion found in this formal similarity is that of unrestricted quantification, which refers to the set of everything that exists – call this set, **D**. But, as Savitt shows, the sense of ‘exists’ can be ambiguous, for various senses are available to choose from, such as taking ‘exists’ to be either a tensed, a detensed, or a tenseless verb. It is, he claims, when **D** appears ambiguous due to not specifying which sense of ‘exists’ is being applied that the

tensed-tenseless debate can appear substantial. Thus, Savitt writes of the notion of unrestricted quantification that, “once it is understood – once it is specified unambiguously – the standard way of trying to distinguish presentism from eternalism evaporates” (Savitt 2006 pp. 117-118). Savitt later adds:

One should not hastily conclude, however, that alleged difference between these venerable positions has been shown to be *merely* verbal. . . [There is] a difference in perspective as well as a difference in language. Presentists adopt a point of view that is close to temporal experience, confronting the actually occurring, as opposed to merely past or future, events. Eternalists consider the totality of actual, as opposed to merely possible or otherwise non-historical, events. The latter perspective seems necessary for physics, for the determination of the geometric structure of space-time. The former perspective is, as it were, those living inside the structure contemplated by the latter from “outside”. . . Each perspective is compelling, unless it errs by thinking that it is the only point of view worth taking, (Savitt 2006 p. 124)

Thus, for Savitt, the structure of reality that both *A*-theorists and *B*-theorists refer to is one and the same. There is no substantial difference between their theories. The difference is both verbal and perspectival, with each method of description or point of view being equally valid.

The opposite approach is taken by the presentist Mark Hinchliff, who maintains that there is a substantive difference between the two perspectives. Hinchliff argues that, unlike the eternalist, for whom time is like space, for the presentist,

time is like modality: other times are like other possible worlds; they are not real. As there is something special about what is *actual* – it is all there is – so there is something special about the *present* – it is all there is. The way things are is the way things presently are. (Hinchliff 2000 p. S576)

Hinchliff informs us that here the word “‘presently’ should be read as an indexical tense operator”, in contrast to ‘exists’ which should be taken as non-indexical; and the quantifiers “should be read as unrestricted quantifiers” (Hinchliff 2000 p. S576). In doing so we will understand the difference between the sentences ‘Newton exists’ and ‘Newton presently exists’ in that the former expresses the same proposition at different times, whereas the latter indicates different propositions at different times. The claim is that the “difference in

the semantics enables us to express the substantive difference between presentism and eternalism” (Hinchliff 2000 p. S577).

I believe that the roots of scepticism regarding any substantial difference between tenseless and tensed theories within analytic metaphysics can be directly traced back to the ambiguous way in which McTaggart characterised the *A*- and *B*-series. In a bid to dispel this ambiguity, I have been at pains throughout to ensure the ontological separation of the *A*- and *B*-scales of time. However, I think that all analytic metaphysicians of time – even those who dislike the labels *A*- and *B*-series – might well agree with this statement from Bourne:

[I]t is possible to define the [propositional] operators [**P**, ‘it was the case that’ and **F**, ‘it will be the case that’] by quantifying over times and invoking the *earlier than* relation. **Tenses can then locate objects by specifying how much earlier or later objects occur in relation to the present.** . . . One major advantage of this approach is that it enables us to have some **common ground between tensed and tenseless theories.** . . . [T]he tenseless theory uses the ‘*B*-series’ relations *earlier than*, *later than*, and *simultaneous with* to order objects in time. This results in the difference between the *A*- and *B*-series amounting to this: **objects in the *B*-series are earlier than, later than, or simultaneous with each other, whereas objects in the *A*-series are earlier, later than, or simultaneous with *the present*.** Thus calling those relations ‘*B*-series’ relations is a misleading way of putting it, since they are relations that can be shared by both *A*- and *B*-scales.
(Bourne 2006 p. 8, his emphasis, boldface added)

This is in complete accord with the original exposition of the *A*- and *B*-scales as introduced by Mellor to clarify McTaggart’s ambiguous description of the *A*- and *B*-series. Recall my critique of Mellor’s *A*-scale in 2.4 where I argued that the earlier than relation is the distinguishing attribute of McTaggart’s *B*-series and thus is a strictly *B*-relation that is non-applicable to the *A*-scale. I further argued that when Mellor does apply the earlier than relation to the *A*-scale, although the two series are kept separate by the relation having different relata in each series, in doing so it fails to ascertain a metric within the past and future.

This is because, when any two past events are viewed as being earlier than *the present* (Mellor’s distinguishing feature of the *A*-series) this merely confirms them as being past. It does not indicate which event is further back in the past than the other. Only when McTaggart’s original (distinguishing) *B*-relation of earlier than is applied to past events in relation to each other – not to the present – can we say which past event is earlier than the

other. By combining the two (supposedly distinguishing) applications of the earlier than relation, we can ascertain that: (i) the two events are in the past, (from Mellor's 'A-earlier-than-relation'); (ii) one past event is earlier than the other (from McTaggart's and Mellor's 'B-earlier-than-relation'); therefore, (iii) one event is further back in the past than the other. Hence, Mellor's 'A-earlier-than-relation', that ensures the difference between the A- and B-series, cannot by itself ensure that the past and future positions in A-time possess a metric of degrees of pastness and futurity.

However, the 'B-earlier-than-relation' that just is the original distinguishing B-relation, when introduced into the A-scale, is sufficient for the construction of an expansive metric. Only when McTaggart's three-positioned A-scale of the fundamental A-series becomes entangled in thought with the multi-positioned B-scale does there arise (in the mind only) such degrees of pastness and futurity. Thus, not only my 'strong' separation of the two scales, due to (any application of) the earlier than relation being strictly withheld from the A-scale, but also Mellor's 'weak' separation, that allows the earlier than relation into the A-scale, results in an A-scale with only three positions: past, present, and future. This confirms that any talk of 'two past events with one being further back in the past' (such as Hegel's birth and death) is indeed purely folk discourse.

