An examination of Alfred North Whitehead's "Philosophy of Organism" to determine compatibility with contemporary arguments for the primacy of process in science of biology.

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Abstract

Alfred North Whitehead's 'Philosophy of Organism' is a philosophy that does not deny the existence of things in the world such as tables and chairs, but asserts that everything is ultimately made of processes. The purpose of this thesis is to understand better whether Whitehead's philosophy is relevant to contemporary process philosophers of biology. John Dupré and Daniel Nicholson are examples of contemporary philosophers of biology who claim that living beings should be viewed as 'processes', as Whitehead envisaged, and not as "things" or "substances". Specifically, we are interested in those topics associated with process ontology and epistemology in the context of the science of biology. The thesis is composed of four parts. The first chapter provides an overview of the historical background of process philosophy and the issues that arose in its development. The second chapter examines Alfred North Whitehead's philosophy of organism. Next, I present an analysis of contemporary philosophers of biology and their process theories, including the work of Daniel Nicholson and John Dupré, Johanna Seibt, Stephan Guttinger and Thomas Pradeu. Lastly, I provide arguments regarding the relevance of Whitehead's philosophy to contemporary philosophers of biology and their process philosophies. Part of this analysis will involve comparisons of these views with generally accepted process qualities distilled from contemporary process philosophers such as Nicholas Rescher, Didier Debaise and George Lucas. The thesis makes the positive claim that Whitehead's philosophical contributions are still relevant to contemporary process philosophers of biology, beyond what is currently recognised. If Whitehead's arguments were to be taken more seriously, this would strengthen the arguments of contemporary process philosophy in the domain of philosophy of biology.

Keywords

Alfred North Whitehead, Process Philosophy, Philosophy of Biology, Philosophy of Science, Philosophy of Organism, History of Process Philosophy, Process Ontology, Process Epistemology, Integrated Systems, Biological Identity, Immunology, Biological Mechanism, Logical Construction.

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1. Chapter One: Introduction and Background

One of the objectives of philosophy is to figure out what underlies everything in the universe. There are two leading candidates and various views on what entities are most basic and fundamental. Alfred North Whitehead supported one of these candidates: That the universe and everything we perceive as real in the world is composed of 'processes'. This thesis aims to better understand whether Whitehead's philosophy is relevant to the contemporary philosophers of biology who are, or may be, process philosophers (contemporary process philosophers of biology), specifically those topics associated with process ontology and epistemology of living beings. For example, John Dupré and Daniel Nicholson are contemporary philosophers who claim that living beings should be viewed through the lens of 'process ontology' as Whitehead envisaged and not as "things" or "substances" in the Aristotelian lineage.

To better understand what it means to endorse process as fundamental to reality, we will first explain the other main candidate, which is 'substance'. Philosophers who advocate this view will refer to 'things' we observe in the world collectively as being 'substances', and they claim that substance has primacy in what underlies everything in the universe. For example, our senses perceive reality as a collection of 'things' such as tables and trees. Given that we can see, touch and smell these things with our senses, there is a tendency for us to view things in the world to be what is fundamentally real.[1] The strongest substance view is that there are only substances in the universe, and they organise themselves in various configurations to make up everything that exists.

A more moderate substance-based philosophical view does not exclude the possibility that processes exist and likely influence and change substances. For example, this view allows that a

[1] Note: 'substance' is classically considered to represent matter; in this thesis ', substance' and 'things' will be used interchangeably to refer to matter in the substance definition or objects such as chairs and tables that are substance-based. When 'things' is used in another context, such as an indicator "…the thing in the corner of the room." this will be highlighted.

seed grows into a tree through the process of germination. However, in this case, substances are viewed as fundamental, and processes only act upon them. A moderate process view allows both processes and substances to exist, but processes have primacy, and things come from processes. Finally, the more extreme process philosophy claims that what is fundamentally real are processes exclusively and that substances do not exist.

Alfred North Whitehead's 'Philosophy of Organism' is a process philosophy that does not deny the existence of things in the world such as tables and chairs, but asserts that processes are the underlying stuff that everything is made of. Whitehead influenced the 'organists' in the early twentieth century, a name given to the biologists that promoted 'process' as foundational to biology. However, his relevance to contemporary philosophical debate is controversial, given the perceived obscurity of his philosophical theories and lack of perceived relevance to contemporary philosophy of biology.

This thesis makes the positive claim that Whitehead's philosophical contributions are more relevant to contemporary process philosophers of biology than many currently recognise. There is an opportunity for contemporary process philosophers of biology to incorporate and further expand on Whitehead's philosophical work, or at the very least contrast his ideas with their research, for the following reasons: (1) Criticism as to the legitimacy and usefulness of Whitehead's philosophy for biology is overstated. (2) Whitehead conjectures that philosophers of biology, science and biologists are unaware of their own bias towards 'substance' based metaphysics. Whitehead made a case that we need to be aware of our metaphysics and pay attention to our decisions when developing philosophical frameworks. And, (3) Whitehead's philosophy highlights several gaps in the process philosophy of contemporary philosophers of biology that, if considered, might strengthen their arguments against substance philosophy. His philosophy explains how 'novelty' and 'creativity' are features of the natural world and how processes might interact and relate with each other to be scaled up in size and complexity to become macro-objects such as trees and humans.

Whitehead was in a unique place to identify what features would be necessary for process to have primacy in biology and science. As a scientist, he spent his career defining the logical foundations for the natural sciences, and his project was to extend his methodology to the physics and geometry of the world. He established a logically defendable position that events, rather than localised matter, are more fundamental in nature. As a mathematician, his project was to develop a 'logico-mathematical' system for the 'logical construction' of objects that exist in the world. As a philosopher, he took this project further to understand what it would take for a world to be grounded in process rather than substance. An outcome of his work was an approach to unify the macro world of objects we perceive with the world represented by quantum mechanics. His view is that, given biology is grounded in the natural sciences, it is reasonable to include living beings within this unified framework.

In order to assess Whitehead's significance and relevance to contemporary process philosophers of biology, this thesis will progress through a number of steps. In the following sections of this chapter, I will provide the historical background of process philosophy and the historical development of the view that nature and evolution are dynamic processes. This includes an introduction to some of the most significant issues in process philosophy, primarily drawing on work from Nicholas Rescher and George Lucas. Lastly this chapter will provide a glossary of certain words such as 'thing' and 'substance' throughout this thesis. Whitehead's philosophy is given focus in chapter two. First, I will provide a chronological overview of the contributions made over his career, followed by an analysis of his rejection of localised matter and the bifurcation of nature. I then examine his theory of occasions, the fallacy of misplaced concreteness, the theory of extensive abstraction, his views on the role of metaphysics in science and his philosophy of organism. The chapter concludes with a brief review of Whitehead's impact on the early twentieth-century organists (Biologists). Chapter three will examine work in contemporary process philosophy of biology, drawing from philosophers such as Daniel Nicholson, John Dupré, Johanna Seibt, Stephan Guttinger and Thomas Pradeu. The fourth chapter will use material from the preceding chapters to make a positive case for the relevance of Whitehead's philosophy for

contemporary process philosophers of biology. We begin with a discussion of what is a process and what constitutes a process philosophy.

1.1 What are processes?

The purpose of this section is to develop a better understanding of what commitments a process metaphysics entails. The intention is to use this material as a reference throughout the thesis and specifically for analysis in Chapter 4. There are several different branches or schools of process philosophy that share common core traits but are quite different in emphasis. For example, two schools of process philosophy include the pre-Darwinian evolutionists and the realists of the early twentieth century. The founding of process philosophy is attributed to no particular thinker, but a survey of the historical development of process philosophy is included later in this chapter. Process philosophy is customarily described by a series of shared common metaphysical commitments stressing the importance of time and change, and the idea that events are the fundamental constituents of the universe rather than a static substance. Other common traits of process philosophy include novelty, creativity, partial self-creativity or partial indeterminism, and a lack of distinction between the subject and object as represented by language (Lucas, 1989, p. 20).

A commonsense argument for the ontological primacy of process is that nature appears to us as a sequence of processional events. We have a strong metaphysical intuition that time is required for change to occur. Later in this chapter we discuss the distinctive qualities of what makes up a process. However, intuitively, the forces that we identify through observation and science such as electricity, weather, fluid dynamics, and biological systems, all appear to us as processes. Biological evolution, the emergence of macro properties from micro properties, and novelty and creativity are all features of the world that we can explain or observe as processes. Therefore, given the observation of a dynamic world, we might intuitively view that all objects in the world are reduced to underlying physical processes, and have an inherent ability to change as nothing remains static and unchanging. An alternative weaker hybrid position is that the underlying

processes are necessarily antecedent to the creation of objects we see in the world and have ontological primacy whilst acknowledging the existence of substances (Rescher, 1996, p. 28-31).

> "A process is a coordinated group of changes in the complexion of reality, an organized family of occurrences that are systematically linked to one another either causally or functionally.[…] nature is built upon the past and is not a series of arbitrary unconnected presents. Process provides consistency even when what is in a process might change – thus processes can preserve their self-identity." (Rescher, 1996, p. 38-40)

An additional argument for a process approach is that a central issue with substance ontology is how to account for the persistence and endurance of objects over time. For example, how do we account for the lifecycle of a frog as it changes into a tadpole and eventually to a frog, and what makes the frog the same throughout this change over time (Nicholson and Dupré, 2018, p. 18)? For substance-based approaches to claim that the frog is the same organism as the tadpole, they must identify an essential identity element that does not change over time. Substance-based philosophers debate what this essential identity element should be and what its characteristics are, and the difficulties here provide motivation for the view that objects reduce to underlying physical processes. A process approach doesn't have this issue as related processes over time are interconnected, providing continuity and persistence. Rescher explains this interconnectedness as being "linked" with one another, and we will discuss what it takes for processes to be related later in the chapter. As we will see, this idea is similar to Whitehead's view that new events are formed from the direct past events in a process of perpetual continuity.

Now that we have considered some intuitive arguments for process philosophy, we will now consider these ideas in further detail, to understand process philosophy claims and directly contrast them with the substance framework. Table I below is a list of the main characteristic qualities, distilled from various process philosophers, of both process and substance philosophies

and the commitments that each entails[2] (Rescher, 1996, p. 4-9, 2000; Lucas, 1989; Bickhard, 2011; Seibt, 2024). When describing metaphysical concepts, it is sometimes easier to initially discuss the features or qualities of that concept to allow a better understanding. For example, if asked 'What is time?', we might initially note that time is perceived as sequential and that time can be measured using instrumentation that has periodicity such as a clock. Likewise, Table I below sets out an agenda to further explain the main qualities to understand an answer to the question 'What are processes?' It is important to note that Table I lists substance qualities compiled through the lens of process philosophers. These qualities largely overlap with those endorsed by substance-based philosophers, although they may differ in emphasis and priority.

