QUEST FOR COHERENCE: TRACING PARALLELS BETWEEN LOOP QUANTUM GRAVITY AND THE PROCESS PHILOSOPHY OF BERGSON AND WHITEHEAD

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Cover: From left to right: Landau, Bohr, Rosenfeld and Bronstein. Quantum Gravity emerged from the discussion of these four. The original photograph was taken in Kharkiv and published in the newspaper Khar'kovskii rabochii (The Kharkiv Worker) on May 20, 1934.

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LQG Loop Quantum Gravity 16

GR General Relativity vii

QM Quantum Mechanics vii

QG Quantum Gravity vii

Introduction

0.1 Parallel Paths: Towards Coherence in Metaphysics and Physics

Aristotle titled its subject-matter the "first philosophy", or "first science", or "wisdom". Since Aristotle, many philosophers have had various applications of metaphysics, or the philosophy of reality. According to Van Inwagen and Sullivan in their article on metaphysics for *The Stanford Encyclopedia of Philosophy*, the problems of these philosophers can be roughly divided into two categories: the "old" and "new" metaphysics.[1] "Old" metaphysics inquires into, for instance, being as such, universals and particulars and substance. Accordingly, for Aristotle *meta*physics was the study of things that do not change, whereas physics studied change, "for change is the defining feature of the natural world". "New" metaphysics considers issues as freedom and determinism, the mental and the physical, and space and time. And although many philosophers, most famously the logical positivists of the Wiener Kreis, have called into question the possibility of metaphysics, "either because its questions are meaningless or because they are impossible to answer", here it is assumed that metaphysics *is* possible, and perhaps even fruitful.

If the existence of metaphysics is assumed and the branch is defined by its subject-matter, then one discovers that over the past twenty-five centuries metaphysics has been seriously partial. Its problems have been looked at mainly from the substance perspective. This concept may itself be just as hard to characterise as metaphysics. For the sake of simplicity, we will follow Robinson's article on substances for *The Stanford Encyclopedia* and let there be two definitions of it. Firstly, in the generic sense, substances are the fundamental entities of reality in some philosophical system, such that every realist system accepts substances. Secondly, in the narrower sense, substance is used to refer to "the intuitive notion of individual *thing* or *object*."[2] The problems of metaphysics have been largely analysed from this narrow definition, i.e. from the ontological position that the fundamental entities of the world are individual things.

The substance approach is still alive and well in many domains of thought. Bruno Latour reminded us of our tendency to view the Earth as composed of isolated and disconnected mining fields.[3] In theoretical physics, renowned Stephen Hawking has been influenced by substance presuppositions. In his 2018 *Brief Answers to the Big Questions*, although the book's content is popular science and does not provide definitive ontological statements, Hawking suggests that to "cook up a universe", one needs just three ingredients:[4]

> The first is matter - stuff that has mass. [...] The second thing you need is energy. [...] The third thing we need to build a universe is space. Lots of space.

So, the substance framework in physics did not end with Newton. With Einstein's $E = mc^2$, energy becomes matter, such that even for Hawking all that there is, is matter and space. To indicate the origins of this view, one has to visit the camp opposed to substance. According to process philosophers, substance frameworks are incomplete, the result of intellectual abstraction and blindly following confused language. "What philosophy has lacked most of all is precision", wrote one of the first modern process philosophers, Bergson.[5] Rather, processists start from experience, and everything in experience needs to find its own place in their framework. Understandably, as coherent systems often result in more rigorous reasoning and clarity, as well as stronger explanatory powers: the philosopher's dream. To realise this dream, they contend that processes and events

1. Peter van Inwagen and Meghan Sullivan, "Metaphysics," in *The Stanford Encyclopedia of Philosophy*, Winter 2021, ed. Edward N. Zalta (Metaphysics Research Lab, Stanford University, 2021).

2. Howard Robinson, "Substance," in *The Stanford Encyclopedia of Philosophy*, Fall 2021, ed. Edward N. Zalta (Metaphysics Research Lab, Stanford University, 2021).

3. Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime* (John Wiley & Sons, 2017).

4. Stephen Hawking, *Brief Answers to the Big Questions* (John Murray Publishers, 2018), 29–30.

5. Henri Bergson, *The Creative Mind* (The Philosophical Library New York, 1946), 7.

hold ontological primacy over substances, thus not necessarily denying the existence of temporally stable aspects of reality. The processual demand for coherence and antireductionism, or holism, is something most scientists seek as well, albeit not explicitly.

Hawking abandoned the belief in coherence, of an "ultimate theory that can be formulated as a finite number of principles", only later in his life.[6] His most famous contribution to physics is arguably the discovery of Hawking radiation, which entails that some particles *can* escape a black hole. However, many problems surrounding black holes are still extant. Perhaps Hawking did not solve them all because of his emphasis on substance. Another field that probes black holes is the discipline of Quantum Gravity (QG).

The goal of Quantum Gravity is to cook up a coherent theory out of two ingredients, namely Einstein's General Relativity (GR) and Quantum Mechanics (QM). An arduous task, given their conflicting views, for instance on time. GR sees space-time as a dynamic entity, whereas for QM, time is part of an absolute background. One of the candidates is Loop Quantum Gravity (LQG). Its purpose is thus not a "Theory of Everything" (for example, it is not fully compatible with the Standard Model, a theory about electromagnetism, the strong and weak nuclear force), unlike the aim of its better-known rival String Theory. A theory of Quantum Gravity was to be more of a by-product of String Theory. Conversely, LQG could "open the door" to a unifying theory.[7]

Whereas GR and QM have been confirmed through numerous experiments and observations, in Quantum Gravity there are no reasonably well-defined theories.[8] The difficulty of theory-construction is not only due to lack of data (QG works in the extremest of scales: at very small distances or high energies. Moreover, it is unknown what sort of effects a theory of QG exactly would predict, note Butterfield and Isham[9]). Because it is also due to conceptual problems, philosophical discussion should not wait until Quantum Gravity is better established. Furthermore, the current lack of data does not render QG unavoidable.[10] On the contrary, Wüthrich, working on the philosophical foundations of QG, states that:[11]

> Quantum Gravity is rich with implications for specifically philosophical, and particularly metaphysical, issues concerning not just space and time, but also causation, reduction, and even modality. Quantum Gravity thus turns out to be a very fertile ground for the philosopher.

According to Butterfield and Isham, one way a philosopher can go about the debate concerning Quantum Gravity is by studying it "in the context of some traditional philosophical ideas [...], one can think of such a relation in two ways: the philosophical idea giving constraints on quantum gravity; and vice versa, quantum gravity reflecting back on the philosophical idea".[12] This approach has been applied to both of QG's "ingredient" theories. QM leaves open many interpretations, of which the number of processual analyses is not lacking. The advent of GR was the motivation for Whitehead, one of process philosophy's founding fathers, to switch career paths from mathematics to metaphysics. Accordingly, the old tools of Western (substantive) metaphysics are useless in one of their possible amalgamations, LQG.

On the one hand, process philosophy aims to produce a more coherent worldview. On the other hand, LQG seeks to answer big questions, such as about the origin of the universe, by combining the minuscule (QM) with the astronomical (GR). However, the parallelism does not end there. The fundamental entities in both theories, processes and events, are comparable. Moreover, some processual conceptions of space-time display similarities with LQG's notion of it.

In this thesis, the main representatives of process philosophy will be the contemporaries from the latter half of the nineteenth century and the first half of the twentieth century, Bergson and Whitehead. Bergson, a French philosopher, developed a philosophy of duration and intuition. He argued that time is not merely a measurement but rather a lived experience, a continuous flow of subjective duration: *durée*. According to Bergson, traditional scientific methods are inadequate in capturing this duration because of their tendency

6. Stephen Hawking, *Gödel and the End of Physics*, Lecture, Texas A&M University, College Station, Texas, March 8, 2017.

7. "Francesca Vidotto: The Quantum Properties of Space-Time," Yvonne Bang, May 2020, accessed May 3, 2020, https://daily.jstor.org/francesca-vidotto-the-quantum-properties-of-space-time/.

8. Jeremy Butterfield and Christopher Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," *Physics meets philosophy at the Planck scale*, 2001, 10.