Bourne is quite right to recognise that it is this seemingly universal placing of the earlier than relation within the A-series that constitutes the "common ground between tensed and tenseless theories". However, he fails to see that it is precisely this "common ground" that guarantees that there can be no substantial difference between analytic tensed and tenseless theories. The phrase, "they are the same theory under different descriptions", sums up the situation in a nutshell. Recall McTaggart's starting point: "Positions in time, as time appears to us *prima facie*, are distinguished in two ways" (McTaggart 1908 p. 459, his emphasis). Thus, he explicitly begins from the manifest image of time, or folk time. This time can be described in two different ways, as A-time or B-time. Any theory of this one time, then, will be a theory of the one manifest image of time. The "different descriptions" just are A- and B-descriptions. The debate arises when one side holds that the A-term description is the correct one, while the other side holds that B-terms correctly describe time and that A-terms arise from either practical need or just plain illusion. However, both sides are merely claiming different parts of the manifest image as being how time really is.

This analysis echoes much of what Savitt has said. However, where Savitt understands the two descriptions as differently describing the same structure – the geometric structure of spacetime – I view them as describing different parts of the manifest image of time, or folk time. Though, in saying that, these two different parts of the manifest image represent within themselves either scientific time (*B*-descriptions) or notional time (*A*-descriptions), which explains the success of the manifest image in guiding both our everyday and scientific practical activities. As for Hinchliff, while I reject his view that there is any substantial difference between the theories of eternalism and presentism (for the reasons just stated) I believe his approach to semantics avoids Savitt’s argument concerning ambiguity over the notion of unrestricted quantification. Such semantics will further enable the expression of substantial differences between tensed and tenseless real patterns that were raised in 7.1. Thus, although there is no substantial debate to be had between tensed and tenseless theories of time, there can be a substantial debate between which real patterns are tensed and which are tenseless.

Standing apart from the analytic debate, there is a substantial cleavage between tensed and tenseless real patterns that depends on the ontic scale of time at which the patterns exist. Thus, when the earlier than relation is restricted to the micro- and meso-scales of time there can be no ‘common ground’ between tensed (past, present, and future) macro-scale real patterns and tenseless (earlier than) micro- and meso-scale real patterns. And so, on the one hand, all content constituting the Meso-Block exists tenselessly, which, described using classical concepts, is solely ordered in accordance with the earlier than relation and may be loosely referred to as forming a *B*-series. Thus, no meso-content can exist either in the past, present, or future. It exists in that notional now that is a sempiternal duration and is ontologically prior to any *A*-scale. On the other hand, all content that comes into existence (at the present) and continues to exist (as past) can do so only at the macro-scale of time. This macro-process, that just is the emergence together of macro-content and *A*-scale as an *A*-series, is, of course, tensed. We can say, then, that the world is both tenseless and tensed.

Some may argue that if the tensed or dynamic part is ontologically dependent on the tenseless part, then the world is fundamentally tenseless. This may be a perfectly reasonable conclusion – but it is not warranted according to rainforest realism. Recall from 1.4 that rainforest realism accepts all real patterns as on an ontological par; so that all real patterns,

whether extra-representational or irreducibly representational (as second order), are equally real. Thus, macro-scale tensed real patterns that emerge from, or are ontologically dependent on, meso-scale tenseless real patterns are no less ontologically fundamental, or real, than those ‘basis’ patterns. Metaphysically speaking, the world fundamentally consists in real patterns *simpliciter*.

And yet Ross, Ladyman and Collier have couched the question of the temporal structure of the world in terms of the more usual disjunction thus:

[T]he notional worlds we must construct to track most real patterns are irreducibly dynamic and time-asymmetric. By contrast, the actual world occupied by all observers we know about is *either* truly tensed, or else merely seems to us to be so given the measurements we can obtain, but is in fact a block universe. A PNC-compatible metaphysics should avoid presupposing either side of this disjunction.

(Ladyman *et al.* 2007 p. 246, their emphasis)

However, as stated in 1.5, I do not accept that the Principle of Naturalistic Closure need be complied with when doing naturalistic metaphysics. Besides, elsewhere Ladyman and Ross look beyond this disjunction so that: “One possibility is that neither the dynamical or block extremes are the whole story” (Ladyman *et al.* 2007 p. 173). And, of course, the present metaphysical thesis concurs with Omnès’ claim in as much as this possibility is not only not ruled out by current physics but its realisation may result from a natural limit to quantum theory itself. If that is right, then reality is a *conjunction* of tenseless and tensed. And so, far from the temporal structure of the world being one of either: “Still or sparkling?” (Ladyman *et al.* 2007 p. 162) it is, in fact, both: it is ‘still sparkling’.

7.2.3 How Open is the Empty Future?

In this subsection I propose to make liberal use of folk concepts of time as it makes for easier reading. After the earlier folk discourse explaining the metaphysical referents of these concepts, there should be little chance of misunderstanding. Now, the openness of the future is usually contrasted with the fixed past. David Lewis calls this view “asymmetry of openness”, which is

the obscure contrast we draw between the “open future” and the “fixed past”. We tend to regard the future as a multitude of alternative possibilities, a “garden of forking paths” in Borges’ phrase, whereas we regard the past as a unique, settled, immutable actuality. These descriptions scarcely wear their meaning on their sleeves, yet do seem to capture some genuine important difference between past and future. What can it be?

(Lewis 1987 p. 37)

Lewis gives his own answer to this question as: the asymmetry of counterfactual dependence. This just means that Borges’ ‘forking paths’ are alternative futures that would occur if we supposed the present were different in various ways, whereas the past is “counterfactually independent of the present” (Lewis 1987 p. 39). In other words, change the present and you change the future but not the past. Lewis recognises that such ‘change’ is merely counterfactual supposition; so that were we to act differently in the present then the future would be different, but either way the past would remain the same. This counterfactual notion of the asymmetry of openness is independent of whether the world is deterministic or indeterministic, for Lewis writes that “indeterminism is neither necessary nor sufficient for the asymmetries I am discussing” (Lewis 1987 p. 38).