Substance:	Process:
- discrete non-interactive	- interactive relatedness
- non temporal	- temporally related (change over time)
- separate (reductionism)	- wholeness (totality, holism)
- fixity and static	- dynamic and active (transformation)
- uniformity of nature	- creativity and novelty
- passivity (being acted upon)	- activity (agency)
- cause and effect	- becoming (dispositional change)

Table I

When we consider the main qualities endorsed by substance metaphysics, we are committing to the idea that substance underlies everything that exists. Further, substances are separate, unchanging and static at a fundamental level, and they are not affected temporally (Howard, 2021, para. 4-12; Seibt, 2024; Strawson, 1959). The idea that substance is not temporally affected is due to the need for an essential identity element to be maintained over time, which is unchanging (Rescher, 1996, 38-40; 2000; Seibt, 2024). To understand this view we can draw upon the presocratic philosopher Parmenides who proposed a static and unchanging universe where

[2] These qualities have been selected from the works of philosophers referenced, namely Rescher, Bickhard and Lucas. However, many of the same themes can be attributed to other philosophers. A summary of the historical development of process philosophy is included in section 1.2.

all that there is in the universe is all that there ever was or ever will be: "…that what-is is ungenerated and imperishable, a whole of a single kind, unshaken, and complete. Nor was it ever, nor will it be since, it is now all together one together." (Parmenides, B8: Tr. Cohen, Curd & Reeve, 2016). The reason for highlighting Parmenides is that these early philosophical ideas regarding an unchanging and static fundamental reality have developed over time into the modern conception of substance prevalent in Western philosophy and science. In the modern context, this idea continues as the view that all things in the universe are reducible to some atomist physical matter (substance) as discrete building blocks.

A key concept associated with the substance approach is that one can take an inventory of everything at an instantaneous point in time and know the states of affairs and facts (Seibt, 2024). This is not to say that substance-based metaphysics endorses determinism; instead, it means that at a given point in time, the facts about all the entities are known. Additionally, at a fundamental level, substance is passive in that it requires an external cause, and thus a passive substance results in a uniformity of nature (Seibt, 2024, para. 38). Parmenides believed it is impossible for anything innovative and new to occur, as this would require something to come into existence from 'nothing'. Similarly, he believed that things cannot perish, as this would require the acknowledgement that a 'nothing' as a concept exists (Bickhard, 2011, p. 91).

In contrast to a substance approach, when endorsing a process metaphysics, philosophers such as Whitehead make the opposite commitment: That processes underlie everything. These processes can be described as activities, events and experiences. An activity requires a duration of time and does not exist as an instantaneous moment in time or state of affairs. When we consider the macro example of an activity such as a rainstorm, while the activity of the storm is underway it can be viewed as a series of events that progress in a sequential manner and change over time. Without time the activity of the events of the storm cannot be observed (Rescher, 1996, 2000).

Another core tenet of process metaphysics is that change is not viewed as pieces of matter impacting each other, similar to the analogy of billiard balls impacting each other. Rather, process philosophy employs the concept of 'becoming', where ingredients merge to become a new entity (Anjum and Mumford, 2018; Rescher, 1996; Seibt, 2024). The analogy of this concept is when a salt cube is introduced to a glass of water and combines over time to become a new saline liquid. Becoming has a non-reductionist quality, where processes combine to become a new whole or totality, the example being cells that combine to make what is a whole and total human (Nicholson and Dupré, 2018, p. 26-27).

In contrast to Parmenides's substance-based view of the world, the presocratic Heraclitus uses the analogy of the river, where he saw everything as a changing process *panta rhei* ("everything flows"). Heraclitus saw the world as dynamic, involving perpetual conflict and change. Here, processes interact with each other in a dynamic flux, as they are not static and independent. However, this makes it difficult to explain how any qualities endure over time. For this reason, many process philosophers have taken a more moderate approach to accommodate the concept of an enduring quality. For example, Whitehead viewed the quality of solidity as an enduring feature that processes can use when creating new objects in the world.[3] We will discuss Heraclitus further in the historical summary later in this chapter, and review Whitehead on this point in more detail in the next chapter.

Lastly, a crucial distinctive quality of a process view is the ability to accommodate the novelty and creativity we perceive in the world. In contrast, substance-based views focus on uniformity at a fundamental level in the world. Whitehead promoted novelty and creativity as a principal feature of his cosmology, commenting that the absence of this would render a world that was doomed to repeat itself in a monotonous manner. Another more extreme view is that processes are required for creativity due to their ability to disrupt or destabilise the status quo as a balancing reaction of 'order' (Rescher, 1996, p. 75; Pepper, 1938).

[3] His idea of an enduring quality has some similarities to Plato's idea of the realm of ideal forms where perfect qualities of what is in the world exist.

1.2 Process Philosophy's Historical Context

"History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed." (Thomas Kuhn, 1962, p. 1)

Despite substance metaphysics being the predominant focus for Western philosophy, there have been thinkers who developed process philosophy throughout history. As discussed in the prior section, although process philosophies share several common traits, they also differ in some of their commitments. For example, some process views are interested in the ontological assertion that process underlies everything, while others focus on the nature of dynamism. This section will survey prominent historical thinkers who have contributed to the development of the process qualities reviewed in the prior section. Additionally, this section will provide a chronology of the development of the main characteristics of process philosophy, and position Whitehead's philosophy in this historical context, explicitly mentioning where there is a clear influence on Whitehead's work. A biography of Whitehead and a review of his philosophy of organism is contained in Chapter 2.

Historically, philosophers have been interested in explaining what they observed in the world: What underlies what we observe in the world? Why is what we observe dynamic and appears to always be changing? What accounts for the persistence of the things we observe? How should we explain the novelty that emerges in nature? And, how should we classify what there is in the world? As discussed above, Heraclitus (~540 B.C.E) was a presocratic thinker and an early recorded proponent that process is fundamental in the universe. Heraclitus asserted that the world is dynamic and is in a perpetual state of becoming. He rejected the idea that the world was made up of unchanging objects that organised themselves into things we observe in the world such as rivers, rocks, trees, and animals. He claimed that what underlies everything in the universe is a violent 'fire' that drives the transformation of things that are only temporarily stable and not permanent, as everything continually changes and is in flux (Rescher, 1996: 9). Heraclitus's key insight was that "…all things happen by strife and necessity" (Heraclitus, B80, Tr.

Cohen, 2016), due to the ongoing conflict he witnessed in nature. Therefore he concluded that reality is a process of perpetual change with the analogy of a dynamic flowing river, "Upon those who step into the same rivers, different and again different waters flow" (Heraclitus, B12, Tr. Cohen, 2016).

As mentioned in the prior section, the contrast at the time to Heraclitus was the presocratic philosopher Parmenides, who, like Heraclitus was interested in understanding what underlies everything and in what explained why things in the world changed. However, Parmenides developed his theories as an extension of Zeno's ideas and is best known from his Goddess *proem* (poem), where he claims that everything is an unchanged one, whole or monism, "…it is what is: for it can be, but nothing is not…"[4] (Parmenides, B6: Tr. Cohen, 2022). Parmenides could not reconcile the idea that we cannot contemplate the concept of "nothing". For example, how could a thing be created from nothing? He believed this must be impossible, and therefore all there is in the universe must already exist. Parmenides posited a static unchanging world where everything there is, is already in existence. This laid the ground for the Atomists Leucippus, Democritus, and Epicurus argue that the world was made of material atoms that are discrete and not reducible (Howard, 2021). This is the crucial characteristic of substance metaphysics, which is prominent in Western philosophy and continues to be developed to this day.

Like Heraclitus, both Plato and Aristotle were interested in understanding what underlies everything and why the world they observed appeared to change and be dynamic. They also tried to resolve why, in a dynamic universe, things such as rocks and trees seemed to have long periods of persistence and stability over time (Howard, 2021; Seibt, 2024).

In the dialogues Theaetetus and Timaeus, Plato appears to agree with Heraclitus that the world is in perpetual change. Plato accepted that the world as we observe it is just what we perceive

[4] This concept is similar to the contemporary theory of Minkowski's four-dimensional manifold block universe, which - thanks to Albert Einstein - is prevalent in our modern interpretation of the universe. One might plot an object with spatiotemporal coordinates where some objects and the associated events happen prior or after other objects. For example, the objects and events of World War I are prior to the person setting foot on the moon. However, the objects order and sequential placement in the block universe do not change.

through our sensors, and also that it is processional and constantly changing. Like the later process philosophers, Plato grappled with explaining the existence of enduring qualities of things. For example, when we observe a tree, we recognise it because we have memories of other things that appear to be trees, given they have the same qualities, such as colour, texture and solidity. Without these qualities, we would not have a category of "trees", as there would be no consistency in what defines a tree. To solve this problem, Plato posited a realm of ideal forms separate from the realm of particulars. The ideal form of a given object existed, stable and unchanging, in this realm. Plato's theory is essential for understanding Whitehead's philosophy. Whitehead further developed this idea by speculating that eternal entities exist that have enduring qualities over time. However, Whitehead's eternal entities differ from Plato's ideals as they are more analogous to design patterns and recipes (Rescher 1996, p. 10).

Aristotle's metaphysics is grounded in substance with significant features of process ontology. Aristotle's contribution to process philosophy is his identification and explanation of 'activity' and 'motion', which are concepts grounded in a process approach. His work identified several observable properties in the world: potency, activity, motion and change (Rescher, 1996). However, Aristotle proposed an active world where substances collide through motion and arrange themselves to maintain the internal processes or functions found in living beings, such as blood circulation. Aristotle interpreted the permanence of qualities he observed and his ability to characterise living beings by species as evidence that nature had a 'developmental tendency' towards an end-state or '*Telos*'. An example of this idea is where the embryo develops into the adult woman, which he would have viewed as an end-state.

Prior to the modern scientific enlightenment around the 1600s, Western philosophy was mainly focused on the development of Aristotle's substance-based ideas. However, some thinkers developed process philosophies, notably Thomas Aquinas (1225-1274) and Plotinus (204-270). Aquinas and Plotinus both built upon Plato's and Aristotle's ideas to make sense of the impetus for novelty and creativity they observed in nature. In his treatise known as the *Enneads*, Plotinus outlines a Platonist system, which includes a god that provides the impetus for dynamicity in

nature.[5] Plotinus claimed that creativity, novelty and the impetus for a changing nature comes from the creator god, which emanates as a type of on-going perpetual force (Plotinus, V.2.1, tr. Gerson et al., 2018). Aquinas proposed that god is necessary for creativity and novelty to be a feature of the world, as only god can create something novel from nothing: "creato ex nihilo" (Aquinas, Summa Theologica I, Q45, a.5; tr. Freddoso, 2023).