9. Butterfield and Isham, 9.

10. Butterfield and Isham, 37–39.

11. Christian Wüthrich, "Raiders of the Lost Spacetime," *Towards a theory of spacetime theories*, 2017, 30.

12. Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 12.

to reduce time to space. Instead, he emphasised the importance of intuition, alongside intellect, in comprehending reality. Bergson will serve to introduce process philosophy and its emphasis on becoming, rather than being.

Whitehead, an English mathematician and philosopher, widely recognised for his collaboration with Russell on *Principia Mathematica*, aimed to bridge the gap between the sciences and ordinary experience, that is, to heal the vicious "Bifurcation of Nature". For Whitehead, becoming is atomic: there is a process of continuity but not a continuity of the process itself. This notion aligns with the atomistic perspective found in LQG.

Perhaps to do away with the obstacles withholding LQG from formulating a completely coherent theory, such as the problem of time and the emergence thereof, physicists need to consult Bergsonian and Whiteheadian process philosophy: complete and coherent systems that already demonstrate significant similarities with LQG. Nowadays, truly pioneering technology is necessary to advance in natural sciences. But this technology need not be material instruments. It could be concepts as well, and Butterfield and Isham think that "in the search for a satisfactory theory of quantum gravity, a fundamental reappraisal of our standard concepts of space, time and matter may well be a necessary preliminary".[13] Whitehead illustrates this:[14]

> Philosophy is the welding of imagination and common sense into a restraint upon specialists, and also into an enlargement of their imaginations. By providing the generic notions philosophy should make it easier to conceive the infinite variety of specific instances which rest unrealized in the womb of nature.

Perhaps even process philosophers can benefit from LQG, aligning with their meta-philosophical principle of refuting ultimate theories.

0.2 Structure of the Thesis

To demonstrate the evolution of the process philosophy explored in this thesis, Chapter 1 begins with an overview of its rival, substance philosophy. Next, this chapter delves into firstly Bergson's and thereafter Whitehead's process philosophy, investigating how each attempts to enhance coherence in the framework prior to his. In Chapter 2, only a global account of Loop Quantum Gravity is given, since a PhD in the field, or at least a completed Master's (which the writer of this thesis currently does not hold), is required to fully understand its mathematical framework. Subsequently, the parallelisms between LQG on the one hand, and Bergson and Whitehead on the other hand, are outlined in Chapter 3. Then, it is proposed how LQG could learn from Bergson and Whitehead to overcome the Bifurcation of Nature. It is suggested that this could help the theory achieve coherence and thus aid in addressing its current problems. Finally, the conclusion (Chapter 4) summarises this thesis, exploring the extent to which process philosophy and LQG, both driven by a quest for coherence, can benefit from each other. Indubitably, this problem will not be solved completely. Luckily, Bergson-connaisseur Deleuze notes that for the former:[15]

> The truth is that in philosophy and even elsewhere it is a question of finding the problem and consequently of positing it, even more than of solving it.

13. Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 12.
14. Alfred North Whitehead, *Process and Reality* (The Free Press, 1979), 17.
15. Gilles Deleuze, *Bergsonism* (Zone Books, 1997), 15.

Chapter 1

Substance vs. Process: The Metaphysical Debate

1.1 Substance Metaphysics

Aristotle, Ockham, Descartes, Spinoza, Leibniz, Locke, and Kant: nearly all notable philosophers have explored the concept of substance. Evidently, there is not one "type" of substance metaphysics. Aristotle, for instance, can even be considered a member of the opposing camp of process philosophers, notes Rescher in his *Process Metaphysics*[1] However, for the sake of simplicity, we identify eight overlapping ideas that typify substances, in accordance with Robinson's article on Substances for *The Stanford Encyclopedia of Philosophy*:[2]

(i) being ontologically basic – substances are the things from which everything else is made or by which it is metaphysically sustained;

(ii) being, at least compared to other things, relatively independent and durable, and, perhaps, absolutely so;

(iii) being the paradigm subjects of predication and bearers of properties;

(iv) being, at least for the more ordinary kinds of substance, the subjects of change;

(v) being typified by those things we normally classify as objects, or kinds of objects;

(vi) being typified by kinds of stuff.

(vii) substances are those enduring particulars that give unity to our spatio-temporal framework, and the individuation and re-identification of which enables us to locate ourselves in that framework.

(viii) the substances in a given system are those entities crucial from the teleological or design perspective of that system. 'Crucial' means that other things exist either to constitute them or to provide a context of operations for them.

Some substance philosophers acknowledge only one idea, whilst the Aristotelian tradition acknowledges almost all. During the Middle Ages this school of thought was prevalent as Scholasticism. However, particularly because this type of metaphysics was not conducive to science, Descartes introduced his famous Mind-Matter dualism. This model, one of the first accounts of the "Bifurcation of Nature", tenaciously separates "objective" science and "subjective" experience. Although more coherence was introduced into metaphysics by accommodating mathematical calculation and empirical measurement, the limits of his model would eventually be reached, understood and accepted, as with all abstract models.

The first limitation to the substance model is that it fails to accommodate various types of entities within its framework. Rainstorms, heat waves, rumors and performances of symphonies, are not examples of (v).[3] Secondly, most substance philosophers would agree that space-time is some framework or background for things (the few ones fitting the framework), as illustrated by (vii).

1. Nicholas Rescher, *Process Metaphysics: An Introduction to Process Philosophy* (Suny Press, 1996), 10–12.
2. Robinson, "Substance."
3. Rescher, *Process Metaphysics*, 29.

1.2 Bergson's Durée

To provide an introduction to process philosophy, we will examine Bergon's work. One of his objectives was to challenge the scientist's "mathematical" time, a sort of background-dimension. Furthermore, Bergson argued that conceiving of reality in terms of processes rather than entities leads to a more coherent worldview. How did the lacking substance model arise in the first place, then?

Next to mathematical time, another assumption of substance metaphysics Bergson was constantly suspicious of is (iii): the uncritical use of the subject-predicate construction in language. He makes this clear in *The Creative Mind*. There, he writes that "metaphysics must have conformed to the habits of language, which in turn are governed by the habits of common sense".[4] Language is equivalent to symbols, which create illusions by dividing real, continuous, experience. The problems of substance metaphysics, preventing coherence, are the result of such abstraction. Bergson writes in *An Introduction to Metaphysics* that "the inherent difficulties of metaphysic, and the contradictions into which it falls, the division into antagonistic schools, and the irreducible opposition between systems are largely the result of our applying, to the disinterested knowledge of the real, processes which we generally employ for practical ends".[5] The processes employed for practical ends are those of the intellect.

In Chapter 2 of one of his major works, *Time and Free Will*, Bergson discusses two faculties of the mind and their relations to mathematical and "genuine" time. The faculty or "power" that enables us to abstract, and perhaps also to speak, is the intellect.[6] Intelligence is an analytic, practical, tool for humans. It is "destined first of all to prepare and bear upon our action on things",[7] and is "intended to secure the perfect fitting of our body to its environment, to represent the relations of external things among themselves": to think matter in the substantialist sense.[8] The intellect concerns itself with juxtaposed things in homogeneous space, extension, and quantitative multiplicity. Using this faculty is how the mathematician arrives at her mathematical understanding of time:[9]

> All through the history of philosophy time and space have been placed on the same level and treated as things of a kind; the procedure has been to study space, to determine its nature and function, and then to apply to time the conclusions thus reached. The theories of space and time thus become counterparts of one another. To pass from one to the other one had only to change a single word: "juxtaposition" was replaced by "succession".

As the mathematician's time is reducible to space, it is not real, continuous, time. Her spatialised time is simply the "ghost of space".[10] It could be, for instance, illustrated by the snapshots of a cinematographic film:[11]

> Succession thus understood, therefore, adds nothing; on the contrary, it takes something away; it marks a deficit; it reveals a weakness in our perception, which is forced by this weakness to divide up the film image by image instead of grasping it in the aggregate. In short, time thus considered is no more than a space in idea where one imagines to be set out in line all past, present and future events, and in addition, something which prevents them from appearing in a single perception.