I think that Lewis provides a good description of how the folk think regarding this ‘asymmetry of openness’. It fits nicely with the folk idea that there are different degrees of pastness and futurity. Indeed, the very idea of future paths is dependent on the notion that there are degrees of futurity stretching out before us in time. Hence, while the past may be viewed as a single path stretching back from the present that is strewn with (fixed) content at various degrees of pastness, the future may be viewed as forking paths that stretch out before us, with each path attributed with different possible content. However, I want to show a metaphysical ‘asymmetry of openness’ that affords some credence to this folk counterfactual notion.

Determinism holding in the world means that how the world is at one time fixes how it is at both earlier and later times. Indeterminism allows that earlier and later times are not so fixed. Hence, my claim that the future is empty of content does not entail that the future is open, since, if determinism is true, then what will happen in the future is determined by our present actions in combination with the laws of physics. In which case there is no possibility that the content that comes to fill the future will be anything other than what is now determined to

be; and so, the future, though empty, is not open. On the other hand, indeterminism does not entail that the future is open, for if the world is a standard Block Universe, then the future is as fixed as the past – although, due to being indeterministic, it (as well as the past) might have been different to what it happens to be.

However, I argue that all content of time is separated by ontic scales of time. At the meso-scale lies Bacciagaluppi's generic quantum entanglement, forming what I have called the Meso-Block; at the macro-scale there emerges Omnès' passage of time together with content that is a unique actualisation of quantum probabilities as 'objectification'. Of course, such objectification or 'quantum measurement' is ubiquitous and independent of anthropocentrism. Thus, consciousness was able to arise over time, following the evolution of species, only because of physical processes of objectification or 'quantum measurement' that have been happening long before life, let alone consciousness, had developed. An A-series *per se*, then, that results from such objectification, is not a mental construct – only an A-series with added degrees of pastness and futurity is.

Now, although the notional future is empty of content, times later than the present (the 'future part' of the Meso-Block) can have content. Since macro-content of the future will be formed from information at both meso- and macro-scales interacting at the (then) present time-atom, what is possible for actualisation in the future is partly constrained by the meso-content that is 'already' existent there. This is so because content of the Meso-Block is structured according to the deterministic, linear, time-dependent Schrödinger equation; and so, for any later-than-now part of time possessing content, that content is fully determined.

Note that the physical 'interaction' that occurs when meso-content somehow 'interacts' with macro-content in objectification is analogous to a chemical reaction involving a catalyst: the meso-content somehow affects macro-content without itself being in turn affected by macro-content. If this were not the case, then there would occur robust, rather than anaemic, change at the meso-scale. Hence the description, in 6.4.2, of objectification as a 'causal mechanism' of notional causation strictly at the macro-scale of time. Therefore, any meso-content that is later than now is not *of* the future but may be *for* the future (if or when the 'containing' time-atoms become present).

The situation is quite different at the macro-scale, where all past content is the result of the interaction, in the (then) present, of indeterministic quantum objectification and (then) present information about the past. Therefore, indeterminism might seem to be the rule at the macro-scale of time. For instance, here is an interesting passage from Lewis in which he anticipates Bacciagaluppi in telling us of his “guess” that objectification, or ‘quantum measurement’ is in no way anthropocentric, that it is continually happening all around us, and further that it leads to an indeterministic world:

The theoretical foundation of quantum mechanics is probably wrong to say that reduction is brought on when people measure. But the working quantum mechanics of radioactive decay, coherent solids, chemical bonding, and the like can somehow stand on its own. It does not need this unfortunate anthropocentric foundation. Then the laws of nature that govern our world really are indeterministic. Whatever we make of the reduction of the wave function supposedly brought on by measurement, at any rate there are chance processes involved in radioactive decay, in the making and breaking of chemical bonds, in ionization, in the radiation of light and heat, and so on. These processes are pervasive. So much so that not only is the world as a whole indeterministic, but also it can contain few if any deterministic enclaves.
(Lewis 1987 p. 60)

In response to this, I would add that we, along with all other things existing at the macro-scale of time, are ourselves *products* of such objectification. All present things are in a continuous process of creation as objectification. However, while this process is indeterministic, “the world as a whole” is not indeterministic. I have already claimed that the world at the meso-scale is deterministic, and in Chapter 4 we saw where many “deterministic enclaves” may be found at the macro-scale of time – when we take ontological emergence and the scale relativity of ontology seriously.

Batterman notes that there is a preponderance of those who think of emergence in terms of mereology, and that while he acknowledges that sometimes this is useful when contrasting emergence to reduction, he maintains that the part/whole approach fails to reveal what is most important in many instances of emergence. Thus, he writes:

In fact, what is most often crucial to the investigation of the models and theories that characterize systems is the fact that there is an enormous separation of scales at which one wishes to model or understand the system's behaviors – scale often matters, parts not so much.
(Batterman 2015 p. 116)

Recall from 4.3.2 how Batterman's description of Laughlin's and Pine's 'protectorates' as "stable states of matter that are in effect decoupled and largely independent of physics at shorter length/higher energy scales" (Batterman 2010 p. 1040) was claimed as an expression of the scale relativity of ontology. Importantly for the issue at hand is that such emergent phenomena "display a kind of autonomy" (Batterman 2015 p. 117). Batterman emphasises the relative nature of this autonomy; so that, though the emergent phenomena do not supervene on the emergence bases, they do not float free of them either. There is still a relation of dependence acting as a constraint on the emergent behaviour. Just what the specific nature and degree of autonomy that holds for any 'protectorate' at whatever scale is, of course, for science to discover. The philosophical point to be made is that these 'protectorates' may be viewed as candidates for Lewis's "deterministic enclaves". The mere fact that they are described as 'stable states of matter' and claimed as real patterns, being projectible, suggests that there may be some sort of deterministic behaviour involved in the phenomena.