Gottfried Wilhelm Leibniz (1646-1717) claimed that the world was composed of experiences. His ontology was pluralist, with numerous experience entities he called 'monads' and monist in the sense that monads are one type being 'experiences' (Rescher, 1996, p. 12). As described in Leibniz's 'Monadology', monads have a perspective or a type of primitive consciousness that makes them aware of other monads. Leibniz called this awareness between monads 'appetition' and said it was necessary for nature to change. Monadology helps us to understand Whitehead's views, as he held a similar idea to appetition, which he called 'prehension' and 'subjective aim'. For Leibniz, monads changed from one internal state of affairs to another by morphing over time towards some desired outcome or new goal, as follows:

> "The activity of the internal principle which produces change or passage from one perception to another may be called Appetition. It is true that desire [l'appetit] cannot always fully attain to the whole perception at which it aims, but it always obtains some of it and attains to new perceptions." (Leibniz, Monadology; tr. Latta, 1898, para. 15)

Many process thinkers have focused on change and flux. However, the evolutionary cosmologists who worked prior to Darwin and through into the twentieth century were interested in transformation and a rejection of reductionism and the mechanism of biology. These thinkers endorsed 'holism' and the importance of the whole or totality rather than the reduced parts.

[5] As will be reviewed in chapter two, Whitehead adopted the similar idea as Plotinus that "god" may explain the impetus or rhythm of continual change as observed in nature. For whitehead, god is not anthropomorphic but more like a universal or eternal object that is an additional necessary ingredient to creativity and change. Contemporary philosopher Charles Hawthorn brought these collective ideas together in his contributions towards process theism, which is not a focus of this thesis as we are not concerned with the philosophy of religion (Hawthorn, 1953).

Diderot (1754) was an early evolutionist who developed a cosmology in which the universe is an organic, self-sufficient entity, perpetually transforming, organising and reorganizing matter in a manner similar to living organisms. For Diderot, the universe is like all living bodies and must follow an organising principle that unifies the functioning of the whole organism towards a self-sustaining evolutionary drive, towards biological complexity and sophistication (Diderot, 1754, 1769, 1780; Lucas, 1989, p. 23).

Another early evolutionary thinker, Jean Batiste de Lamarck (1744-1829), was interested in explaining nature's development, and proposed a theory of the evolution of living beings (Lamarckianism) before Darwin. His theory advocated a "punctuated evolution" and emphasised that environmental processes are interconnected and relational. Punctuated evolution is a process where organisms are stable for an extended time, followed by rapid transformations and modifications which take place in response to ecological changes. These increase the chances that the favourable traits are then passed on to offspring (Lucas, 1989, p. 24).

Many of the themes from Lamarck's portrayal of nature as an interconnected whole with reciprocity and dynamism were combined with Kant's 'transcendental' view of nature being "…the end-product of the activity of human understanding" by the German Idealists and Romantic philosophers. For example, Friedreich Schelling (1775-1859) claimed that nature was a dynamic, creative process that culminated in the production of human consciousness (Braekman, 1985).

Georg Wilhelm Friedrich Hegel (1770-1833) is another German idealist, who promoted a wide variety of theories relevant to the philosophy of process, with the primacy of the process of living things and the "…organic purposive behaviour in nature". However, as Lucas and Dieter Henrich claimed, much of Hegel's notions of "…finite freedom, novelty and creativity, contingency, temporal flux, and becoming" are ignored by contemporary philosophers, given the conservative and selective translations of Hegel's material by McTaggart and Bradley. Furthermore, according

to Lucas, It might be for this reason that the twentieth-century empiricists and realists, including Whitehead, largely rejected Hegel's ideas (Lucas, 1989, p. 27; Henrich, 1958, p. 131).

The American Pragmatists, including Charles Sanders Peirce (1839-1914), William James (1842-1910), and John Dewey (1859-1952), viewed the ontological primacy of process as being reality. They did not view any scientific laws or laws of nature to be unchangeable. The need for a pragmatic approach based on agency and experience is the pragmatist's answer for coping with a world of flux and change. The key concepts from their philosophy include the predominance of natural relatedness, that time is required for nature to exist, and the preoccupation of the natural sciences with the fixity of a discrete matter is based on abstraction rather than reflecting reality (Rescher, 1996, p. 20). As we will see in Chapter 2, Whitehead was influenced by the pragmatists in each of these respects.

Charles Sanders Peirce (1839-1914) was influenced by evolutionary ideas of life and nature and accordingly observed that nature evolves as an ongoing process of development with a teleology. Unlike substance philosophy, where laws of nature are static and unchanging, Peirce believed that both universals and laws of nature can change and evolve. His philosophy of nature was grounded in the concepts of 'chance', 'spontaneity' and 'synechism' (relatedness), all viewed as processional from his perspective (Rescher, 1996, p. 14).

Like Pierce, James saw the world as a chaotic sea of changing processes, where the agent's cognitive ability provides the necessary structure for coping with this chaos. 'Novelty' is a feature of James's ontology to the extent that it promotes indeterminism, free will and chance: "…we live, as it were, upon the front edge of an advancing wave-crest, and our sense of determinate direction in falling forward is all we cover in the future of our path." (James, 1912, p. 54). Similar to James and reviewed in Chapter 2, Whitehead's philosophy incorporates a process for 'becoming' a new entity that is goal-oriented, which he names the 'subjective aim'. However, even though this process is goal-oriented, the future new entity is not determined.

Dewey became well known in the 1920s for a series of lectures on the works of both James and Bergson. Dewey expanded on James's work by emphasising the role of the agent with free will, who, when equipped with capacities and time, can create works of art and novelty. An analogy for this is the artist who doesn't know what they are creating until they begin to paint, "…an artist standing before a blank canvas [who] puts up his brush, [and] no one—not even he himself—can know ahead of time what the result will be." (Rescher, 1996, p. 19).

Henri Bergson (1859-1941) was a French philosopher whose book 'Creative Evolution' influenced James and Whitehead. Bergson asserted that a fixed point of the discrete matter is not real, as it is isolated, does not relate to other matter and is disconnected from the continuous flow of time. He viewed this representation of discrete matter as an abstraction, leveraged for the scientific method. As discussed in Chapter 2, this idea of abstraction formed a central theme in Whitehead's philosophy of organism (Whitehead, PR, 1929: Preface xii). Bergson also viewed process as primary in contrast to substance metaphysics. However, he was more interested in the temporal features of processes. His idea was that reality is divided into durations of experience, and that our mind abstracts these to create thoughts that deal with 'things'. Bergson emphasised psychological duration being composed of experiences rather than analysing time into defined periods. He claimed that these psychological durations represent a whole experience of reality. Further, these experiences cannot be dissected or broken up into smaller components unless abstracted from reality and analysed using mathematics or science which he labelled "…a distorted transformation'. We will discuss in the next chapter how Whitehead was also influenced by Bergson's idea that 'time's passage' is required for nature to exist (Debaise: 2017, 4; Rescher, 1996, p. 17).

That concludes our brief overview of the development of process thought up until Whitehead. In the next section, I will discuss some of the vocabulary and nomenclature used throughout this thesis.

1.3 Vocabulary and Nomenclature

This section summarizes some of the terms and concepts used throughout this thesis, where an understanding of how they are defined, synonyms, or related terms is helpful to the reader. Understanding these terms will be especially helpful in the next two chapters, where we examine Whiteheadian and contemporary philosophies.

Term: **process**
Definition: Processes are made up of events being units of process that underly everything.
Synonyms: events, experiences, actual entities, actual occasions
Related Terms: Whitehead's theory of occasions
Example: The process of becoming an actual entity (event) is concrescence.

Term: **substance**
Definition: Things that underly everything that exists.
Synonyms: things, matter, localised matter
Related Terms: 'Objects' in the world, spatiotemporal, simple location
Example: 'Substances' are isolated, with spatiotemporal location.

Term: **process relations**
Definition: Concept and approach for process-to-process interaction.
Synonyms: process relating, process interactions, prehension
Related Terms: concrescence [Whiteheadian term; process of becoming a new actual entity]
Example: 'Process relations' is important to understand how processes interact with each other.

Term: **becoming**
Definition: Concept where a new event is created.
Synonyms: concrescence, change, dispositional change, new actual entity, new event
Related Terms: past entities, prehension, feeling, subjective aim, eternal entities.
Example: Whitehead names the process of 'becoming' concrescence.

Term: **dynamic**

Definition: Processes continually interacting and changing.

Synonyms: flux, activity, change

Related Terms: durations, time, temporal, spatiotemporal, instantaneous, events

Example: The world is dynamic and constantly changing over time.

Term: **change**

Definition: To move from one state to the next, or become something new.

Synonyms: dispositional change, new actual entity, new event

Related Terms: past entities, prehension, subjective aim, eternal entities

Example: Dispositional change is similar to melting a sugar cube in water.

Term: **eternal entity**

Definition: Concept similar to a universal in a standard philosophical context.

Synonyms: universal, enduring qualities, enduring object

Related Terms: primordial nature of god, persistence, essential characteristic of objects

Example: An eternal entity is used to add creativity as part of becoming a new process.

2. Chapter Two: Discussion of Alfred Whitehead's Philosophy of Organism

Whitehead is a giant in the development of process ontology, but the majority of his contributions are largely eschewed by contemporary philosophers of biology. To address why I think this is a mistake, we will need to understand his claims. So in this chapter I will outline the primary themes in his thought and what motivated them. We will first explore how his philosophy and published works developed over time. Then, we will examine what exactly he rejected, namely the bifurcation of nature and localised matter. These two rejections are the motivation for his philosophy of organism. We can then review his Philosophy of Organism as documented in his book, *Process and Reality* (1929), with more confidence. Whitehead's philosophy has a reputation for being difficult to understand. This is partly due to his tendency to take key concepts and label them using words of his own invention. For this reason, we take time in this chapter to provide a background of only those key themes necessary to understand better why Whitehead's philosophy remains relevant to contemporary process philosophy of biology. We then pivot to discuss why Whitehead viewed metaphysics as necessary to science and biology, as this also forms one of my arguments as to why his work is relevant. And lastly we will explore how Whitehead's work related to the early twentieth-century biologists, known as organists, who were aligned, if not directly influenced by, Whitehead's work. At the completion of this chapter we will have covered Whitehead's philosophy of organism, which will be helpful background for the next two chapters when considering Whitehead's relevance to contemporary philosophy of biology.

2.1 Chronology of Whitehead's philosophy development

This section will first provide an overview and chronology of Whitehead's academic background and published philosophy. Next, we will examine what Whitehead rejects. It is important to understand how his ideas developed over time and appreciate how his academic background in physics and mathematics influenced his philosophy.

2.1.1 Background

Alfred North Whitehead was a mathematician, physicist and philosopher (1861-1947) who is best known for his work in the foundations of mathematics and philosophy of science. Early in his education he attended Trinity College, Cambridge and earned a BA in Mathematics. Following his appointment as a fellow of Trinity, he spent much of his early academic years teaching. In 1903, after publishing his book *Treatise on Universal Algebra* (1903), he was awarded Fellow of the Royal Society. He then collaborated with Bertrand Russell, a student of Whitehead's who also later became a Fellow of Trinity, to create a logical system for the foundations of mathematics. Russell and Whitehead published several volumes of the '*Principia Mathematica'* (Whitehead & Russell, 1910, 1912, 1913). In his early 50s, Whitehead left Cambridge, and was appointed Professor of Mathematics at the Imperial College of Science and Technology in London. During his time at Cambridge and Imperial College, he researched logic and relativity, developing a competing theory to Albert Einstein's theory of general relativity (Whitehead, 1922). Unfortunately his book on the subject, *The Principle of Relativity* (1922), did not receive much attention, although it was viewed as a viable alternative to Einstein's theory (Broad C. D., 1948, p. 143).