Treating time as such results in the systematic avoidance of *duration*, which Bergson considers as true time and the essence of reality. Duration is constituted by "a process of organization or interpenetration of conscious states", embodying the qualitative flow of time that is continuous, heterogeneous and indivisible.[12] It bears the attribute of succession, rather than juxtaposition, as it "has no moments which are identical or external to one another".[13] Intuition, a non-conceptual power complementary to the intellect, allows

4. Bergson, *The Creative Mind*, 12–13.
5. Henri Bergson and Thomas Ernest Hulme, *An Introduction to Metaphysics* (G.P. Putnam's Sons, 1912), 67.
6. Henri Bergson, *Time and Free Will: An Essay on the Immediate Data of Consciousness* (Dover Publications, 2001), 97.
7. Bergson, *The Creative Mind*, 13.
8. Henri Bergson, *Creative Evolution* (Cosimo Classics, 2005), xix.
9. Bergson, *The Creative Mind*, 12.
10. Bergson, *Time and Free Will*, 99.
11. Bergson, *The Creative Mind*, 17.
12. Bergson, *Time and Free Will*, 108.
13. Bergson, 120.

us to grasp durée. For him, intuition serves as a method that presupposes duration. The "precision" of philosophy, as precise in *its* field, relies on intuition.[14] Intelligence "hides [...] the moving reality of being which the path of instinct and intuition, the alternative to intelligence, discloses".[15] To this end, one has to turn the attention to pure, rather than abstracted, experience: indivisible sensible qualities, such as motion, acts and processes.

Accordingly, Bergson was a radical empiricist. Two aspects of his thought exemplify this. Firstly, metaphysics becomes experience itself. Whereas previously, "metaphysics was led to seek the reality [...] outside what our senses and consciousness perceive". "Metaphysics will then become experience itself; and duration will be revealed as it really is, – unceasing creation, the uninterrupted up-surge of novelty", he writes in *The Creative Mind*.[16] He believed that the method of intuition would enhance coherence, as it perhaps could solve the great problems that "traditional", substance philosophy poses.[17] In *The Perception of Change* Bergson suggests that "the difficulties raised by the ancients around the question of movement and by the moderns around the question of substance disappear, the former because movement and change are substantial, the latter because substance is movement and change".[18]

Secondly, Bergson's radical empiricism manifests itself through his anti-reductionism. Starting from perception, *all* experience, including facts, knowledge, theories, but also substances, must have their place within the framework. In *The Perception of Change* he writes:[19]

> But suppose that instead of trying to rise above our perception of things we were to plunge into it for the purpose of deepening and widening it. Suppose that we were to insert our will into it, and that this will, expanding, were to expand our vision of things. We should obtain this time a philosophy where nothing in the data of the senses or consciousness would be sacrificed: no quality, no aspect of the real would be substituted for the rest ostensibly to explain it. But above all we should have a philosophy to which one could not oppose others, for it would have left nothing outside of itself that other doctrines could pick up; it would have taken everything. It would have taken every thing that is given, and even more, for the senses and consciousness, urged on by this philosophy to an exceptional effort, would have given it more than they furnish naturally.

The role of philosophy is then to displace our attention to immediate experience and thus "lead us to a completer perception of reality".[20] This way, what metaphysics "may lose in comparison with science in utility and exactitude, it will regain in range and extension", Bergson writes in *An Introduction to Metaphysics*.[21] Moreover, for him, modern science is not only lacking because it considered just space and abstractions of the mobile. It furthermore demands a "new" metaphysics that corresponds to its mode of thought, as science and metaphysics are two "halves" of the absolute, Deleuze writes in *Bergsonism*.[22] Bergson himself asserts that "science and metaphysics therefore come together in intuition" and that "a truly intuitive philosophy would realize the much-desired union of science and metaphysics".[23] Furthermore, Deleuze notes that without metaphysics, science would "remain abstract, deprived of meaning or intuition". Hence, Bergson's metaphysics is concerned with "immanent and constantly varying durations", as science begins when "movement is related to any instant whatever".[24]

In returning to direct perception of change and mobility, we open our eyes to truly reality.[25] Bergson writes in *The Perception of Change* that "there are changes, but there are underneath the change no things which change: change has no need of a support. There are movements, but there is no inert or invariable object which moves: movement does not imply a mobile".[26] Moreover, "change is real and even constitutive

14. Deleuze, *Bergsonism*, 14.
15. Bergson, *Creative Evolution*, xviii.
16. Bergson, *The Creative Mind*, 16.
17. Bergson, *The Creative Mind*, 15–16; Bergson, *Creative Evolution*, xxiv.
18. Henri Bergson, *Henri Bergson: Key Writings*, ed. John Mullarkey and Keith Ansel Pearson (New York: Continuum, 2002), 265.
19. Bergson, 251.
20. Bergson, 253.
21. Bergson and Hulme, *An Introduction to Metaphysics*, 71.
22. Deleuze, *Bergsonism*, 116.
23. Bergson and Hulme, *An Introduction to Metaphysics*, 74.
24. Deleuze, *Bergsonism*, 116.
25. Bergson, *Henri Bergson*, 259.
26. Bergson, 259.

of reality".[27] Reviving Heraclitus, De Saint-Ours concludes that "Bergson means that the essential feature of reality is change [...], things change and evolve but they don't change in time".[28]

Summarizing, Bergson is not only coherent because metaphysics becomes experience, but also because, conversely, *everything* in experience is accounted for as well.

However, in another of his major works, *Matter and Memory*, Bergson admits that his metaphysics "is frankly dualistic", as it "affirms both the reality of matter and the reality of spirit".[29] In *Time and Free Will*, he states that "we have to do with two different kinds of reality, the one heterogeneous, that of sensible qualities, the other homogeneous, namely space".[30] Other examples of his dualisms are quantity-quality and continuous-discontinuous. How then to reconcile these "bifurcations" and Bergson's demand for agreement with experience? We rely on Deleuze for an elucidation. He notes that Bergson is aware that things are always mixed together: "experience itself offers us nothing but composites".[31] The problem is that we tend to see only differences in degree, where there are differences in kind:[32]

> According to Bergson, a composite must always be divided according to its natural articulations, that is, into elements which differ in kind. Intuition as method is a method of division [...] The composite must therefore be divided according to qualitative and qualified tendencies, that is, according to the way in which it combines duration and extensity as they are defined as movements, directions of movements.

Going beyond realism and idealism, Bergson's combinative solution is that two extremes "are "sewn" together, through memory, in the continuous heterogeneity of duration", note Lawlor and Moulard-Leonard in their article on Bergson for *The Stanford Encyclopedia*.[33]

A detailed analysis of many other of Bergson's vital topics, such as the inherent creativity of becoming, free will, *élan vital*, a perception and memory, is beyond the scope of this thesis. Some of his concepts, such as the idea that matter is not substantial, or that the movement and position of a body are not simultaneously determinable, resonate strongly with Quantum Mechanics.[34] Numerous discussions have already explored the relationship between Bergson and Quantum Mechanics, see for instance Capek's *Bergson and Modern Physics*, De Broglie's *The Concepts of Contemporary Physics and Bergson's ideas on Time and Motion*, and Landeweerd's recent dissertation *Time, Life & Memory: Bergson and Contemporary Science*.[35] Moreover, the concepts addressed here may fall short of fully capturing the essence of Bergson's ideas: language abstracts, reduces, necessarily. However, for the purpose of introducing Whitehead to establish parallels between process philosophy and Loop Quantum Gravity and their potential contributions to each other's coherence, the following two points are of importance. Firstly, Bergson conceived of the world as a composition of processes, rather than substances, as these are merely intellectual abstractions of processes. Secondly, he viewed time as duration, as lived experience of qualitative multiplicities, rather than a background dimension for events or a linear sequence of moments.