The world at our scale – the classical world – is certainly not *experienced* as either fully deterministic or fully indeterministic. At the much larger spatiotemporal/lower energy scales at which we live our ordinary lives, we believe that we successfully use folk (and notional) causation to both influence and predict the future. In science, induction is widely and successfully used to predict behaviour of phenomena, which again suggests some form of deterministic behaviour is at play.

Before any of this, however, there is the question of the existence of matter itself. Recall from 4.2 that Lehmkuhl cogently argues for the ontological dependence of matter on spacetime; further recall from 3.3 that I argued for the possibility of pure, or empty time. If these ideas are right, then the deterministic Meso-Block need not have existed – even though the spacetime and time that its existence depends on both exist. Hence, the deterministic Meso-Block may be the result of pure chance, or indeterminism. In which case, the Meso-Block

would appear to exhibit a 'kind of autonomy' from such indeterminism. From the deterministic Meso-Block there appears to emerge real patterns that are thought to be indeterministic at the scale of 'objectification', or 'quantum measurement'. Objectification occurs at the boundary of the meso- and macro-scales of time. This boundary, of course, is shared by these two ontic scales and, depending on perspective, is either the largest duration at the meso-scale or the smallest duration at the macro-scale. As we advance 'upward' to larger spatiotemporal/lower energy scales, we seem to discover real patterns displaying deterministic behaviour. Who among us truly doubts that the sun will rise tomorrow?

Hence, to Batterman's vague notion of 'kind of autonomous' I think we may add the equally vague notions of 'kind of indeterministic' and 'kind of deterministic'. The world, then, may consist in 'enclaves of determinism' as well as 'enclaves of indeterminism' that are 'kind of autonomous'. The idea of such a possibility is open only to those who hold that there is no fundamental level to the world. Whereas for those who hold that there is a bottom level, then the world will be either fundamentally deterministic or indeterministic. The rainforest realist will not be at all concerned by this outcome. After all, ontic vagueness is built into the very notion of different real patterns existing at different ontological scales. We have just seen the vagueness of the boundary between meso- and macro-scales of time (is it a meso-duration or a macro-duration?). Perhaps it is this very ontic vagueness that facilitates the interaction of meso- and macro-content, otherwise known as 'objectification'.

If various enclaves of determinism and indeterminism do in fact exist at different ontological scales, then the answer to the question How open is the empty future? will be extremely complicated. It will be for science and practical living to make progress in answering it.

7.3 Experience and the Specious Present

I end where I began – with the manifest image of time. In 1.1 I argued that the two parts of the manifest image, the *A*- and *B*-series, were intimately connected to the way we experience through the specious present. Later, in 3.4.3, I argued that the epistemic entangling of these two series was a very considerable folk achievement. I want to finish by further examining these issues.

I have already quoted Dainton in 1.1, where he says that through the specious present we apprehend change and succession. This notion of the specious present was held by William James, and elsewhere Dainton writes that for James the specious present

is also a stable, invariant *structural* feature of our consciousness: it is that which remains unchanged while many and varied contents stream through it. Husserl took a similar view, characterizing the living present as a *nunc stans*, a “standing present”, though with the qualification that this standing present is not static, it is a “standing flowing present”, i.e., it combines sameness – an “absolute abiding form” – with continual change and renewal.

(Dainton 2013 p. 391, his emphasis)

Invariant structure, as previously pointed out, is of special interest to structural realists; and for physicists, invariant structure implies objectivity. The question is, are James and Husserl correct here? I argue that they are.

There appears to be an isomorphism between the structure of the specious present (as given here and in 1.1), and the structure of the notional present (as described in 3.4.2) – but only if we take the specious present to be durational rather than as instantaneous. Dainton calls a durational specious present ‘Extensional’, and writes that it

consists of collections of experiential contents which are bound together by two forms of phenomenal unity: *synchronic co-consciousness*, which connects simultaneous contents, and *diachronic co-consciousness*, which holds when non-simultaneous contents are experienced as successive. The constituent parts of an Extensional specious present are distributed over a brief interval of ordinary clock time – probably no more than a second or so in a typical case, perhaps less – and are typically dynamic in character.

(Dainton 2013 p. 396, his emphasis)

In 1.1, the structure of the specious present is described as ‘of one time’ (apparently atomic) but its contents are viewed as ‘either earlier/later than each other or as simultaneous’. In 3.4.2, the structure of a notional objective present duration (time-atom) is similarly described as having content that is earlier/later than each other. Thus, in both cases, the structure is of a sort of ‘atom’ having content that is distinguishable in time through being earlier or later than other content. This ‘atomic’ nature of the specious present is well expressed by Dainton:

A specious present is a maximal diachronically unified experiential whole; as a consequence, the proper (i.e., briefer) parts of a specious present do not themselves

count as specious presents. In a more precise vein, we can say that a collection *C* of stream-phases (i.e., momentary or very brief phases of a stream of consciousness) constitute a single specious present if each of these phases is diachronically co-conscious with all the other members of *C*, and there is no larger collection of stream-phases *C** whose constituents are all diachronically co-conscious with one another, and which include *C* as a proper part.
(Dainton 2013 p. 406 n. 4)

Now, when we recall from 1.4 that which defines a real pattern for rainforest realism – whether the terms used are information-theoretic, statistical, or dynamical – then it appears that a specious present may qualify as a real pattern. This impression is reinforced if we agree with James and Husserl that a specious present is an invariant structure of our consciousness.