In 1924, at the age of 60, Whitehead retired from teaching in London and took a position as Professor of Philosophy at Harvard until his retirement in 1937. During this time at Imperial and Harvard, he wrote and published books prolifically, including *The Concept of Nature* (1920), *Science and the Modern World* (1929), *Process and Reality* (1929), *Adventures of Ideas* (1933) *and Nature and Life* (1934). He was appointed to the British Academy in 1931 and awarded the Order of Merit in 1945. Whitehead died in 1947.

2.1.2 Chronology of Whiteheadian Philosophy

To understand Whitehead's philosophy, it is vital to appreciate that Whitehead was originally a mathematician and theoretical physicist, grounding his worldview through a mathematical lens. The implication is that his later philosophy of organism is the culmination of his life's academic experience as a mathematician and not a rejection of his analytic background (Emmet, 1932). For

example, Whitehead's overall project might be speculatively summarised as an attempt to complete *Principia Mathematica volume 4* (Clarke, 1992). This volume would have been concerned with the foundations of geometry being the basis for physics and the 'logical construction' (logico-mathematical method) of all "things" in reality. A chronology of the development of Whitehead's ideas is outlined below.

(1900-1905) Whitehead and Russell collaborated (*Principia Mathematica*) to develop a system for the 'logical construction'[6] of natural numbers deductively rather than inductively using 'Peano's axioms'. Both Whitehead and Russell were determined to achieve a level of certainty and clarity that, in their view, could only be achieved using deduction. For example, one of the tasks they set themselves was to logically describe the number "2" without using mathematical axioms. The idea of a 'logical construction' or what Whitehead called a 'logico-mathematical method' became a core idea for Whitehead. Although Russell is attributed with the term 'logical construction', Russell himself attributes Whitehead with the definition of what 'logical construction' is and its application to geometry and physics (Russell, 1929: p.v.).

Russell and Whitehead used logical constructions to derive numbers, and later Russell extended their application to solve problems in language, particularly with descriptive and denoting

[6] 'Logical construction' of a number is a mathematical technique initially used by Frege, Dedekind and Cantor to derive numbers without using inference from axioms such as the Peano axioms.

For Russell and Whitehead 'inference' lacks the discipline of certainty and clarity that deduction can provide. For example, let's infer "2" such that "if n + 1 = 2, therefore n = 1"; however, what do "+" and "1" mean as they are metaphysical entities? Leveraging Cantor's earlier work, Russell's key insight is that between 'classes' (sets) that are different but related on a one-to-one basis, they can be seen as equinumerous and provide the necessary mechanism to derive the object (number) given their similarity. For example, 'logical construction'; where 'classes' specifying one type, such as cardinal numbers, are related to 'classes' of another type, such as the set of couples given their similarity. Russell provides an example of the logically constructed number "2" in his book *Introduction to Mathematical Philosophy*:

"We naturally think that the class of couples (for example) is something different from the number 2. But there is no doubt about the class of couples: it is indubitable and not difficult to define, whereas the number 2, in any other sense, is a metaphysical entity about which we can never feel sure that it exists or that we have tracked it down. …Accordingly, we set up the following definition:—The number of a class is the class of all those classes that are similar to it. Thus the number of a couple will be the class of all couples. In fact, the class of all couples will be the number 2, according to our definition." (Russell, 1919, p. 38.18)

phrases. Whitehead's foray into foundational mathematics, and his attempt to create a logical deductive system for the 'logical construction' of numbers, laid the groundwork for his work to develop a similar geometric system of 'logical construction' for physics and, ultimately, his cosmology of reality. The project was similar to that taken up by Rudolf Carnap in his book *The Logical Structure of The World* (1967), who was influenced by both Russell and Whitehead (Clarke: 1992, 131).

In his book *An inquiry into the principles of natural knowledge* (1919), Whitehead defined his logico-mathematical method using sets of events to abstract objects in nature, which he called his theory of extensive abstraction. A detailed account of the method Whitehead employed is beyond the scope of this thesis. The method to abstract objects from sets of events is similar to the approach to derive the number "2" as per Footnote 6 and detailed in 'Section IV – in *Process and Reality* (1929).

(1905-1919) Whitehead wrote several papers, including *On mathematical concepts of the material world* (1905), that furthered his project of creating the logical construction of reality based on relativistic physics. This is an extension of his work with numbers and arithmetic towards the foundations for geometry (Whitehead, 1905).

(1919-1925) In his books *An enquiry into the principles of knowledge* (1919), *The Concept of Nature* (1920) and *The Principles of Relativity* (1922), Whitehead develops a mathematical rationale and outline of his argument and primary theories that form the basis for his future work. These works are aligned with Whitehead's quest to understand the foundations of geometry and physics. They progressively outline his ideas, including: (i) the rejection of the bifurcation of nature and localised matter, which invokes an instant of matter in space-time with no temporal extension or relatedness to other objects; (ii) the theory of occasions (events); and (iii) the theory of extensive abstraction (logical construction). An explanation of these theories is covered in more detail in section 2.3 of this chapter.

(1925-1933) During this time Whitehead transitioned to Harvard's Philosophy department, where, in a series of lectures and subsequent books, he developed his speculative 'philosophy of organism' from his early mathematical theories of nature and physics. In his book *Science and the Modern World* (1929), he positively reviews the historical accomplishments of modern scientific efforts. However, he sees that the scientific community needs to be careful to understand that these accomplishments are based on an abstraction of reality. He asserted that scientists are relying on an assumed 'substance' based ontology that may limit their ability to draw conclusions from experiments, given there is abstraction involved. For example, when a scientist observes a specimen under a microscope that has been dissected, they are not viewing a specimen that is alive or, at the very least, the specimen is not interacting in its typical environment and following its normal day-to-day behaviours. Therefore, any conclusions about the specimen are limited to the context of the experiment rather than the specimen's everyday context. Circumscribed conclusions certainly might be achieved as long as the scientist appreciates these constraints and is aware of the experiment's limitations.

Process and Reality (1929) describes Whitehead's speculative 'Philosophy of Organism', which we briefly introduced in Chapter 1. It is regarded by contemporary process philosophers as the work that covers Whitehead's process metaphysics most comprehensively. The Philosophy of Organism is a process philosophy that does not deny the existence of things in the world such as tables and chairs, but asserts that the underlying stuff that everything is made up of is events[7]. Much of this chapter is dedicated to understanding Whitehead's process metaphysics and we will outline the key themes from his Philosophy of Organism.

[7] As discussed in section 1.3, 'Nomenclature and Vocabulary', we use events interchangeably with 'processes', 'experiences', 'actual entities', and 'actual occasions'. For readability purposes, in this thesis, we will tend to use 'processes', as they are more commonly used by contemporary process philosophers of biology, and this will make comparisons between theories easier. However, there are nuances in the use of these terms. Whitehead predominantly used 'events' or 'actual entities' to describe what underlies everything, which are basic durations of experience that combine with other actual entities to form new actual entities. This process of becoming is called 'concrescence' and forms part of his theory of occasions that we will examine in section 2.3.1.

2.1.3 The influence of Henri Bergson and William James

To understand Whitehead's philosophy it is helpful to consider the relevant work of Henri Bergson and William James. Both Bergson and James influenced Whitehead's view that scientists should be conscious of the role abstraction plays in their work. He was heavily influenced by Bergson's book *Creative Evolution* and Bergson's idea that a fixed point in space and time is an abstraction. In Bergson's view, there is no system of isolation, and everything is related. However, scientists standardly abstract and isolate components of the universe in an artificial way to make conclusions.

> "It is undeniable that there is no entirely isolated system, yet science finds means of cutting up the universe into systems relatively independent of each other, and commits no appreciable error in doing so." (Bergson, 1911, p. 214).

Both Whitehead and Bergson would agree that this is fine in the pursuit of scientific progress. Still, scientists need to be aware of limitations and their own philosophical leanings (Whitehead, PR: 1929, Preface xii).

A second idea that influenced Whitehead's belief that events underlie everything, was Bergson's observation that 'time's passage' is required for nature to exist. Whitehead extended this idea to consider events as basic, where "events" are synonymous with various lengths of 'durations of experience'. For example, consider an embryo from the initial stages of cell cleavage to the later differentiation and further development required to become a newborn. The development from embryo to newborn is processional because various stages of its duration can be identified over time. The embryo only exists while there is the passage of time, as the embryo will cease to exist if its development is temporally suspended. However, as an analogy, when we examine any biology textbook, it will show pictures of the embryonic process, with staged diagrams in an artificial and abstract way. The embryonic process exemplifies what Bergson and subsequently Whitehead promoted: that nature is a continuous series of durations of experience over time. As we will explore in the next section, this fundamental idea underscores why Whitehead rejected the doctrines of localised matter and bifurcation of nature.

Another influence for Whitehead was William James, who further underpinned Whitehead's rationale for the rejection of substance metaphysics and concept of localised matter. James's idea is that there is a tendency for Western philosophy and science to view what underlies everything as "irreducible matter" that is "spread throughout space in a flux of configurations", which he calls scientific materialism. He criticised this 'matter' as being "senseless, valueless and purposeless" and says that it does what it does based on external relations (causes) that are not attributed to the 'matter' itself (James, 1912; Whitehead, 1929, p. 16-17).

2.2 What does Whitehead reject?

In this section we examine what Whitehead rejects, as this is an important first task in preparation for the next section, where we will explain the key themes of his philosophy of organism. In the book *The Concept of Nature (1920),* Whitehead outlines his reasons for rejecting the 'bifurcation of nature' that he viewed as what leads us to mistakenly believe that 'localised matter' underlies everything.

My summary of Whitehead's argument is outlined below, and then each step will be discussed in further detail:

1. Because of the bifurcation of nature (as promoted by scientific and philosophical modernity such as Newtonian physics, Hume's account of cause and effect, and Descartes' discussion of mind and body), there is a dualist view of nature (i.e., where nature is viewed in two realms of a causal and apparent nature) (Debaise, 2017, p. 5-15).
2. The bifurcation of nature assumes the existence of causal nature, consisting of localised matter (i.e., point of matter in space-time) (Debaise, 2017, p. 16-19).
    2.1. The bifurcation of nature entails that points of matter are entirely isolated. By definition, these are 'instantaneous', not temporally extended or related to any other point of matter in the universe.
3. Our experience of nature is through the passing of time or 'duration' (Whitehead, 1920).
    3.1. We do not have experience or evidence to suggest an instantaneous time exists.

3.2. Given a short or long duration everything can be said to change and be viewed as an event; for example, “the man is hit by a car” is an event, and over a longer duration, the “life of the tree” or the “Eifel Tower in Paris” are also events (Debaise, 2017, p. 30-33).