1.3 Simondon: from Bergson to Whitehead

Before abandoning Bergson, a final of his seemingly dualisms is presented: the virtual and the actual, two complementary aspects of reality. Virtuality is understood as non-actual reality, capable of becoming actual through the process of becoming. Bergson inserts the virtual in an abstract field of pre-existence, such that

27. Bergson, *Henri Bergson*, 261.
28. Alexis de Saint-Ours, "The Rediscovery of Time through its Disappearance," *The Nature of Time Essay Contest*, 2008, 7.
29. Henri Bergson, *Matter and Memory* (New York: Zone Books, 1994), 9.
30. Bergson, *Time and Free Will*, 97.
31. Deleuze, *Bergsonism*, 22.
32. Deleuze, 22–23.
33. Leonard Lawlor and Valentine Moulard-Leonard, "Henri Bergson," in *The Stanford Encyclopedia of Philosophy*, Winter 2022, ed. Edward N. Zalta and Uri Nodelman (Metaphysics Research Lab, Stanford University, 2022).
34. Joël Dolbeault, "From Mind to Matter: How Bergson Anticipated Quantum Ideas," *Mind and Matter* 10, no. 1 (2012): 25.
35. Milic Capek, *Bergson and Modern Physics: A Reinterpretation and Re-evaluation*, vol. 7 (Springer Science & Business Media, 2012); Louis De Broglie, "The Concepts of Contemporary Physics and Bergson's Ideas on Time and Motion," *Bergson and the evolution of physics*, 1947, 45–62; Laurens Landeweerd, "Time, Life & Memory: Bergson and Contemporary Science" (PhD diss., Erasmus University Rotterdam, November 2022).

it is not a possibility, "which is nothing more than a human and intellectual mechanism that retroactively refers to the unpredictable emergence of reality". Rather, it is "conceived as an energy – an *élan vital* – that precedes every actual entity, a truly metaphysical force that continues to guide the evolution of reality", writes Piatti in his article on Bergson, Simondon and Deleuze.[36]

The concept of virtuality returns in Simondon's work. Simondon acuses both the substantialist and the hylomorphic stance of circularity, as they seek the explanation of the formation of the individual within the already formed individual. So, he introduces the concept of pre-individuation, which he explains via thermodynamic terms. Individuality is not a given, but rather the result of a process of individuation. A being's pre-individuality is analogous to supersaturated potential charges within a meta-stable system. Due to over-tension, the system produces processes of differentiations and individuations. Garelli explains in the Foreword to Simondon's *Individuation in Light of Notions of Form and Information*:[37]

> Thus, it is by phase-shifting that a metastable system charged with a supersatured energetic potential individualizes while also simultaneously spouting-from its not-yet-individualized internal tensions a profusion of individualizing forms, which, afterwards, are capable of being structured into further systems and reforming into new metastable equilibria.

The virtual in Simondon is full of tensions, capable of going in all directions, in an irremediable conflict characteristic of a fragile, meta-stable equilibrium.[38] Furthermore, for Simondon, Bergson's continuity of duration is only one of the possible ways to understand time:[39]

> individuation instead entails a complex mix between concrete continuous time and discontinuous quantic shifts, [...] the passage from a meta-stable state to an actual individual is an abrupt transition, a quantum jump, which implies the invention of a new dimension, equivalent to a truly creational shift.

In short, Simondon attempts to expand Bergson's concept of time by allowing for multiple ways of jumping between durations. To this end, he employs various concepts from thermodynamics and quantum mechanics, such as metastability, entropy, phase transitions, quantum conditions and quantum leaps. Yet the most important process philosopher inspired by physics is Whitehead, albeit by a completely different theory, namely Einstein's General Relativity. His Epochal Theory of Time displays strong resemblances to Simondon's notion of time as a "complex mix between continuous concrete time and discontinuous quantum shifts".

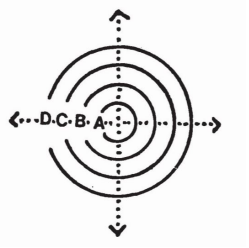
1.4 Whitehead's Concrescence

Whitehead states in the preface to his *Process and Reality* that he wanted to save Bergson's type of thought from accusations of anti-intellectualism. To this end, he not only introduced novel concepts, but also made his metaphysics less anthropocentric. In his panexperientialist view, every thing, even atoms, bottles and animals, experience. The tendency to abstract, to analyse the world via static concepts, is however not an inherent characteristic of the intellect.[40]

Whitehead's ontology opposes many well known bifurcations, such as those of primary and secondary qualities, and facts and values. In their article on Whitehead for *The Stanford Encylopedia*, Desmet and Irvine summarise his philosophy as a Philosophy of Organism. Herein, the elementary processes are connected organically and internally related.[41] According to Whitehead in *Science and the Modern World*, "nature is a structure of evolving processes" and "the reality is the process".[42] His "point is that a further stage of

36. Giulio Piatti, "The Life and the Crystal: Paths into the Virtual in Bergson, Simondon and Deleuze," *La Deleuziana–Online Journal of Philosophy* 3, no. 2016 (2016): 53.
37. Gilbert Simondon, *Individuation in Light of Notions of Form and Information* (University Of Minnesota Pres, 2020), xxi.
38. Piatti, "The Life and the Crystal," 54.
39. Piatti, 56.
40. Whitehead, *Process and Reality*, 209.
41. Ronald Desmet and Andrew David Irvine, "Alfred North Whitehead," in *The Stanford Encyclopedia of Philosophy*, Winter 2022, ed. Edward N. Zalta and Uri Nodelman (Metaphysics Research Lab, Stanford University, 2022).
42. Alfred North Whitehead, *Science and the Modern World: Lowell lectures, 1925* (Cambridge University Press, 1926), 102.

Figure 1.1: Illustration of Whitehead's Epochal Theory of Time. Figure taken from Kraus.



provisional realism is required in which the scientific scheme is recast, and founded upon the ultimate concept of *organism*".[43]

The view of the world as "a succession of instantaneous configurations of matter" rests on two presuppositions: the belief in Simple Location, and the fundamental existence of the two categories of substance and quality.[44] Simple Location in space-time is the property of matter by virtue of which a certain set of relations to other entities can be indicated. Kraus writes in her *Companion to Whitehead's Process and Reality*, one of his primary works, that Simple Location presents time:[45]

> under the same abstraction as space – as a container in which events were inserted, as an unbroken, undifferentiated continuum which both separated and externally connected those events, enabling them in the case of time to be placed in an absolute system of "before", "after", or "contemporaneous" relations to each other.

This abstracted, container-view of time renders it irrelevant and ensures that "nature [...] becomes the 'distribution of material throughout all space at a durationless instant of time', and her development 'merely the fortunes of matter in its adventure through space"'.[46] The Fallacy of Misplaced Concreteness is the error of treating abstract concepts as if they have concrete, independent, existence. Consequently, Whitehead wondered whether an organism can be defined "without recurrence to the concept of matter in Simple Location".[47] However, while Bergson considered the mathematicians' concept of time to be reducible to space, thus isolating a "pure experience of time" from space, Whitehead takes a different approach by merging space and time into space-time, exempli gratia, Einstein's Theory of General Relativity. "He asks us to imagine another fundamental form of process alongside that of transition: namely, the atomic process of concrescence", elucidates Segall, highlighting how Whitehead expands upon Bergson.[48]

To this end Whitehead proposed his Epochal Theory of Time. Here, it will be illustrated using the visual model introduced by Kraus, depicted in Figure 1.1.[49] Imagine dropping a pebble in a calm pool. Next, suppose that the ripples spreading out could freeze the moment they had formed. This picture represents the following aspects of Whitehead's account of time.

Firstly, a duration is represented by each wave together with its contained waves. So, the durations are not isolated or self-contained, simply located beads of time. Duration C "contains" duration B, which then "contains" duration A. "Later durations in the enduring object embrace earlier ones".[50] Furthermore, this model illustrates the extensiveness and divisibility of a duration, which is impossible for Bergson. A duration is given with its parts and not run through sequentially. Spatio-temporal relationships are internal, like the parts of an organism.[51]

43. Whitehead, *Science and the Modern World*, 90.
44. Whitehead, *Science and the Modern World*, 71; Whitehead, *Science and the Modern World*, 3–74.
45. Elizabeth Kraus, *The Metaphysics of Experience: A Companion to Whitehead's Process and Reality* (Fordham University Press, 2018), 19.
46. Kraus, 12.
47. Whitehead, *Science and the Modern World*, 144.
48. Matthew T Segall, "Time and Experience in Physics and Philosophy: Whiteheadian Reflections on Bergson, Einstein, and Rovelli," in *Einstein vs. Bergson* (De Gruyter, 2021), 7.
49. Kraus, *The Metaphysics of Experience*, 22–25.
50. Kraus, 23.
51. Whitehead, *Science and the Modern World*, 174.

However, continuity is not an attribute of time, as time is understood as sheer sequence rather than divisible extension. In this model, time is represented by an ordered succession of durations. The process of temporalisation, or atomic succession, is captured by the spreading process. Temporalisation can be seen as the realization of a complete organism, an event that embodies its spatio-temporal relationships both within itself and beyond itself throughout the spatio-temporal continuum. Each wave in this process is like "a drop of space-time with its own 'here' and 'now,' which synthesizes other 'here's' and 'now's".[52] The spatial dimension of each wave is inseparable from its durational aspect. For Whitehead, unlike for Bergson:[53]

> There is a becoming of continuity, but no continuity of becoming. The actual occasions are the creatures which become, and they constitute a continuously extensive world. In other words, extensiveness becomes, but 'becoming' is not itself extensive. Thus the ultimate metaphysical truth is atomism.