‘Past’ and ‘future’ are not terms that arise immediately within the specious present. They arise with the appearance and subsequent disappearance of content within these invariant structures. In the case of objective time, with changing content of the present there emerges an objective *A*-series of notional time as previously present content becomes past and the present ‘moves’ to the next empty time-atom. In the case of subjective time, with changing content of the specious present, there emerges a subjective *A*-series with its specious present, remembered past, and anticipated future. Just like the objective *A*-series with its ever-changing present, the structure of a subjective *A*-series with its changing specious present is analogous to the ‘transient autonomy’ of Humphreys’ virtual micro-patterns described in 3.4.2. Thus, the mind-independent *A*-series that continually (re)create the (approximately) three-dimensional world we see around us are mimicked in consciousness and mirrored – but at a much larger scale – in the mind-dependent world of our experience.

This ‘mimicking’ seems to be a trick of consciousness that ensures that time appears to us as is found in the manifest image. It is the indirect awareness of the passage of time as revealed by reflection on memories that makes us aware of the past and future. And only then do we become (indirectly) aware that the immediate awareness of change from earlier to later constitutes the specious present *as* ‘present’. For, as Le Poidevin writes: “To perceive something as present is simply to perceive it: we do not need to postulate some extra item in our experience that is ‘the experience of presentness.’ It follows that there can be no ‘perception of pastness’” (Le Poidevin 2019 Section 5). In the specious present, then, the immediate awareness of change is from earlier to later, not from present to past.

In objective time, though the earlier-to-later change in content is diachronic, it occurs only at the meso-scale within a time-atom and so is strictly anaemic. Thus, there is no dynamism or passage of time involved in such change. The 'trick' performed by the brain consists in the creation of an 'atom of consciousness' (specious present) with content that is experienced as changing successively from earlier to later in the 'now'. However, this macro-scale content has been dynamically created in the passage of *A*-time. Since the relata of this earlier than relation are themselves of a dynamic nature, in this case the change from earlier-to-later appears as robust. And so, as different content successively enters and exits the 'now' of the specious present it comes to be viewed as presently robustly changing. In this way, we can seem to have an immediate experience of continuous motion – as in the case of a second hand moving over a watch face.

The (re)creation of a subjective *A*-series is an ongoing process resulting from objective *A*-series processes involving the brain. However, the subjective *A*-series is an expansion in consciousness of the structure of the objective *A*-series. We have already seen the expansion of the present (being a single position in notional time) into the specious present (having multiple positions in folk time). These multiple positions are experienced within a specious present as earlier or later than each other and constitute the non-dynamic part of the manifest image of time. Hence, to the paradoxical situation of 2.5 is added a further paradoxical situation in which static positions in time appear to have dynamic content. The subjective *A*-series is also an expansion of the single positions of past and future in objective *A*-time into the multiple positions of McTaggart's expansive *A*-series. The expansion of the past and future is achieved through the entanglement in thought of the separate (fundamental) *A*- and *B*-series, as explained in 3.4.3, that just is the (complete) manifest image of time. This expansion manifests as an image of time that includes the far and near past and future as degrees of pastness and futurity.

Hence, the manifest image of time is created within the specious present by combining the immediate experience of changing earlier-to-later (but dynamically created) macro-content with a rational inference involving memory of previous content. This combination not only makes us (indirectly) aware of the existence of a past and future beyond the specious present itself but also introduces the earlier than relation into both past and future durations. And so, we can recall both that some content exited the (specious) present earlier than other content

and that the same content had previously entered the present successively in the same order. Thus, through the 'seemingly seamless union' of the two parts of the manifest image as experienced in the specious present, are degrees of pastness and futurity created in the mind.

Whitehead's notion of 'significance' may help in understanding the expansive subjective A-series. He writes that the basis of his concept of significance is the "disclosure of an entity as a relatum without further specific discrimination of quality", and continues:

Thus significance is relatedness, but it is relatedness with the emphasis on one end only of the relation. . . [I]n discerning an event we are also aware of its significance as a relatum in the structure of events. . . The most simple expression of the properties of this structure are to be found in our spatial and temporal relations. A discerned event is known as related in this structure to other events whose specific characters are otherwise not disclosed in that immediate awareness except so far as that they are relata within the structure. . . These signified events must include events in the remote past as well as events in the future. We are aware of these as the far off periods of unbounded time.

(Whitehead 2004 p. 51-52)

Using Whitehead's terms, a discerned event in the immediate awareness of a specious present is not only experienced as earlier or later than other discerned events within that present, but also signifies to us a continuation of the structure of time beyond the specious present. Hence, it signifies that there is both multiple earlier times and multiple later times than the present. When this 'significance' is combined with memory within a specious present, the signified vast expanse of times that are earlier and later than the (specious) present are understood as past and future. However, being divisible into earlier and later times, the past and future now consist in degrees of pastness and futurity. This manifest image of time introduces to consciousness the possibility of both planning for the future and understanding of the past – the *sine qua non* of agency. Additionally, with the expansive (specious) present of relatively large duration, it provides us with the time to think.

The process of composition of a subjective A-series is itself dynamic and is based on, or emergent from, processes of objective A-series. A subjective A-series takes a huge number of time-atoms to construct. To illustrate, let us assume that a time-atom is Planck time (10^{-43} of a second) and that a specious present is 1 second in length, then it would take 10^{43} time-atoms to compose a specious present. That is a lot of (re)creations of objective A-series by

which the structure of a specious present is (re)created. However, the number of ordered successive experiences that can belong to a specious present at any one time seems paltry by comparison.