3.3. Objects persist over time such as the “Eiffel Tower in Paris,” which, given enough duration, is built, reshaped, altered, and ultimately likely destroyed.

4. #2 and #3 are in tension with each other.
5. Given that we have more evidence of our experience of nature as durations (events), Whitehead claimed that a position that supports isolated matter located in space and time is absurd or, at the very least, unlikely (Whitehead, 1934, p. 35).
6. Therefore, nature’s base ontology is events, namely processes. (Debaise, 2017, p. 26).

We will now discuss Whitehead’s argument in more detail, as outlined in premises 1-6.

First, Whitehead observed that ‘dualism’ exists in our perception of nature, which is made up of both the apparent nature from our observations and an assumed casual nature regarding what causes the effects that we observe.

Secondly, Whitehead asserted that we assume there must be some form of substance that makes up the things that we observe in the world. For example, we can see a car on the road, and we assume that the vehicle is made up of some form of substance, perhaps atoms and electrons. We assume that these substances exist even though we cannot see them. Whitehead promoted that this assumed underlying substance is made up of “localised matter”, which is isolated and located at discrete points in space and time. Later in this section we will expand on these important concepts of localised matter and the bifurcation of nature.

Next, in premise 3, Whitehead observed that we do not experience nature as an instantaneous moment in time; rather, we experience nature as a series of interconnected durations that persist over time. This is where Whitehead introduced the concept of the passage of time, necessary for the existence of nature as promoted by Bergson, which we discussed in the prior section.

Lastly, there is a tension between the concepts of substance which is viewed as instantaneous discrete localised matter, and our experience, which informs us as to nature's continuous passage of time. Whitehead viewed this as good grounds to claim that it is absurd to posit that the world is constructed from a substance comprising of localised matter, and that his own theory – that events underlie everything – is therefore preferable.

Now that we have the outline of Whitehead's argument, we should discuss the key ideas in that argument, namely localised matter and the bifurcation of nature.

2.2.1 Rejection of the bifurcation of nature

In his book *Science and the modern world* (1929), Whitehead discusses Newton's contributions to science, and raises concerns about Newton's corpuscular theory, which claimed that light was made of tiny particles and promoted the idea of localised matter. Whitehead was not rejecting Newtonian physics in totality, he was rejecting the idea of the bifurcation of nature, which he believed Newton's corpuscular theory promoted by requiring two realms in nature. The first realm is the apparent nature that we perceive, while the second causal realm consists of Newton's particles, which we cannot see but cause the things we perceive. Whitehead took exception to the dualist view as promoted by Newton and other philosophers such as Descartes and Hume. Descartes is known for his doctrine of cartesian dualism[8] of 'mind and body' and Hume for his theories associated with 'cause-and-effect'. Whitehead understood that the everyday person's common-sense view of nature is that things that appear to persist over time and have distinct identities such as trees, houses, dogs, people and rocks. Further, in our everyday lives, we observe things that have locomotion and causally interact with each other. Whitehead attributed the predominant dualist view of the world, which promoted localised matter and substance, as both a result of our common-sense perceptions and theorising by philosophers and scientists over the ages such as Aristotle, Descartes, Newton, Hume and Locke

[8] Note: Whitehead does not directly write about the linkage to cartesian dualism in his work. Some philosophers have speculated that he is more concerned with the "rabbit hole" that this view of nature promotes being that of localised matter (Debaise; 2017, 4).

(Descartes, R., 1641; Newton, I., 1687, tr. Tr. Cohen and Whitman; Hume, D., 1748; Locke, J., 1690, p. 2.8.35). Whitehead claimed that although we cannot see this localised matter such as particles like electrons, we assume that they exist and are then arranged in some configuration to make all the things we see in the apparent nature. For example, grass is made up of atoms and particles, which we do not see, yet we assume conceptually that they constitute the basis for a causal nature. However, the apparent nature is what we see, smell and hear are the qualities of the grass such as the colour green, the scent of freshly cut grass and the sound of the wind through the grass blades. Whitehead observed that we perceive that there are these two realms of nature, one we do not see but assume exists and the other we do see and think is the effect of the former. He is critical of this way of viewing nature, as he believes that this is why there is a tendency to reduce everything down to a fundamental cause, that being 'localised matter', which he rejects as absurd.

> "What I am essentially protesting against is the bifurcation of nature into two systems of reality. One reality would be the entities such as electrons that are the study of speculative physics. This would be the reality that is there for knowledge, although on this theory it is never known. For what is known is the other sort of reality, which is the byplay of the mind." (Whitehead, 1919, p. 30)

Additionally, for Whitehead, the result of this Newtonian emphasis on the systemisation and mechanism of nature and Hume's excessive reliance on 'sense perception' creates an arbitrariness or "a dead nature," a nature without purpose or aesthetics of thought and feeling.

> "Thus, for Newtonians, Nature yielded no reasons: it could yield no reasons. Combining Newton and Hume we obtain a barren concept, namely, a field of perception devoid of any data for its own interpretation, and a system of interpretation devoid of any reason for the concurrence of its factors. …My own belief is that this situation is a *reductio ad absurdum* and should not be accepted as a basis for philosophical speculation." (Whitehead, 1934, p. 25)

2.2.2 The localisation of matter, Newtonian physics and Relativity

Whitehead rejects the idea of the existence of localisation of matter, presented by both Einstein's theory of relativity and Newtonian theory. Whitehead understood 'localised matter' to be a physical substance of some type which constitutes matter being located in spatial coordinates known by philosophers as 'simple location'[9] (Broad, C. D., 1923, p.29). Whitehead understood localised matter to be very small particles such as electrons, that he refers to as bits of matter:

> "To say that a bit of matter has simple location means that, in expressing its spatiotemporal relations, it is adequate to state that it is where it is, in a definite region of space, and throughout a definite finite duration of time, apart from any essential reference of the relations of that bit of matter to other regions of space and to other durations of time." (Whitehead, 1929, p. 35)

To clarify when we say that Whitehead rejected the idea of localised matter, we are saying that he rejected the notion that bits of matter are situated in 'simple location', and specifically these bits of matter are spatially situated without any relation to other bits of matter and temporal relations. Rather, he promoted the idea that everything in the universe is related, for example, that one duration of experience is related to the next duration of experience. Thus Whitehead considered any metaphysics that has a non-relational basis, such as localised matter, to be absurd (Debaise, 2017).

Whitehead rejected three premises that he believed are required to promote the notion of simple location and the concept of localised matter (Debaise, 2017, p. 14).

(P1) Localized matter can only occupy one instantaneous spatiotemporal point.
Whitehead claimed it is absurd to consider that there are isolated bits of matter, wholly separate unto themselves as discrete units of reality where past and present, as well as antecedent and

[9] 'Simple location' is the idea that matter without any other qualities occupies a spatial location. The introduction of this concept is attributed to modern philosophers, including John Locke and his work *An essay concerning human understanding (*1689).

consequent relations, are irrelevant. Whitehead believed it to be contradictory to suggest that discrete matter can occupy the same space and time in succession, which is what substance metaphysics claims. To illustrate why Whitehead viewed this as absurd, consider the analogy of nature being like a car engine turned on for a moment and then turned off until the next moment it is turned on again. Whitehead observed that it is not our experience of nature to view instant after instant, similar to frames in a roll of movie film. Rather, we witness nature as a continuous passage of time. Specifically, matter exists with some period of duration that has temporal extension, where past and present events form parts of future events. Whitehead also posited the idea of continuous over-lapping event durations, also known as Whitehead's 'theory of occasions', which we will examine in more detail in the next section (Debaise, 2017, p. 14).

(P2) Matter is that which is fundamental and concrete.
Whitehead rejected the idea that localised matter exists and that it is concrete in that it can be relied upon as what underlies everything. Whitehead coined this as the fallacy of misplaced concreteness, which is explained in section 2.3.5 (Whitehead, 1920, p. 20).

(P3) Other qualities associated with the existence of matter are exclusively phenomenal.
Whitehead took exception to the bifurcation of nature, as it promotes the idea that secondary qualities such as texture and colour, and that these qualities involve the mind as a phenomenal operation (Whitehead, 1933, p. 132-133).

2.3 Philosophy of Organism (Process Metaphysics)

Now that we have discussed Whitehead's background and have a better understanding of what he was rejecting, we are in a better position to review his philosophy of organism. In his book *Process and Reality* (1929), he outlines his philosophy of organism in detail. His philosophy of organism is a departure from substance metaphysics and proposes a metaphysical framework based on the ontological primacy of processes. This view is a collection of several theories that make up Whitehead's process metaphysical framework, including the 'theory of occasions' and the 'theory of extensive abstraction', which we will cover further in this section.

Whitehead's *Process and Reality* is viewed as his consummate work. It brings together many of his earlier ideas in a logically consistent cosmology and provides the rationale for his speculative philosophy. Whitehead viewed the goal of metaphysics to be to push the boundaries of the scientist's imagination (Apgar W. E., 1936, p. 16-34; Sherburn, 1965, p. 224-225).

Process and Reality has a reputation as being opaque and difficult to understand. We will discuss whether this is an entirely fair assessment further in Chapter 4. Dupré and Nicholson note that the difficulty is partly due to Whitehead's rejection of Aristotelian 'subject–predicate' construction in everyday common language (Dupré & Nicholson, 2018, p. 11). Whitehead was concerned about the predominance of 'subject–predicate' language, which promotes that the objects we observe contain an enduring substance with attached changing qualities. This creates a problem for process philosophers and how they want to describe their philosophy whilst avoiding substance-biased language. Whitehead's approach was to express his theories using invented words, making his work very difficult to understand.

> "The technical phrase 'subject-object' is a bad term for the fundamental situation disclosed in experience. It is really reminiscent of the Aristotelian 'subject-predicate.' It already presupposes the metaphysical doctrine of diverse subjects qualified by their private predicates. This is the doctrine of subjects with private worlds of experience. If this be granted, there is no escape from solipsism. The point is that the phrase 'subject-object' indicates a fundamental entity underlying the objects." (Whitehead, 1929, p. 151)

The purpose of this section is not to develop a dictionary of the vocabulary for Whitehead's philosophy or to conduct a detailed exposition of his unique language. Rather, the goal is to highlight key themes and theories that Whitehead identified as important. We will review Whitehead's 'theory of occasions', where he introduces the concept of 'actual entities' referring to the basic unit of 'events'. Next, we will review Whitehead's approach regarding process-to-process relations. A key concept for any process philosophy to accommodate is how processes

relate to each other. Finally, we will examine what Whitehead calls the "fallacy of misplaced concreteness".

To this end to help navigate what follows, I have included Table II below, which maps the process qualities from Table I to Whitehead's theories from his philosophy of organism documented in his book, *Process and Reality* (1929). The comments included are sourced predominantly from Donald Sherburne's book, *A key to Whitehead's Process and Reality* (1965).