The "actual occasions" above are the entities engaging in Whitehead's theory of becoming. Albeit atomic, they are inherently interconnected. "There are no single occasions, in the sense of isolated occasions. Actuality is through and through togetherness", Whitehead writes.[54] These reside in the realm of actualities and are constantly "prehending", or incorporating other entities in their environment to form their own subjective experience. Similar to Leibniz, "in Whitehead, 'the world is in the individual' [...] and vice versa, 'an individual is in the world"', points out Nassiopoulou in her dissertation on Whitehead.[55] However, these experiencing individuals do not need be mind-equipped. The other realm is the realm of potentialities, constituted by eternal objects, comparable to Spinoza's modes, which are actualised time and again. Real potentialities become actual, or concrete, through concrescence, "so that being is found on becoming."[56] These two categories are thus inseparable, because they are united in the process of becoming, or *concrescence*.

It is important to note that the process itself is not inherently temporal or spatial, such that it does not occur *in* space or *in* time. Rather, each actual occasion is associated with some quantum of space and time, but becoming does not occur in an extensive space-time: "the occurrence is accompanied by the becoming of a 'bubble of spacetime' ".[57] Time becomes with the actual entity. This means that you cannot extract processes "from their environment without destruction of their very essence".[58] So, Whitehead treats space-time as any other entity that comes into and goes out of existence: it is not a container. Subsequently, Whitehead accepts the claim that time is not ontologically prior to change, or that conversely, time is change-dependent. Nassiopoulou writes in *An Interpretation of the Structure of the World Based on Whitehead's Notion of Dipolarity*:[59]

> Finally, since change is defined on the nexus of occurrences and time is an occurrence, in order to give an account of time e.g. its passage, one needs firstly to give an account of change between occurrences. That is, in order to measure time, we need to consider the relevant changes between nexus of actual occasions.

Ultimately, in healing the substance ontology common to science from the bifurcations of Nature, Whitehead's ties his metaphysical system inseparably to his theory of feelings, in an attempt to end "the divorce of science from the affirmations of our aesthetic and ethical experiences".[60] "Each actual entity is a throb of experience" and "apart from the experiences of subjects there is nothing, nothing, nothing, bare nothingness".[61] Dismissing lived experience of temporal becoming entails that Nature is less than our experience reveals. For Whitehead's time, at least the bifurcation between time's "inner" mental and "outer" material aspects is resolved: extension is necessarily processual.

52. Kraus, *The Metaphysics of Experience*, 23.
53. Whitehead, *Process and Reality*, 35.
54. Whitehead, *Science and the Modern World*, 244.
55. Vasiliki Nassiopoulou, "An Interpretation of the Structure of the World Based on Whitehead's Notion of Dipolarity: A New Ontological and Physical Framework for Theories of Quantum Gravity" (PhD diss., University of Leeds, 2014), 23.
56. Nassiopoulou, 16.
57. Nassiopoulou, 28.
58. Whitehead, *Science and the Modern World*, 91.
59. Nassiopoulou, "An Interpretation of the Structure of the World Based on Whitehead's Notion of Dipolarity," 46.
60. Whitehead, *Science and the Modern World*, 218.
61. Whitehead, *Process and Reality*, 190; Whitehead, *Process and Reality*, 167.

Chapter 2

The Metaphysics of Loop Quantum Gravity

The question "what is quantum space-time?" captures the problem of Quantum Gravity succinctly. Recall that the aim of Quantum Gravity is to combine two contradicting theories, General Relativity and Quantum Mechanics. Now, GR taught us that space-time and the gravitational field are the same entity. QM informs us that all fields display quantum properties at a small enough scale. Theoretical physicist Carlo Rovelli, a leading expert in Loop Quantum Gravity and responsible for popularising it, notes that the "objective is to find a theory [...] but, above all, a coherent vision of the world, with which to resolve the current schizophrenia between quanta and gravity".[1] "It's a theory made up of coherent but distinct parts. It seeks to be "only" a coherent description of the world as we understand it so far".[2]

Philosopher Butterfield FBA and theoretical physicist Isham, whose work will be cited often in this chapter (the *Stanford Encyclopedia* article on QG refers to another review of Isham as "excellent"[3]), distinguish four types of approaches, or methods, to QG.[4] For instance, the most radical of these, clearly, is to "start ab initio with a radically new theory". LQG mostly follows the least radical method, namely that of quantising GR. However, there is an ongoing debate about which of these approaches will ultimately prove to be the most successful. Additionally, Butterfield and Isham point out that when faced with the challenge of constructing extremely exotic theories, researchers often rely on assumptions about what the theory should look like. This results in the development of theories that align with some preconceived conceptual framework, and are internally consistent in a mathematical sense. Therefore, it is crucial to identify and examine the underlying assumptions of each approach.[5] So, what are the metaphysical, and specifically ontological, presuppositions of LQG?

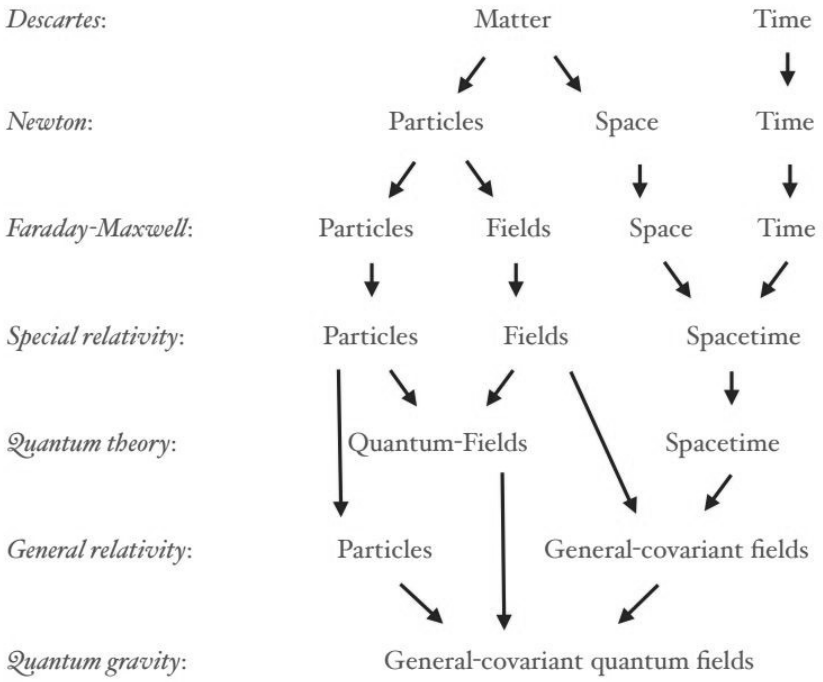
2.1 The Monist Processual Ontology of Loop Quantum Gravity

In this and the following sections, we will mainly follow Chapter 1 of Rovelli and Vidotto's *Covariant Loop Quantum Gravity*, as well as some of Rovelli's articles, essays, and popular science books. The ontology of the world, according to Loop Quantum Gravity, is astonishingly simple: all that there is, are (covariant) quantum fields. General Relativity transformed space-time into a dynamic field like all others, the gravitational field. Then, Quantum Field Theory showed that every field is made of quanta, that it has a granular structure. So, LQG's conclusion is that the gravitational field is granular as well. Figure 2.1 illustrates this process.

This entails that the fields do not live *in* space-time (quantum fields can exist without being grounded in an external space[6]). Rather, the world consists of field on fields. Space-time is no longer the absolute background, but formed out of elementary grains: "space and time come *after*, and not *before*, the quantum states".[7] The "quanta of space" exist at the Planck scale (it can be derived that space-time is no longer a smooth manifold at this scale of 10^{-33} cm) and form "spin networks". A ring in the spin network is called a

1. Carlo Rovelli, *Reality Is Not What It Seems: The Journey to Quantum Gravity* (Penguin, 2017), 127.
2. Carlo Rovelli, *The Order of Time* (Penguin, 2018), 108.
3. Steven Weinstein and Dean Rickles, "Quantum Gravity," in *The Stanford Encyclopedia of Philosophy*, Summer 2023, ed. Edward N. Zalta and Uri Nodelman (Metaphysics Research Lab, Stanford University, 2023).
4. Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 40–43.
5. Butterfield and Isham, 9–10.
6. Rovelli, *Reality Is Not What It Seems*, 169.
7. Carlo Rovelli and Francesca Vidotto, *Covariant Loop Quantum Gravity: An Elementary Introduction to Quantum Gravity and Spinfoam Theory* (Cambridge University Press, 2015), 9.