Dainton estimates this number as follows. The 'order threshold' is the length of time above which humans can perceive the order of succession as one event follows another. Beneath this threshold two successive events in objective time can be perceived as occurring at different times but their order is indiscernible to our consciousness; and beneath this again lies the 'coincidence threshold', beyond which two objectively successive events are perceived to coincide. Dainton tells us that the coincidence threshold varies for different senses, but the order threshold is the same for all senses and is approximately 30 msec, and continues:

If we assume that a total experience is a phenomenal *succession*, then given that the order threshold is around 30msec, we would expect successive total experiences with discernibly different content to be separated by this sort of interval. In which case, between two co-streamal total experiences E_x and E_y separated by a single second (e.g. from the end-point of E_x to the end-point of E_y) there is unlikely to be greatly many more than thirty others.
(Dainton 2006 p. 170-171, his emphasis)

This underlines the difference in temporal (and hence ontological) scales between the process of quantum 'objectification' near/at the atomic scale of notional time and the process of classical 'objectification' at the temporal scale whereby folk discern a classical world of three-dimensional objects persisting over time. Since such objects, as real patterns, themselves emerge via quantum processes of objectification and decoherence, they are objectively existent at specific spatiotemporal scales and are independent of any consciousness that could experience them at those scales. One such object is, of course, the human body with its various organs, of which the brain is of special importance. As Dennett writes:

The brain's task is to guide the body it controls through a world of shifting conditions and sudden surprises, so it must gather information from that world and use it *swiftly* to "produce future" – to extract anticipations in order to stay one step ahead of disaster. So the brain must represent temporal properties of events in the world, and it must do this efficiently.
(Dennett 1991b p.144, his emphasis)

The 'swiftness' of this use of information to 'produce future' is of course relative to other processes occurring around us in our environment. And the information used is about the past that appears in the specious present either as memory (as being past) or as 'immediate experience' (as occurring 'now'). Recall from 7.1.1, the 'now' of the specious present is not only a notional duration having macro-content but must have a present time-atom as an essential part. Thus, as the objective notional present changes as content at/near the 'time-atomic scale' changes, so the specific time-atoms that constitute the 'now' duration of a specious present are continually renewed, as future atoms become present and hence part of the specious present, only to be left behind later as the specious present advances into the future with the objective present.

This analysis of a dynamic specious present avoids a problem that Dainton considers as afflicting some other durational (or 'Extensional') models of the specious present, which is, how does experience of one specious present belonging to one time appear to 'seamlessly flow' into a specious present belonging to a later time? In other words, how do different blocks of durational time, as specious presents, join to form a 'stream of consciousness'? Dainton's solution is to introduce additional overlapping specious presents, and so: "Rather than holding that neighbouring specious presents are discrete . . . we hold that they *overlap*, by sharing common parts or phases. . ." (Dainton 2013 p. 398, his emphasis). Thus, the problem is solved by introducing even more specious presents, whose overlapping structure forms a 'stream'.

However, I argue against the very notion of there being multiple specious presents making up a stream of consciousness. As presented here, the dynamic specious present is an invariant structure, a real pattern, continually (re)created in dynamic time. There are neither numerous separate nor overlapping 'blocks', but just the one persisting specious present belonging to each stretch of consciousness. The dynamic specious present does not belong to one time, rather its structure remains invariant as it 'passes over' time, i.e. while passing along a macro-series of time-atoms as the objective present advances into the future. Thus, the one invariant structure that is a specious present is viewed as persisting over time – continually being (re)created as time-atoms and macro-content 'pass through' – hence the analogy with Humphreys' 'transient autonomy' of virtual micro-patterns.

Although this subjective passage results from the objective present ‘leaping’ from time-atom to time-atom, there is experienced a smooth ‘flow’ in consciousness as the specious present advances, rather than one of sudden jumps. Thus, whereas objective passage is digital, subjective passage is analogue. Two things contribute to this ‘flow’ in consciousness. First is the seemingly seamless union in cognition of the experience of succession with the succession of experience in which continuous change and motion is experienced. Second is the huge difference in scale between the approximately instantaneous rate of ‘exchange’ of time-atoms that constitute a specious present as it advances into the future, and the vastly slower rate of change and motion of content as experienced in the specious present. Since our perception is unable to discriminate the fine-grained structure of macro-time (i.e. time-atoms cannot be perceived), a smooth ‘stream of consciousness’ is experienced as the specious present ‘sails’ into the future leaving more and more past experiences in its wake.

This means that a single stream of consciousness, such as wakefulness between two bouts of sleep, is experienced by a single specious present as both it and its content are continually (re)created as a subjective (expansive) *A*-series; the former as invariant structure, the latter as apparently changing over times. This process is dependent on the continual (re)creation of the objective present and its content that occurs at a much faster rate. Both rates, however, are measured by proper time.

In this instance, it would clarify matters were we to separate the notion of flow of time from that of passage of time. ‘Flow’ (as analogue) would then apply to the subjective experience of folk *A*-time, whereas ‘passage’ (as digital) would apply to objective notional *A*-time. However, these two terms are usually viewed as synonymous when applied to dynamic time. For instance, Callender writes that

the flow of time is accorded a central place in many researchers’ temporal metaphysics. Distinguished physicists, philosophers, and philosophers of physics all make room in their metaphysics for objective time flow. The typical idea underwriting temporal flow is that time passes or, more generally is dynamic in some way. The now, viewed as an objective temporal feature, moves or changes. (Callender 2017 p. 227)

Having explained in 3.4 the objective *passage* of time, I have now explained the subjective *flow* of time as being a different process to that of objective passage. Subjective flow occurs

at a different (ontological) scale from objective passage but is nonetheless wholly dependent upon objective passage for its existence. Thus, there can be passage without flow (consciousness) but no flow (consciousness) without passage. In this semantics, therefore, temporal flow just is the (cognitive) experience *as of* passage, not (perceptual) experience of passage.

Callender goes on to write of the importance of an 'enduring self' to the experience as of passage so that "the self, although intimately connected to our memories, provides the something that flows, the object with identity through time missing from the memory account of flow" (Callender 2017 p. 248). After writing that we humans have a rich notion of self, according to which the self both acts in the moment and plans for the short- and long-term, he describes such selves as

constantly representing ourselves in thought, language, and behavior, both to others and to ourselves. The spatial boundaries of the "momentary" basic selves need to be stretched diachronically to accommodate these plans and interactions. But it's crucial that this diachronic self is conceived as one object, for its whole point is to distinguish itself from others in planning and other interactions. This observation brings us to an important point for our purposes: selves *endure* through time. (Callender 2017 p. 249, his emphasis)

The sense of 'endure' here is that of the theory of endurantism, in which things persisting in time are held to be "wholly present at each time" (Callender 2017 p. 249) – though he makes clear he is only helping himself to this sense of the concept and not endorsing the theory. The whole point about selves is that they see themselves as separate from all other things external to them; and they see the external world as populated by objects that endure (in the endurantist sense), and yet can change over time. Selves also view themselves as enduring, and changing, in tandem with external objects (including other selves).