Process Category / Philosophical System	Interactive Relatedness & Order (processs to process relations)	Temporal Related (change over time)	Wholeness (totality and holism)	Dynamic and Activity (transformation)	Creativity and Novelty	Becoming (dispositional change)
Process - (Whitehead) [Comments sourced from Donald Sherbume, 1965: 205-248]	Process relations are described in the process of concrescence and transition from concrescence to subjective aim (final cause) for the new actual entity. [PR 320, PR 327]	Theory of extensive abstraction requires the passage of time in the form of continuous event durations. [PR 105, PR 148]	Totality is included in concepts of Nexus and Societies that form the complexity of macro objects such as, trees and living beings. Order is a feature of Nexus and Societies, the absence of is chaos. [PR 29-30, PR 112]	Philosophy of organism contemplates a dynamic universe where events underly everything described in theory of actual occasions. [PR 27-28]	Creativity is a core concept as one of categories in the 'category of the ulitimate'. [PR31, PR38]	Becoming is accomodated in the process of concrescence, where actual entities are created as a process of becoming into new actual entities. [PR 91, PR 113]

Table II

2.3.1 Theory of Occasions (Actual Entities)

Whitehead's theory of occasions is an argument for the base unit of his ontology, 'events', which he calls 'actual occasions' or 'actual entities'.[10] When there is a concentration of actual entities, they come together to form more complex objects in the world such as trees and living beings. Whitehead coined these complex objects as a 'nexus' or 'society' of actual entities (Sherburn, 1965, p. 17).

Process philosophy has traditionally viewed Heraclitus as the pre-Socratic philosopher who endorsed that reality is flux and ever-changing over time, and that impermanence is a feature of reality. Whitehead did not fully agree with Heraclitus that the world is in perpetual flux, given that tables and chairs are enduring objects. And we know that enduring objects persist, because we remember the tables and chairs from one day to the next. Whitehead proposed a

[10] Note: this section will use event, actual entity, occasions and object interchangeably as they approximate each other in definition from Whitehead's perspective, and he uses them interchangeably in his work.

multilayered approach for the persistence of enduring objects he names ‘Nexus’, where events from the same ‘family’ are integrated and combined through a complex process of what he coins ‘transmutation’, into the objects we see in nature, such as tables, chairs, trees and people. For example, events first compose atoms, and these more complex nexuses of events come together to form societies of molecules, and eventually, the tree or the person is a series of hierarchical order (Sherburn. 1965, IV, p. 72-97).

In contrast to substance-based ontologies, the bedrock of Whitehead’s system is the relations that events have with other events. These relations form the nexus of events that become the objects that exist in the world. Whitehead’s 'theory of extensive abstraction’ is his approach, based on his earlier work on logical construction, to explain how the nexus (sets) of events transforms into objects we observe in the world (Emmet, 1932, IV, p. 69-101).

2.3.2 Theory of Extensive Abstraction

A crucial part of Whitehead’s project was to account for how observable objects can be constructed from events. For this, he employed his theory of extensive abstraction (Whitehead; An enquiry concerning the principles of natural knowledge, 1919).

As discussed earlier, our senses reinforce that objects such as trees, tables, and chairs, exist and endure over time. And also, as we have discussed in the prior two sub-sections, given the bifurcation of nature we assume that localised matter and substances are arranged and make up these objects. The challenge for Whitehead was to claim that event durations are what underlie everything and explain how they might make the trees and tables we observe. Recall from section 2.1.2, that Whitehead’s early project was to theorise how to logically construct geometry and physics using deduction from sets. According to Whitehead, enduring objects are derived from sets of events, as explained in his book *Principles of Natural Knowledge and the Concept of Nature* (1919) and Section IV of ‘*Process and Reality*’ (1929). Whitehead’s ‘Method of Extensive Abstraction’ first leverages his view that nature is experienced as the passage of continuous overlapping events. Whitehead viewed these events as the basic building blocks of reality. He understood that events may be smaller and smaller in time duration, and that they will converge

towards a mathematical limit but never actually get to an instantaneous point in time. Whitehead asserted that if a time duration were to reach an instantaneous point, then nature would effectively stop.

Next, Whitehead proposes taking these events as sets where their intersection can be used to abstract a point in space. Like Euclidian geometry, once a point in space has been identified, everything else that is perceived in nature can be constructed.[11] Whitehead provides an example to show how living beings and enduring objects can be viewed as events. His example is a man crossing the road as an event is the same in concept as the pyramids in Egypt that endure over time. The rationale is that the pyramids, over time, are abstracted by slices of durations or events that contain enduring identities that overlap with past pyramid events. The pyramid events are just like the walking man events and include elements such as the gravity of the planet and the photons from the sun. For both, all of these elements for each event overlap with the next event continuously.

2.3.3 Process-to-process relations.

As discussed above, Whitehead argued that one of the primary difficulties of substance-based philosophy is its treatment of localised matter as being entirely isolated. Accordingly, relations between processes is a key tenet of his metaphysics. The core idea he promoted is that all events relate to other events temporally. Whitehead adopted a view of causation that is more organic than the idealized accounts of cause-and-effect predominant in Western philosophy. He believed that causation is a process of becoming another new actual entity, where actual entity ‘A’ and actual entity ‘B’ contribute together through the process of ‘concrescence’ to create and become

[11] Note: Whitehead’s theory of extensive abstraction has similarities to topology studies in mathematics. Rafal Gruszczynski, from his analysis of various modern mathematical approaches, has concluded that although it is difficult to fully contemplate Whitehead’s extensive abstraction in the context of modern ‘category theory’, there are definite similarities beyond mere intuition to suggest Whitehead ‘points’ do have alignment with these contemporary approaches. Additionally, he recommends that further research might be beneficial (Gruszczynski, 2022).

actual entity ‘C’. Whitehead coined the term ‘concrescence’, which is literally the coming together of many past and present actual entity selections, guided by the final cause or ‘subjective aim’ to become a new actual entity (Sherburn, 1965, p. 6-15). Whitehead named the ‘relating’ activity of taking past events and merging them into new events in the future as ‘prehensions’. The doctrine of prehensions is Whitehead’s approach to process relations in contrast to the problems with the localised matter and associated non-relatedness (Whitehead, PR, 1929, p. 88-89). The entire process of ‘becoming’ is ongoing, and the boundaries between actual entities are not clearly distinct (Sherburn, 1965, p. 13).

2.3.4 Creativity, Indeterminism and Order

The other distinguishing feature of Whitehead’s philosophy is to account for ‘creativity’ and the degree of ‘potentiality’ (indeterminism) observed in nature.

Creativity is a central theme throughout Whitehead’s philosophy. He proposed a complex approach for how creativity is accounted for in his philosophy, which he named the ‘categories of the ultimate’. I will summarise the four-step process employed by Whitehead’s categories of the ultimate as follows: Initially, Whitehead discusses the notion of “the many” as the first step that takes place when the universe’s events are in a disjointed state. Second, as discussed earlier, there is a transmutation of past events towards a new complex unity of events through the process of concrescence. Third, novelty arises during this concrescence, as the new complex unity of events taps into ‘eternal entities’. Whitehead uses eternal entities, similar to universals in the tradition of Platonism, to provide ingredients available in the universe for the actual entities’ selection.[12] This selection is through ‘prehension’, Whitehead’s invented concept for how and why actual entities relate with each other. This supports the creation of new objects and their

[12] The use of the word “selection” suggests there is an agent “that selects” something. But this is not how Whitehead uses the term. This is likely why Whitehead created the concept of ‘prehension’ as a new concept to explain what he meant. ‘Selection’ in this context is the idea that qualities, such as colour or solidity, are acquired from ‘eternal entities’ for use in the process of concrescence, without an agent’s direction, but also not wholly by chance. As we will discuss in chapter 4, Whitehead is not a ‘panpsychist’ in the normal philosophical sense, that everything has some level of consciousness or agency. However, by suggesting that events and eternal entities are “selected”, a contemporary philosopher might be forgiven for erroneously coming to this conclusion based on his use of language.

qualities, for example, a ball that is the colour red or a table that has solidity (Emmet, 1932, V, p. 102-139). Novelty comes from the different combinations of the "selections" of the eternal entities. For example, a rock might select to be brown or grey, and hard or brittle (Sherburn, 1965, p. 20). The last step is for the universe to revert back to a disjointed state, with many events awaiting the next successive concrescence and creativity cycle. In this last point, Whitehead asserted that the universe has an ongoing rhythm of merging the past with the present to create a novel future that, in turn, becomes the present and then the past as a cycle.

Whitehead attributed the potentiality and the level of indeterminism of the universe to what he coined the 'primordial nature of god'. The primordial nature of god exerts a limitation on the process of concrescence, which is needed to maintain order in nature (Emmet, 1932, p. 192-202). Additionally, Whitehead viewed the primordial nature of god as the impetus for the rhythm of the ebb and flow of nature. The catalyst or impetus for nature to move forward in an orderly manner, after the many selections that events make from past events and eternal entities during concrescence, is attributed to god's primordial nature. The idea is difficult to understand. However, in effect he depends on some non-anthropomorphic god that is another eternal entity in order to manage nature's creative process so that it does not get too chaotic.

To be clear, I am not endorsing the above as the correct approach to account for creativity and novelty in nature but merely describing Whitehead's framework. From a literal perspective, for a rock to prehend an eternal entity and select, without any agency, the quality of solidity is a radical concept, and admittedly might be difficult to comprehend scientifically. However, as we will examine in Chapter 4, it is not necessary that we agree with Whitehead's approach in all respects. His philosophy does highlight a challenge that any coherent process philosophy needs to be able to address: how to account for the novelty and creativity that we observe in nature and biology.

2.3.5 Avoidance of the 'Fallacy of Misplaced Concreteness'

In section 2.2.1 we discussed why Whitehead rejected substance metaphysics and the existence of localised matter. Whitehead understood that using the notion of localised matter for scientific

work is effective as it likely simplifies the scientific method of abstraction and analysis. Furthermore, he did not reject the use of abstraction as a method in the course of scientific inquiry, rather when we don't appreciate when abstraction is at play. Whitehead made the point that there are many levels of abstraction, including during the scientific method, and as long as the scientist knows they are abstracting and its limitations, then no harm and no foul. As Whitehead wrote, "Again every science is an abstraction from the full concrete happenings of nature" (Whitehead, 1934, p. 42). The issue arises when the scientist and philosopher misplace their trust in the concreteness of the abstract 'point of brute force matter'. He called this the 'Fallacy of Misplaced Concreteness'.

> "I shall argue that among the primary elements of nature as apprehended in our immediate experience, there is no element whatever which possesses this character of simple location. It does not follow, however, that the science of the seventeenth century was simply wrong. I hold that by a process of constructive abstraction we can arrive at abstractions which are simply-located bits of material, and at other abstractions which are the minds included in the scientific scheme. Accordingly, the real error is an example of what I have termed: The Fallacy of Misplaced Concreteness." (Whitehead: 1929, 58-59)

Therefore, Whitehead claims that we should avoid the fallacy of misplaced concreteness by being aware of the abstraction at play within the scientific method.