Figure 2.1: The ontology of the world in Loop Quantum Gravity. Figure taken from Rovelli and Vidotto.



"loop", hence *Loop* Quantum Gravity. The interweaving of the networks is what, or so LQG claims, makes space-time smooth on large scales.

However, "the quanta of space [...] should not be taken too naively as actual entities, but rather as modes of interaction".[8] A process is a space-time region, and conversely, a space-time region is a process.[9] Thus, quantum fields, including the gravitational field, are processual in nature. There is a smallest unit, but it is not isolated: LQG is "a description of how arbitrary partitions of nature affect one another".[10] According to De Saint-Ours, in his chapter for the *The Ontology of Spacetime II*, for Rovelli's LQG, "the world is not made of things evolving in time, it is made of processes".[11]

2.2 The Problem of Time and Change

In the absence of a background spatio-temporal framework, the problem of time becomes a serious issue.[12] This actually is " a cluster of problems that arise principally from the disparate ways in which time is treated in Quantum Theory and in General Relativity".[13] QM views time as absolute, whereas in GR (space-)time is dynamical. Loop Quantum Gravity's radical solution to this puzzle is that at the fundamental level, there is no space-time, solely the gravitational field.

However, Rovelli's view on time does not entail its disappearance.[14] Rather, it is the *parameter t* that has vanished, such that "physical time is introduced as a reading on a 'physical' clock".[15] Consider, for instance,

8. Rovelli and Vidotto, 141.
9. Rovelli and Vidotto, 52.
10. Rovelli and Vidotto, 55.
11. Dennis Dieks, *The Ontology of Spacetime II* (Elsevier, 2008); Alexis de Saint-Ours, "Time and Relation in Relativity and Quantum Gravity: From Time to Processes," *Philosophy and Foundations of Physics* 4 (2008): 265.
12. Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 68.
13. Chris J Isham and Jeremy Butterfield, "On the Emergence of Time in Quantum Gravity," *arXiv preprint gr-qc/9901024*, 1999, 41.
14. Saint-Ours, "Time and Relation in Relativity and Quantum Gravity," 263–267.
15. Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 69.

a runner and a clock. By choosing to describe (physical) changes in the runner in terms of (physical) changes in the clock, and vice versa, we can get rid of the "fundamental" time-variable. As time can be abstracted from any change, there is no independent time variable. Ultimately, "space is just a convenient name for labeling relationships between physical entities".[16] The t-parameter "simulates time in the equations but does not capture its essence", which is change, Rovelli argues:[17]

P1 The background independence of General Relativity entails that, since there can not be any preferred time variable t, or fixed, non-dynamical background space-time, there is no time in Loop Quantum Gravity.

P2 The radical relationalism of General Relativity and Quantum Theory involves that, since the physical world ultimately consists uniquely of interacting dynamical entities (i.e., quantum fields), including space-time, in Loop Quantum Gravity all that exists is dynamical.

C In Loop Quantum Gravity there is dynamics, but no background time or space-time. In other words, there is change, but no time.

That is, LQG endorses the claim that time is change-dependent, leading "to a timeless physics which truly grasps processes".[18] Although Rovelli claims that all extant theories can be formulated in a timeless language (in which the time variable is not special anymore, but interpreted as all the other variables), according to Butterfield and Isham, it remains unknown whether this can truly be achieved.[19]

2.3 The Emergence of Time

The two main differences between the problem of time and the emergence of time are the following. To begin with, the problem of time is mainly concerned with time, rather than space, whereas the emergence of time also covers the emergence of space-time. Secondly, there is a difference in scale. The problem of time is about defining time in QG, whilst the emergence of time seeks an explanation of how "classical" time emerges from quantum time, or in this case, from the absence thereof.[20] ("Emergence" and "classical" are vague predicates. To clarify the concept of "emergence," Lam and Esfeld introduce three types: temporal emergence, causal emergence, and supervenience emergence. Emergence here is of the last type: a theory T_1 emerges from T_2 if T_1 approximates the results, taken in the broadest of terms, of some regime of T_2. Moreover, Aristotelian logic falls short of conveying successfully that classical "can refer to special states whose evolution over time follows classical laws, or to certain quantum quantities taking values in a range where classical theory is successful").[21]

According to Rovelli, the interweaving quantum spin networks give rise to smooth, classical space-time, in a fashion similar to how thermodynamic concepts, such as temperature and entropy, emerge from the statistical behaviour of particles at the microscopic level: his Thermal Time Hypothesis. Here, the observer plays an important role. Because of the immense number of chaotically changing variables in macroscopic systems (the "information" about its constituent particles), the full microstate of a system cannot be known. So, when it is said that a certain variable is "the time", we are not making a statement concerning the fundamental structure of reality. Rather, the statement is about the statistical distribution of the system in question, and "the time" serves as an observer's description of the system's macroscopic properties.[22] Calamari concludes from Rovelli's multi-layered conception of time that ultimately, "our common temporal experience is entirely unaffected by what happens at the Planck scale".[23] It is only at this scale that the world

16. Saint-Ours, "Time and Relation in Relativity and Quantum Gravity," 264.

17. Saint-Ours, "Time and Relation in Relativity and Quantum Gravity," 265; Martin Calamari, "The Metaphysical Challenge of Loop Quantum Gravity," *Studies in History and Philosophy of Science Part A* 86 (2021): 75.

18. Saint-Ours, "Time and Relation in Relativity and Quantum Gravity," 265.

19. Carlo Rovelli, ""Forget time" Essay written for the FQXi contest on the Nature of Time," *Foundations of Physics* 41 (2011): 1475–1490; Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 69.

20. Isham and Butterfield, "On the Emergence of Time in Quantum Gravity," 46–47.

21. Vincent Lam and Michael Esfeld, "A Dilemma for the Emergence of Spacetime in Canonical Quantum Gravity," *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 44, no. 3 (2013): 291–292; Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 71–73.

22. Rovelli, ""Forget time" Essay written for the FQXi contest on the Nature of Time," 1486.

23. Calamari, "The Metaphysical Challenge of Loop Quantum Gravity," 75–76.

is not "flowing through time". However, Rovelli is careful to admit that this theory is highly speculative: "I am not sure if we are dealing with a plausible story, but I do not know of any better ones".[24]

At least two standard quantum problems pose difficulties for the emergence of space-time in LQG. For instance, it is still contested whether a solution to the measurement problem is necessary to account for the emergence of time. The measurement problem is the issue of quantum-to-classical transition, or how and why quantum systems, which are described by multiple possible states, "collapse" into a definite state when measured. For example, Wüthrich states that:[25]

> It should be noted that none of this solves the measurement problem. Only a full solution of the measurement problem will ultimately give us complete comprehension of the emergence of classicality from a reality which is fundamentally quantum. But to solve this problem is hard in non-relativistic quantum mechanics, harder still if special relativity must be incorporated, and completely mystifying once we move to fully relativistic quantum theories of gravity. In light of this, I submit that we would have reason to uncork our champagne even if we only managed to articulate a complete and consistent quantum theory of gravity with a well-understood approximation to semiclassical states and a somewhat rigorous limiting procedure connecting these semi-classical states to classical states of the gravitational field.

Contrarily, Healey believes that a solution to the measurement problem is not a prerequisite for the recovery of space-time.[26]

Additionally, Lam and Esfel conclude that quantum entanglement presents a dilemma for LQG.[27] Either space-time originates from non-spatio-temporal entities that are more fundamental, but it remains unclear how these entities are not within space-time themselves, or space-time is already an intrinsic part of the fundamental quantum gravitational field, and the emergence of classical space-time is simply a matter of different levels of description.

24. Rovelli, *The Order of Time*, 137.
25. Wüthrich, "Raiders of the Lost Spacetime," 29.
26. Christian Wüthrich, Baptiste Le Bihan, and Nick Huggett, *Philosophy Beyond Spacetime: Implications from Quantum Gravity* (Oxford University Press, 2021), 222.
27. Lam and Esfeld, "A Dilemma for the Emergence of Spacetime in Canonical Quantum Gravity."