Callender argues that the idea of "the 'illusion' of time flowing is due to the conception of self as enduring" (Callender 2017 p. 491) but claims not to need a metaphysical theory of the self to underpin the argument. I have already dealt with the claim of 'illusion' when discussing Hoerl in Chapter 1. Here, I merely claim that the metaphysics of time and of the specious present developed in the present thesis demonstrates that Callender puts the cart before the horse. The conception of an enduring self, which Callender claims leads to the 'illusion' of

time flowing, is itself due to time flowing through a specious present, which in turn is due to the objective passage of time.

Let us recall what Callender requires of the enduring self: it provides an object that flows, it is intimately connected with memory of the recent and distant past, it acts in the moment, it plans for the near and far future. Additionally, the enduring self needs to be stretched diachronically so it can carry out its plans, though this diachronic self is conceived as one enduring object. In other words, the enduring self finds itself wholly present in the specious present of an (expansive) A-series, wherein it has time to act and to recall past events at which it was wholly present and to plan for future events at which it expects to be wholly present.

Now, I have argued not only for a diachronic specious present but for a dynamic one whose structure is invariant (i. e. it 'endures' and 'flows') over time. Therefore, the same specious present that was 'wholly present' at past events, is now 'wholly present' at current events, and will be 'wholly present' at future events. An 'enduring' specious present, then, is the 'mechanism' that allows both the construction, and the movement through time, of the 'enduring self'. Without this specious present, we could not have experience as of an enduring self; and of course, this 'mechanism' is itself wholly dependent on objective passage for its emergence.

In light of this 'enduring' specious present, the argument given in Chapter 1 for the seemingly seamless union of the experience of succession and the succession of experience needs to be modified. There, the standard view of multiple (static) specious presents making up a stream of consciousness was used to argue that it was the change of content between such specious presents that provides us with succession of experience from which we infer past, present, and future. This argument does not apply in the case of a single dynamic specious present.

A dynamic specious present, as part of an expansive A-series, 'advances' towards the future along a series of time-atoms ordered as if by the earlier than relation. Content of a specious present is experienced as successively earlier and later. However, as the 'enduring' structure of a dynamic specious present advances along the macro-series of time atoms, content exits this invariant structure successively in the same order it had previously entered. The exited content, that is now later in the time-series than that of the specious present is no longer directly perceived, and so affords us succession of experience and is inferred as past. Thus,

the succession of experience arises from the experience of the dynamic specious present 'advancing into the future', as content emerges sequentially into the present – only to consequently exit into the past. Hence, changing macro-content that is both within and immediately outside a single dynamic specious present, is cognised in a seemingly seamless union of the experience of succession and the succession of experience. This just is the expansive A-series in action.

There is another difficulty which this dynamic model of the specious present avoids. The puzzle is raised by Geoffrey Lee thus:

It is well-known that in a Relativistic world, many apparently non-relational properties of objects, like their shape, are instantiated only relative to a frame of reference. But . . . it would be intolerable if the phenomenology of experience was similarly frame-relative. However, there are also arguments that can be given that lead to the strange conclusion that phenomenology *is* frame-relative. The puzzle is to explain how consciousness relates to the physical world in a way that avoids this conclusion.

(Lee 2007 p. 343, his emphasis)

Lee examines various responses to this puzzle but does not mention what I regard as key to its answer, which is proper time. Recall from 6.3 Arthur's strict separation of coordinate time and proper time that was prompted by his belief that many philosophers and physicists tend to regard proper time as "simply the *relative time of an observer in his or her own rest frame*" (Arthur 2008, p. 208, his emphasis). Arthur argued, and I agreed, that becoming and process are connected solely with proper time.

As mentioned in 6.2, Stein believes that conscious awareness cannot be instantaneous and that the required specious present will be durational. For us to be aware of things, writes Stein, "the things we perceive must possess a degree of stability (and must interact with us in stable patterns). . . . But according to relativity theory, interactions are not instantaneous" (Stein 1991 p. 161). Arthur comments on such perception of things, so that

in order for this to occur, it is necessary for there to be very many interactions between the thing perceived and the perceiver; this in turn requires that the moments of experience (specious presents) be long enough to enable there to be very many such interactions between an organism and its immediate environment. (Arthur 2006 pp. 147-148)

Here we have a situation in which real patterns (as 'clocks' or processes) are dynamically and diachronically interacting. Now, I have argued that the real pattern known as 'specious present' is a constituent of a subjective A-series which is itself emergent from objective A-series processes. If this is right, then subjective process is related to objective process through *frame-invariant* proper time, and so the objective length of a specious present just is its proper time. There is no (objective) place for frame-relative coordinate time in any of these processes, and so phenomenology is not frame relative.

However, this is not to say that the experience of the rate of passage of subjective time is directly proportional to that of objective time. For instance, when a student at the University of Warwick, I attended a showing of the excellent Beatles film *Yellow Submarine* at the Film Society. After the opening credits had finished someone got up to leave – thinking the film was over. His friends had a great time in telling him to sit down as the film was only just beginning. They knew he had taken LSD before going in, and now told everyone else around them. His behaviour was immediately explicable to all: his sense of time's passage was being extremely distorted by the psychedelic drug. He laughed, sat down, and was absorbed by (or into?) the rest of the film. Such experiences are well documented: a matter of a few objective minutes can be subjectively experienced as stretching to an hour or two.