2.4 Whitehead's Rationale for Speculative Philosophy (Metaphysics)

In this section we will review Whitehead's approach to speculative philosophy and metaphysics, as he had a positive view of its use in the philosophy of science. This material will help us better understand the relevance of Whitehead's work for contemporary process philosophers of biology, which we examine in Chapter 4.

Whitehead endorsed science-first metaphysics, where philosophy first considers the theories proposed by physicists and mathematicians in our best current science and confirms that any

proposed metaphysics should be consistent with these theories. Therefore, if quantum physics provides a world of probability and wave functions, metaphysics needs to accommodate this science rather than Newtonian science. However, as we have discussed, he disagreed with metaphysics that was not logically disciplined, a view he shared with Bertrand Russell as a core tenet of their academic collaboration (Russell, 1919; Woodger, 1929, p. 268).

Whitehead would have agreed with Peter Godfrey-Smith that philosophical theories should be logical, externally consistent and "hang together" with the current accepted scientific theories.

> "This is necessary, in fact, for philosophy to be able to pursue the task of seeing how everything hangs together. A philosopher will look at how the message of one part of science relates to that of another, and how the scientific view of nature relates to ideas we get from other sources." (Peter Godfrey-Smith, 2014, p. 4)

Whitehead was concerned that metaphysics has the potential to lack analytical discipline, so he gave us rules to follow to make this philosophy well-behaved. Below is a list of Whitehead's rules that metaphysics should adhere, summarised from Dorothy Emmet's book, *Whitehead's Philosophy of Organism* (Emmet, 1932, p. 15-20).

a) Metaphysics of science should be grounded in contemporary science and logically support a worldview, not the inverse where metaphysics dictates the science.
b) Metaphysics should conform to intuitive experience –
   In the article *The Mind and Its Place in Nature* (1925), C. D. Broad asserts that where a reasonable person might doubt the plausibility given their own experience, then the metaphysical theory was unlikely, for example, Broad and Whitehead would regard solipsism as unlikely: "Not a silly or arbitrary theory …this is not a silly armchair theory?" (Broad, C. D., 1925, VII; Emmet, 1932, p. 16).
c) Clarity of propositional content –
   Given his work with Bertrand Russell and other mathematicians early in his career,

Whitehead was well aware of the goal for clarity and specificity of the propositional form and language to be clearly stated.

d) Propositions in metaphysics should be internally logically consistent –
No term in the proposition should undermine the internal coherence by overlapping, repeating or contradicting itself.

e) Propositions in metaphysics and their theories should have external logical consistency –
Whitehead intends that metaphysical theories should be logically consistent with all other contemporary scientific theories that are plausible.

f) Whitehead refers to the concept of 'methodological consequences', which asserts that the intention of all metaphysics propositions should be directed towards a practical outcome. As a mathematician, Whitehead is aware that even the most abstract and speculative ideas can ultimately be applied in practical ways that can help progress science and technology. However, he admits that the practical application of a proposition may not become evident for a period of time, and the philosopher must judge how long a time is reasonable.

Whitehead rejects 'dogmatic' approaches that suggest that the basic elements of experience are clear and distinct, as opposed to being elusive. The example Whitehead provides is quantum physics, which made progress without a clear understanding of what it was at the time. For Whitehead, the primary method available to metaphysics of science is not deduction but rather 'descriptive generalisation' of the scientist's interpretations from their experience, observations and experiments. The philosopher of science may then generalise and test explicit assumptions to see if they appear reasonable and consistent. "Metaphysics categories are not dogmatic statements of the obvious; they are tentative formulations of the ultimate generalities" (Whitehead, PR, 1929, p. 11). It is for this reason that Whitehead rejects the popular constraints often applied to scientific metaphysics, such as realism, reductionism, and physicalism. He argues that these approaches assume a dogmatic level of detail about the elements of any scientific notion, which, according to Whitehead, is neither practical nor pragmatic.

2.5 Whitehead's Influence on the Organists

For this chapter's last section, we will review how Whitehead's work influenced or aligned with the views of biologists and process philosophers of science (biology). Given that he was once relevant, the question that this thesis is attempting to answer is whether he is still relevant to contemporary process philosophers of biology.

The 'organists' were a group of biologists in the early twentieth century who were concerned with a foundational understanding of the science of biology. This group agreed with Whitehead's writings and lectures and sympathised with his view that process had primacy for the special sciences, rather than a mechanistic nature. They mirrored his ideas and arguably were directly influenced by his work, as I hope to demonstrate below using evidence from their writing. This section will provide an overview of notable organists who agreed with some of Whitehead's core philosophical tenets.

2.5.1 John Scott Haldane (1860-1936)

Haldane was a physiologist who spent much of his early research years working with the effects of mines and gases on humans, focusing on carbon monoxide. Additionally, he identified a link between the respiratory and renal (kidney) systems. Later in his career, he developed a gas mask to protect troops in France during World War I. Based on his observations, he developed a new philosophical view called 'organicism', that the organism should be viewed as a whole (not as reducible parts) and understood in the context of the environment. Haldane's philosophical framework therefore agrees with Whitehead in the context of biology:

> "From the standpoint of philosophical physics Whitehead, particularly in his 'philosophy of organism', has pointed out identities between conceptions to which the new physical developments lead, and the phenomena presented in living organisms. General Smuts, in his book Holism and Evolution, has drawn similar conclusions from the biological side, emphasizing on the one hand the fact that the phenomena which occur in living organisms have the specific character of forming actively coordinated wholes, and, on the other, that even in inorganic

> phenomena similar actively coordinated wholes have been revealed by the newer physics" (Haldane, 1935, p. 40).

2.5.2 Edward Stuart Russell (1887-1954)

Having studied at the University of Glasgow, where he achieved an MA in zoology (1907), Edward Russell went on to have a career as a researcher and investigator for the Board of Agriculture and Fisheries. He retired in 1947 having served as the Director of Fishery Investigations for England and Wales. Russell wrote several books that promoted an anti-reductionist and anti-mechanistic view of the science of biology. The first, in the *Form and Function* (1916), he challenged the idea that evolution can be explained by a mechanistic approach, where organisms are viewed as self-replicating machines without passions, goals or desires. In his subsequent book *The Interpretation of Development and Heredity: A Study in Biological Method* (1930), Russell claims that although abstraction as a method of scientific investigation had demonstrated results, different approaches are necessary to better understand the whole of an organism in the context of the environment. He was particularly critical of abstraction as a technique as, in his view, the study of the parts did not generate an understanding of the whole. His response was to borrow some of the ideas from Whitehead and outline a non-vitalist approach to the investigation of the whole organism he names 'psychobiology'.

> "Whitehead bases his whole philosophy of nature on the concept of the organism, as being much more concrete than the abstract ideas of matter and mind, and he defines it in such a wide way as to make it apply to all unities in nature, from the living thing down to the electron. He regards their modes of action as not being mechanically determined in the sense of classical materialism, and he allows for mental states as influencing the general 'plan' of the living organism. This conception of organism is developed from a standpoint which is practically the same as that from which the psychobiologist sets out, for individual living experience is taken to be the ultimate standard of reality." (Russell, 1930, p. 180)

2.5.3 Joseph Henry Woodger (1894 – 1981)

Woodger attended the University College of London in 1911. After this he pursued an academic career in philosophy of science and theoretical biology and retired as a professor in 1957 from the University of London Middlesex Hospital. Woodger was influenced by the Vienna Circle (logical positivists) and Whitehead's earlier work, and sought to bring a positivist philosophy to biology by establishing a new foundational account that reduced to physics and chemistry. In his book *Biology Principles* (1929), Woodger attempts to axiomatise biology like Whitehead and Russell's *Principia Mathematica*. Woodger was sympathetic to Whitehead's view that biology needed to be foundationally critiqued similarly to modern physics. In *Biology Principles* (1929), he attributes 35 pages to Whitehead's theories, and the epigraph is a quote by Whitehead.

> "The progress of biology and psychology has probably been checked by the uncritical assumption of half-truths. If science is not to degenerate into a medley of ad-hoc hypotheses, it must become philosophical and must enter into a thorough criticism of its own foundations." (Whitehead, S&MW, 1929, p. 25)

This concludes this chapter and provides the necessary background for the next chapter where we will examine contemporary philosophers of biology and their process philosophies and theories. Whitehead was clearly relevant to philosophers of biology and biologists at the time he published his work. The challenge for the next two chapters is to understand if he is relevant to contemporary process philosophers of biology.

3 Chapter Three: An Examination of Contemporary Process Philosophers of Biology

This chapter will examine the contemporary philosophical literature from prominent process philosophers of biology. It will provide the necessary background for further analysis in Chapter 4 regarding the relevance of Whitehead's process philosophy for these prominent process philosophers of biology.

Contemporary Whiteheadian-influenced philosophers are also interested in a number of topics that intersect with the science of biology, such as deploying Whitehead's process philosophy to better explain the facts of biology, living beings and nature. These philosophers who are interested in what Whitehead has to say about biology are distinct from standard process philosophers of biology, with their own areas of philosophical interest for example, mental states and biology, teleology, novelty and creativity and emergence.[13] This thesis aims to understand contemporary philosophical process biology and not Whiteheadian philosophers that sometimes consider biology as a topic. Using Peter Godfrey Smith's idea of internal and external philosophy, the Whiteheadian philosophers are external to the philosophy of biology. Instead, this chapter is interested in understanding philosophers who are internal to the philosophy of biology and whether they might benefit from paying more attention to Whitehead's work (Godfrey Smith, P., 2014, 2003). Therefore, Whiteheadian philosophers who have written on the relevance of Whitehead for biology, such as Spyridon Koutroufinis, have not been included in this chapter.

The following four sections do not obviously intersect and might appear a little disjointed. However, they are examples of the current discourse in process philosophy of biology, and each section is important as background for Chapter 4 and as a contrast to Whitehead's work. First we will review recent work from Daniel Nicholson and John Dupré, as they make a case that process philosophy is able to better account for biological systems. Their work is an example of a comprehensive treatment of process philosophy and will contrast with Whitehead's process

[13] Note: Process theism continues to have a following among some Whiteheadian philosophers and theologists, but it is not taken up by philosophy of biology and is not given treatment in this thesis.

philosophy in Chapter 4 to understand whether they both might benefit by considering his work. They have written that they do not believe Whitehead is relevant to them or other philosophers of biology, given his work is overly difficult. Second, we have discussed in Chapter 1 the importance of process philosophy to accommodate the concept of process-to-process relations. Also, in Chapter 2, we discussed that a core tenet of Whitehead's philosophy of organism is temporal process-to-process relations. As such, we will examine Johanna Seibt's work on the potential of 'general process theory' to describe process-to-process relations in the context of philosophy of biology. Next, we will contrast Stephan Guttinger's work on integrated systems with the predominant mechanistic framework. Finally, Thomas Pradeu's philosophy of immunology will be outlined, as his work lends itself to a process interpretation.