Chapter 3

Beyond Bifurcation: How Whitehead's Process Philosophy Can Achieve Coherence in Loop Quantum Gravity

In Loop Quantum Gravity (LQG), the gravitational field exhibits quantum properties, such as discreteness or granularity, indeterminism, and quantum relationality.[1] These characteristics strongly resemble Whitehead's philosophy, as outlined in Chapter 1.4. Desmet and Irvine, in their article on Whitehead for the *Stanford Encyclopedia* on Whitehead, assert that: "the introduction of the atomicity of becoming in Whitehead's philosophy implied the granularity and indeterminism of reality that are needed, next to its relationality, to develop a feasible interpretation of quantum mechanics within the frame of this philosophy".[2]

According to Whitehead's relational ontology, events are interconnected networks of atomic actual occasions. Furthermore, indeterminism in physics refers to the inability to predict the outcome of a measurement in advance, with only the probability of each possible result becoming the actual result being calculable. The realm of possibilities, comprised of eternal objects, next to the realm of actualities, consisting of actual occasions, mirror this quantum property.

This chapter aims to explore further parallels between Whitehead's process philosophy and LQG. To this end, we will employ the method of "pilfering", proposed by Elie During, a philosopher of science and Bergson scholar. Due to the limited scope of the thesis, we will analyse one of LQG's ideas. The physicist will be encouraged to view her ideas from a process perspective by "pilfering" where she "is not looking", such that she can bring something "back home" to "think about for a while".[3] In this case, the idea concerns LQG's quantization of the gravitational field and its metaphysical implications for (space-)time. Moreover, we will investigate how LQG can overcome the Bifurcation by learning from process philosophy. The challenges will be presented, along with proposed solutions from process philosophy.

3.1 Whitehead, Loop Quantum Gravity and the Modern Bifurcation of Nature

Firstly, both the Bergsonian and Whiteheadian ontologies and the ontology of Loop Quantum Gravity are process-relational. The gravitational field in particular exhibits significant similarities with Whitehead's Epochal Theory of Time. Whitehead's notion of atomic becoming captures Rovelli's concept of "quanta of space". Additionally, just as subsequent durations cover previous ones, spin networks are comprised of quanta of space. Moreover, Whitehead's processes do not occur *in* space or *in* time: each becoming is associated with a quantum of space and time, mirroring the layered nature of Rovelli's ontology, which consists of fields upon fields upon fields. Lastly, Bergson, Whitehead, and Rovelli consider change as primary to time.

Rovelli's understanding of time is multi-layered. At the "fundamental" level, there is no time, only change. However, he has yet to demonstrate that all physics theories can be formulated without the t-variable. Furthermore, his "fundamentally" time-less world needs to account for our familiar experience of (continuous space-)time, i.e. the emergence of time. Some physicists, like Einstein, consider "phenomenological time" as "a stubbornly persistent illusion". In *Einstein, Bergson, and the Experiment That Failed: Intellectual Cooperation at the League of Nations*, Canales summarises that in his 1922 debate with Bergson, Einstein argued that the philosopher's conception of time did not exist as it combined psychological and physical

1. Carlo Rovelli, "Space and Time in Loop Quantum Gravity," *Beyond spacetime: The foundations of quantum gravity*, 2020, 6.
2. Desmet and Irvine, "Alfred North Whitehead."
3. Elie During, *Science & Philosophy*, Colloquium, The European Graduate School, Saas-Fee, Switzerland, June 18, 2017.

time. He maintained that psychological conceptions of time were merely mental constructs and logical entities, concluding that there was no intersection between them and physical conceptions of time.[4] Rovelli, by contrast, acknowledges the reality of our experienced time, allows room for philosophical explanations, and even proposes his Thermal Time Hypothesis to explain it. Due to our "blurred" vision, we cannot know the complete microstate of a system. As a result, supposedly, our experience of time "arises" in a similar manner to other thermodynamic concepts such as temperature and entropy.

Yet Rovelli's ontology does not encompass this experiential aspect of time, remaining fundamentally timeless yet in a constant state of change (acknowledging the notion that change can exist without being *in* time or that time is change-dependent, similar to Bergson and Whitehead). This omission of experiential time from his ontology may be a common mistake for quantum physicists, presuming that what occurs at the smallest scale is inherently "fundamental". Experiential time "primarily concerns our cognitive and neurobiological systems, but has no relation with fundamental physics".[5] In their book *Order out of Chaos: Man's New Dialogue with Nature*, Prigogine and Stengers suggest that rather "a multiplicity of levels that are all connected, none of which may have a claim to preeminence" is needed.[6] Perhaps fundamentality lies not in differences of scale but in differences of kind. Thus, by disregarding experiential time in his ontology, has Rovelli truly overcome the modern Bifurcation of Nature? To explore this inquiry, we partially draw upon Segall's work titled *Time and Experience in Physics and Philosophy: Whiteheadian Reflections on Bergson, Einstein, and Rovelli*.[7]

While Rovelli acknowledges that speaking "of the world 'seen from outside' makes no sense, because there is no 'outside' to the world" and that "we know little of the actual relation between what we see of the world and the world itself", he still prioritizes physical models over lived experience in terms of ontology.[8] In the dilemma between "forcing the description of the world so that it adapts to our intuition, or learning instead to adapt our intuition to what we have discovered about the world", Rovelli has "few doubts that the second strategy is the most fruitful one", thereby contradicting his own aspiration for coherence.[9] His relational quantum events are simply transitions of "physical quantities from one to another", lacking any experiential quality, Segall notes.[10] Consequently, Whitehead's actual occasions incorporate Rovelli's quantum events, but not vice versa. Similar to Einstein, Rovelli dismisses the relevance of humans or any life-forms in understanding the universe. Perhaps he fails to fully realise that any ontology requires experience, as experience incorporates any view, including the scientific view. Prigogine and Stengers note that "whatever we call reality, it is revealed to us only through the active construction in which we participate".[11] Ultimately, Rovelli falls prey to model-centric thinking, questioned by Auxier and Herstein, since "what standards might we apply to test our models when our model-centric approach demands that we measure experience by those models, rather than those models by experience?".[12] Just as temperature does not equate to the sensation of warmth, a physicist's explanation of "thermal" time does not equate to our conscious experience of time.

According to Whitehead, in order to genuinely heal the Bifurcation, we must reverse the model-centric approach. "The physical world is in some general sense of the term a deduced concept. Our problem is, in fact, to fit the world to our perceptions, and not our perceptions to the world", he writes.[13] While Rovelli unjustly criticised Bergson for being overly emotional – intuition is not a feeling, but an effort – it is possible that incorporating experience within the world is indeed essential to unravel the mystery surrounding the emergence of time.[14] Segall summarises:[15]

> If Rovelli's theory is not just a convenient model and there is really a network of quantum

4. Jimena Canales, "Einstein, Bergson, and the Experiment That Failed: Intellectual Cooperation at the League of Nations," *MLN* 120, no. 5 (2005): 1176.
5. Calamari, "The Metaphysical Challenge of Loop Quantum Gravity," 75.
6. Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man's New Dialogue with Nature* (Bantam Books, 1984), 300.
7. Segall, "Time and Experience in Physics and Philosophy."
8. Rovelli, *The Order of Time*, 109; Rovelli, *The Order of Time*, 180.
9. Rovelli, *The Order of Time*, 191.
10. Rovelli, *The Order of Time*, 169; Segall, "Time and Experience in Physics and Philosophy," 11.
11. Prigogine and Stengers, *Order out of Chaos*, 293.
12. Randall E Auxier and Gary L Herstein, *The Quantum of Explanation: Whitehead's Radical Empiricism* (Routledge, 2017), 111.
13. Alfred North Whitehead, "Space, Time, and Relativity," in *Proceedings of the Aristotelian Society*, vol. 16 (JSTOR, 1915), 129.
14. Rovelli, *The Order of Time*, 174.
15. Segall, "Time and Experience in Physics and Philosophy," 11.

spin foams at the root of spatio-temporal Nature, Whitehead's philosophy of organism requires that there be some aim realized in this spinning, something it feels like to foam, to endure the topological looping, fraying, and folding of these creative quantum events.