That the subjective experience of the rate of time's passage can differ so markedly at different times within the same stream of consciousness may be due to subjective A-scales having degrees of pastness and futurity. These degrees are pure creations of the mind and so, in conditions where the mind's functioning is either impaired or enhanced (as in the case of ingesting a psychedelic drug), the experienced rate of passage along these degrees may veer considerably from what is ordinarily experienced. Of course, we all experience some variations to the experienced rate of passage in our daily lives – according to how exciting or boring we find ongoing events – while the objective rates of production of these events remain constant in accord with proper time.

8. Conclusion

The temporal structure of the world, as set out in this thesis, is somewhat more complex than the usual portrayals found in the metaphysics of time. The added complexity results mainly from the application of two central pillars of rainforest realism to previous conceptual, metaphysical, and scientific investigations of time. These pillars are the notional category and the scale relativity of ontology (ontological emergence), which together allow for a different metaphysical choice to that of the standard fare of eternalism, possibilism, or presentism. This novel choice has some similarities with both eternalism and possibilism but has nothing in common with presentism.

Since a present time that emerges at the macro-scale is merely the size of a single time-atom, which covers the temporal aspect (instant) of a 'here-now' spacetime point that in turn is not simultaneous with any other instant, the present will have a 'spatial extent' only of the size of the space-atom that covers the spatial aspect (point) of that same spacetime point. Therefore, there can exist no universe-wide present as would be required by presentism. Nor is any member of this set of atomic presents ontologically privileged. Each present, being itself a real pattern, is equally as real as any other real pattern – whether they be notional past or future real patterns or scientific earlier/later ones. Perspective is integral to being a real pattern, and the present is just one perspective among many other equally real temporal perspectives.

However, something akin to eternalism may be said to apply at the micro- and meso-scales of time. Both 'empty' scientific Minkowski spacetime instants and the content of notional Meso-Block time-atoms are ordered by the earlier than relation; and, as there is no *A*-scale at these ontic scales of time, there is no passage. The non-dynamic, 'eternal', Meso-Block – although fully actual – does not confirm eternalism as a theory about the world, for there is additional structure (more real patterns) existing beyond the Meso-Block at the macro-scale of *A*-time, and yet more structure will exist in the future.

On the other hand, as the *A*-scale emerges with macro-content at the macro-scale of time, something akin to possibilism may be said to apply there. At this scale there exist both past and present events but no future events. However, although possibilities are actualised in the present, since that part of the Meso-Block that is later than the present is 'already' actual, the

present's capacity to turn the possible into the actual is strictly limited in scope to just a single ontic scale of time. Also, since an *A*-series of macro-time consists of an *A*-scale of equally real past, present, and future times along with any content located at those times, the future *per se* is not non-existent. Temporal location plus content forms an event. With there being no content at the future part of the *A*-scale there are no future events; but future *time* is nonetheless real. Thus, the temporal structure of the world as described in the present thesis, though having similarities with both, is neither the 'Static Block' of eternalism nor the 'Growing Block' of possibilism.

It should be noted that these similarities are very different to those holding between an eternalist Block Universe and a possibilist Growing Block Universe. The latter closely resembles the former, except that a new slice of existence is added to the later part of a Growing Block with the coming into being of every new universe-wide instantaneous present. There is no corresponding similarity holding between the structure of the Meso-Block and that of the macro-scale of time. Here a radical dissimilarity holds.

Before briefly indicating that which I regard as upsides to the temporal structure of the world found in the present thesis, I mention two major drawbacks its rainforest realist ontology will be seen to have from the viewpoint of the more usual analytic metaphysical tradition. These are: firstly, the relativising of existence to scales; secondly, the ontic vagueness surrounding real patterns existing at those different scales. For those who reject such notions outright there will be little to commend this thesis. On the other hand, for those who keep open minds concerning such issues and who tend towards naturalised metaphysics, I believe there is much to recommend it. The major benefits, as I see them, are as follows.

With all locations in time being equally real, there is no problem in our referring to any or all of them – whether earlier/later or past, present, and future times. Content of the Meso-Block can be referred to in a similar tenseless way to content of the standard eternalist Block. Content at the macro-scale, represented as it is in the two-part manifest image of time, can be referred to either tenselessly or tensed, either separately or together. So, we can say: "The occurrence of the Bolshevik Revolution, being earlier than the founding of the Communist International, is the more past of the two events; and even though both happened long ago, those who are presently communist strive to repeat something similar happening in future." Here, since both past and present times and events exist, any reference to them is either true

or false. The future events, which all good comrades hope will happen, are referred to the empty future. In this way we meaningfully talk of the future, both as existent time empty of (macro-)content and as if our actions in the present can influence the content of events yet to come. Thus, a robust objective becoming that is fully in line with current science is offered by this thesis, which, importantly, involves none of the metaphysical ‘gerrymandering’ of established physical theories – such as introducing a reference-frame of absolute simultaneity into special relativity – as practiced by some presentists and possibilists.

We may be encouraged in the natural hope and belief that we can and do influence the future by the arguments in 7.2.3 concerning the existence in the world of ‘enclaves’ of both indeterminism and determinism – with a ‘kind of autonomy’ between them. Thus, when a future revolution is referred to, if there exist no truthmakers (as content) in an empty future, and if any macro-content that arises later than now is not already fully determined (as argued here) then present propositions about that revolution will be neither true nor false.

Finally, from all the above we can see that the extra complexity claimed here, both for the temporal structure of the world and for McTaggart’s two-part manifest image of time, enables us as folk to have confidence in our everyday representations of temporal structure at the ontological scale at which we operate. Surprisingly perhaps, the scientific metaphysics of this thesis gives more credence to the manifest image of time than the various analytic metaphysical theories constructed on the foundation of alleged ‘common-sense intuitions’ provided by our temporal experience. And so, having analysed our past, we can, in the present, set ourselves goals for the future; and possibly go on to achieve those goals in a present that is yet to come. Thus, having interpreted the temporal structure of the world, we can now look forward to changing it.

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