3.2 Beyond Bifurcation: Embedding Experience in Science?

To establish Rovelli's Loop Quantum Gravity as a coherent system, Bergson and Whitehead's systems propose emphasizing the significance of experience within the ontological framework. While Rovelli's primary entities, quantum fields, account for only half of his bi-layered notion of time, the process philosopher's system explains *everything* through experience. It may be necessary for scientists to employ Ockham's razor in a different way to seek an alternative to experience as the basis for all explanations. Nevertheless, process philosophy shows time and again that this is impossible, reaffirming the importance of experience in understanding the nature of time.

Perhaps achieving coherence should be limited to individual disciplines, as in modern society the unification of diverse disciplines such as philosophy and physics is considered an inconceivable task. A more practical approach to eliminating the Bifurcation would be *interdisciplinary*, focused on establishing pathways between disciplines, analogous to an organic philosophy. Effective communication and collaboration are vital in bringing science down from its Platonic realm of abstract ideas. Prigogine and Stengers write that "communication is at the base of what probably is the most irreversible process accessible to the human mind, the progressive increase of knowledge".[16] However, this is a challenging task as physicists often struggle to communicate even with mathematicians, and vice versa. Moreover, Segall notes that the question of time cannot be properly addressed within any one discipline, "as it requires us to generate and inhabit an intermediary zone between physics and philosophy".[17] According to Prigogine and Stengers, Bergson's task "as a philosopher was to attempt to make explicit inside physics the aspects of time he thought science was neglecting".[18] Fortunately, at least some physicists demonstrate openness to incorporating philosophical insights into their work. Rovelli wishes "the philosophers who are interested in the scientific description of the world would not confine themselves to commenting and polishing the present fragmentary physical theories, but would take the risk of trying to look ahead".[19] Considering the striking parallels between LQG and process philosophy, engaging in a discourse between the two may be precisely what physics needs to achieve the coherence philosophy possesses. Embracing the non-Cartesian idea that the distinction between subject and object does not exist before their relation could be a first step towards overcoming the Bifurcation. It remains uncertain whether addressing the related measurement problem will directly contribute to resolving the emergence of time, as discussed in Chapter 2.3.

However, the question remains: can an interdisciplinary perspective, let alone fully self-coherent systems, truly be achieved? After all, the language of science is still mathematics. According to Bergson, symbolic language necessarily reduces and abstracts the dynamic and experiential reality. "It is clear that fixed concepts may be extracted by our thought from mobile reality; but there are no means of reconstructing the mobility of the real with fixed concepts".[20] The notion of experience as ineffable and constantly eluding capture through spatializing methods and mathematics is still a romantic notion, thereby a fault of the Bifurcation. It is important to note, however, that Bergson does not intend to dismiss the scientific method or its value. Rather, Bergson questions the feasibility of resolving the Bifurcation solely through a scientific perspective by seeking a "primary entity" using the language of science and the faculty of the intellect, as opposed to the non-discursive knowledge of intuition. Butterfield and Isham, albeit not from the perspective of achieving coherence, acknowledge that "the search for a quantum theory of gravity [...] even puts some pressure on its mathematical formalism".[21] Moreover, they note that "from time to time, a few hardy souls have suggested that a full theory of quantum gravity may require changing the foundations of mathematics itself".[22]

16. Prigogine and Stengers, *Order out of Chaos*, 295.
17. Segall, "Time and Experience in Physics and Philosophy," 2.
18. Prigogine and Stengers, *Order out of Chaos*, 301–302.
19. Carlo Rovelli, *Halfway through the Woods: Essays of Exploration*, ed. John Earman and John D Norton (University of Pittsburgh Press, 1998), 182.
20. Bergson and Hulme, *An Introduction to Metaphysics*, 68.
21. Butterfield and Isham, "Spacetime and the Philosophical Challenge of Quantum Gravity," 21.
22. Butterfield and Isham, 80.

While Bergson aimed to formulate a metaphysics compatible with the scientific knowledge of his time, now it may be necessary to reverse this approach, or at the very least give serious consideration to the dialogue between philosophy and physics to overcome the Bifurcation of Nature and effectively tackle the complex challenges faced by contemporary physics.

Chapter 4

Conclusion

Some philosophers are system builders, aiming to create magnificent and harmonious frameworks where everything imaginable finds its rightful place. The pioneers of this tradition ensured that each object had its designated spot, perceiving the world primarily as a collection of individual entities. However, not all philosophers approached the world and its ontology from the perspective of substance. Some recognised its undeniable interconnectedness and relationality. The problematic relation between static being on the one hand and dynamic becoming on the other hand has been central to Western ontology.

Over time, philosophy and science gradually distanced themselves from one another. While their boundaries were once blurred in ancient times, they grew increasingly sharp with the scientific revolution. Science's bifurcated view of nature and its denial of becoming estranged it from philosophy. However, with the emergence of new theories like evolution, General Relativity, and Quantum Mechanics, process philosophy regained momentum, arguing that its systems were more coherent than substantial ones.

Since the time of Heraclitus, Parmenides, and Zeno, every generation has returned to the question of time, including the founding fathers of modern process philosophy, Bergson and Whitehead. Bergson's radically empirical approach leads him to regard metaphysics as experience, moreover ensuring that everything within the realm of experience finds its place within his framework. In treating time as a dimension, science ignores true time, *durée*, which can be apprehended through intuition, a faculty complementary to the intellect. By redirecting its focus to immediate experience, philosophy can offer a more comprehensive perception of reality. However, Bergson does not dismiss science, and his intuitive philosophy aims at unifying science and metaphysics. On the other hand, for Whitehead, becoming is atomic, and space-time is not merely a container. Every occurence is rather accompanied by a "bubble" of space-time. In this way, time emerges alongside actual entities, forming an inseparable part of their existence.

In Loop Quantum Gravity (LQG), time holds a central position as well. This theory does not aim to become a theory of everything, but rather has the ambitious task of unifying Quantum Mechanics and General Relativity, two well-established yet incompatible theories. It employs a radical application of Ockham's razor, adopting a processual ontology in which everything is a quantum field composed of atomic building blocks. Whereas space-time on the smallest of scales is now accounted for, the challenge of understanding how our familiar experiential notion of space-time emerges from this quantum field remains. Consequently, LQG holds a multi-layered notion of time, which requires adjusting our intuition to accommodate discoveries made about the world. LQG tends to neglect experiential time and the broader role of human experience within its ontological framework, thereby reinforcing the modern Bifurcation of Nature and contradicting its own aspiration for coherence.

Philosophy of science often adopts one of two approaches: either it explores ontological implications, as was the case in this thesis, or it delves into methodological foundations. The focus of this thesis was limited, considering only specific aspects of two philosophers in relation to one theory. However, there are other philosophers, such as Simondon or those from Eastern philosophical traditions, whose perspectives could be relevant in this area. Given that LQG adopts one particular approach in formulating a theory of Quantum Gravity, it is possible that a philosophical investigation into the methodology of Quantum Gravity could yield fruitful insights.

The numerous parallels between Bergson and Whitehead's process philosophy and LQG, including concepts like atomicity, indeterminism, processual relationality and the primacy of change, allow for a fruitful exploration of mutual learning between LQG and process philosophy. While a detailed analysis of these

parallels is beyond the scope of this thesis, a deeper investigation could offer an even stronger foundation, fostering coherence within and between these disciplines. That is, physics incorporating process philosophy could serve two interconnected purposes. Firstly, process philosophy, already a coherent system, could guide LQG towards achieving self-coherence by transcending the bifurcation within its own domain, specifically present in its bi-layered notion of time and disregard for the experiential aspect. Secondly, in order to advance the understanding of being and becoming as two related aspects of reality, a meaningful dialogue between physics and philosophy could establish pathways that foster mutual coherence and mutual learning, even if complete self-coherence is not attained.

As suggested in Chapter 3.2, a potential next step involves the formulation of a scientific framework that aligns with process metaphysics, although this inquiry falls outside the scope of the current thesis. Process philosophers emphasize experience, which is precisely what brings coherence to their systems and is often lacking in physics. However, it is possible that LQG may require additional or other elements to base their explanations on and ultimately achieve a unified system that as well addresses the emergence of experiential time from a "fundamentally time-less world". Ultimately, the works of process philosophers are readily available to be utilised by physicists, offering valuable insights and inspiration for advancing their own understanding and theories.

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