3.1 The contemporary philosophical case for process in Biology

In the chapter *A Manifesto for a Processual Philosophy of Biology* (2018), Dupré and Nicholson make the case for a process approach to philosophy of biology, and provide a survey of relevant topics. Their chapter emphasises the epistemic advantages of process over substance-based approaches to explaining living beings. They view themselves as naturalists and assert that process is empirically evident in biology. They endorse both an epistemic and an ontic view that processes are foundational for living beings.

In their collaborative and respective work as contemporary process philosophers of biology, Nicholson and Dupré provide a broad view of process primacy in biology. To recap the metaphysical options presented early in Chapter 1: (a) only processes underlie everything that exists; (b) both processes and substances exist, but processes come before substances; (c) both process and substances exist, but substances come before processes; and (d) substances underlie everything. Nicholson and Dupré's overall metaphysical claim is that processes underlie living beings and that living beings are actually stabilized processes that span different temporal periods. Their position is that, even if they are wrong and substances do exist, processes still have primacy and come prior to things. In what follows, I will explain and comment on a number of

important claims that Nicholson and Dupré put forward in their joint chapter and other work (Nicholson and Dupré, 2018, p. 3-5).

i. Living beings are not made up of 'substantial particles'. [14]
ii. Living beings comprise 'processes' and are "dynamic through and through".
iii. There is a hierarchy of processes, stabilised at different timescales. [For example, molecules, cells, organs, organisms and populations.]
iv. Processes in this hierarchy include processes of various sizes, intensities and magnitudes, and support the conditions for objects to persist.
v. The fact that an entity exhibits stability over time does not entail that it is a substance, as processes can present like this.
vi. If there are substances, they are likely processes that exhibit stability over time.
vii. Substance presupposes process.

The first claim asserts that living beings are not made of 'substantial particles', which rejects the predominant view in philosophy of biology. When considering substances, both Dupré and Nicholson reject what Siebt labels the *Myth of Substance* (Seibt, 1996), where the pervasiveness of bias towards 'subtances' is reflected in our everyday lives and language (Seibt, 1996, p.119; Nicholson and Dupré, 2018, p. 11). Their observation is that the pervasiveness of a substance view in philosophy of biology permeates through language, affecting scientific research and the interpretation of results. They provide an example of the lifecycle of a frog. To hold a traditional substance view is to claim that some part of the organism remains the same even through its transformation and development. The view falsely asserts that as the frog develops from the tadpole, some essential part of the frog is unchanged throughout their development.

[14] Note: When Nicholson and Dupré use the term "things" they refer to macro-objects associated with living beings such as hearts and livers. This may be confusing as they use "things" interchangeably in their work to describe objects in living beings from both a substance and process perspective based on the context of the sentence. In this thesis, we have generally, unless otherwise stated, used the term "things" in the context of substance-based philosophy. Nicholson and Dupré endorse a view that "things" in the world are a hierarchy of processes that are stable and persistent over time; this view is consistent with process philosophy.

Having rejected the idea that living beings are composed of substance, the second claim is the positive view that they are made up of dynamic processes. Nicholson and Dupré define processes similarly to the definition from Table I in Chapter 1, however, they emphasise certain qualities.

- Change creates processes.
- Processes persist with parts that are temporarily different.
- Processes are dynamic rather than sequential.
- Processes come in different magnitudes, intensities and complexity.
- Processes have “fuzzy” boundaries as they are not clearly defined. Many processes exhibit causally interconnected activities, where degrees of process cohesion demarcate individual living things.

We will return to these qualities later in this section when examining why Dupré and Nicholson advocate process philosophy.

The third claim has two parts. The first is that processes are hierarchal, and the second is that they are stabilised at different timescales. Taking the second part first, consider a chemical reaction in a cell, with enzyme and substrate coming together and dispersing in a matter of seconds. This can be contrasted with the growth of an organism, holding itself together for decades. This example illustrates the idea that different biological processes are stabilised and dynamically interact on different timescales.

The first part of the third claim asserts a hierarchy of processes. Nicholson and Dupré’s concept of ‘process hierarchy’ is a little confusing as it implies an orderly layering of processes, such as molecule, to cell, to organ. However, the idea here is that dynamic processes of different sizes and intensities move in and out of each other in a complex web of interactions and integrations (Nicholson and Dupré, 2018, p. 13).

The fourth claim asserts that processes come in various sizes and support the conditions for persistence. The example Nicholson and Dupré provide are the processes constituting the liver and the hepatocyte (liver cell). The hepatocyte can only persist within the liver, and supports the

efficient function of the liver (Nicholson and Dupré, 2018, p. 3). So, per this example, they consider the liver a process and the hepatocyte a smaller process, that persists only within, and depends on, the other process. For Nicholson and Dupré, processes account for all of the biological parts that make up living beings, and these processes persist on different timelines.

As discussed, the chapter states that processes interact with other processes. However, Nicholson and Dupré do not expand on claim four as an approach to how processes relate to other processes. Furthermore, they do not provide a categorisation of types of processes. This is unlike Whitehead, who provides a framework to consider event relatedness and how to categorise events, including their stages of development, and how to become new events. We will review Johanna Seibt's work extending Nicholson and Dupré's concept of process hierarchy along these lines in the next section.

Nicholson and Dupré understand that we observe things in the world such as frogs, cats, hearts and cells. Similar to Whitehead's fallacy of misplaced concreteness, claim five asserts that these biological entities should not mislead us into thinking they must be substances, as they are in fact processes.

This leads directly to claim six, which provides a rationale for why we might be confused that substances exist when they are really processes. Nicholson and Dupré view all living beings and their parts as biological processes that have stability over some time period, giving the illusion of a persistent substance. This idea is explained in the article *Processes within processes: a dynamic account of living beings and its implications for understanding the human individual* (2020), where Dupré considers the difference between a process and a thing. He defines a thing is that where its default equilibrium is stasis, analogous to a machine being turned off. On the other hand, living beings and biological processes cannot stop: they must continually change in order to persist (Dupré, 2020).

Finally, Nicholson and Dupré's chapter provides a caveat that they may be wrong and that substances might exist. However, their view is that if this is the case, then substances are made from processes.

In the next half of this section, we will move on to a discussion of Dupré and Nicholson's positive account outlining what they view as the "philosophical payoffs" and then the "biological payoffs" of process primacy (Nicholson and Dupré, 2018, p. 22-30).

i. According to substance-based ontologies, object persistence requires an essential feature that must endure. This is known as 'essentialism'. Process philosophy can account for persistence without the need for an essential feature to persist. According to process philosophers of biology, this makes process a stronger metaphysical candidate for the persistence of living beings (Dupré 1993, 2002; Hull 1965). The idea of essentialism is useful for substance metaphysics as it allows entities to be organised and categorized. However, when considering this theory in the context of living beings where there are no hard boundaries, Dupré and Nicholson assert that it is difficult to demarcate biological individuals, such that an essence persists over time can be identified. In the book *Process of Life: Essays in the Philosophy of Biology* (2012), Dupré takes a broader process ontological view with the concept of 'promiscuous individuals', where several biological entities might come together to form a collaborative dependency on each other (Dupré, 2012). These concepts are significant in our understanding of processes and biology. They will be discussed later in this chapter when we review Thomas Pradeu's work in the context of biological identity, process and philosophy of immunology.

ii. The claim that biology can be reduced to microlayers has been promoted recently with the success of molecular biology. However, several philosophers of science believe that this approach has a limited ability to explain the facts of the organism, whereas a more holistic view is effective (Dupré 1993, 2010a; Powell and Dupré 2009). For example, a topic that is difficult for substance metaphysics to account for is the emergent properties

that we observe in biology, such as consciousness arising from the neurological structures of the brain. As identified by Jaegwon Kim there are problems with accounting for emergent macro properties that are caused by micro properties and then, in turn, cause macro properties. Kim does not think this makes sense as it suggests that an emergent property causes itself (Jaegwon Kim, 1999, p. 16). Therefore emergent macro-properties of consciousness from the micro neurological structures of the brain are difficult to reconcile from a substance perspective. However, process metaphysics does not have the same constraint and can account for emergent properties in biology and nature (Nicholson and Dupré, 2018, p. 26).

Biological complexity is also viewed by Dupré and Nicholson as a reason to reject reductionism, given the practical challenges to delayer the complexity of intertwined or aggregated processes. Additionally, the numerous relations associated with process-to-process interactions makes deconstruction a challenge for purposes of reductionism (Nicholson & Dupré, 2018; Wimsat 1972, 2000).

iii. Although not universally endorsed by philosophers of biology, historically the predominant view has been that biological explanation is mechanistic. This means that biological entities should be viewed as a series of component parts that operate as a collection of integrated biological machines. A mechanist approach to biology supports the substance metaphysics of clear boundaries and predictable, reliable operation. For example, molecular biology promotes a mechanistic analogy for macromolecules, suggesting that they have clearly defined boundaries, and reliable and predictable outcomes. Dupré and Nicholson challenge mechanistic approaches from a practical perspective for several reasons. First, it is difficult to understand how mechanism's account for many biological lifecycles. The standard conception of mechanisms is that they have a defined purpose and function, and are deterministic and predictable, such that they don't develop. It is this lack of development which makes it difficult to reconcile this picture of biology with a case such as the development of a tadpole into a frog. Lastly,

> Nicholson and Dupré argue that processes have better explanatory power than mechanistic theories, as biological systems never turn off, unlike machines. Living beings and biological processes operate away from thermo-equilibrium, consuming energy and supporting a variety of regulatory activities where, in their view, process has better explanatory power (Nicholson and Dupré, 2018, p. 28; Dupré, 2008; Nicholson, 2013, 2014).

The following is a summary of the implications of Nicholson and Dupré's views on process philosophy's ability to underwrite biological explanation (Nicholson and Dupré, 2018, p. 30-33). Physiology includes the study of structures and functions in biology. Nicholson and Dupré claim that a popular view in philosophy of biology is that the structure-to-function relationship is considered linear and unidirectional, and therefore predictable and determined. Nicholson and Dupré and other philosophers of biology, such as Ludwig von Bertalanffy, assert that this might not be the whole story, as these relationships are likely circular, with the involvement of various regulatory processes supporting a dynamic between biological components.

> "…the old contract between 'structure' and 'function' is to be reduced to the relative speed of processes within the organism. Structures are extended; functions are transitory, rapid processes." (Bertalanffy, 1941, p. 251)

Nicholson and Dupré identify genetics as an area in biology where process thinking helps us to better understand related topics such as inheritance, and evolution. The classical substance view of genetics allows for transferring matter in the form of DNA from the parent to the offspring. Based on work conducted by Mendel that involved experiments on peas, we now believe that the movement of phenotypic information involves the whole genome combined with other external inputs as part of an epigenetic process (Barnes & Dupré, 2008). Historically, the scientific approach was to take time slice intervals of organisms in a species and look for physical changes, which does not allow evolution to be viewed as a process with internal and external relations over time. However, another approach is to consider David Hull's approach, where species are considered individuals that extend over time. Hull is unlikely to be considered a process

philosopher, but his ideas support a holistic view of species development over time (Hull, 1976, 1978). We now understand that evolution is likely a process that involves the integration of internal and external factors, so this finding reinforces the legitimacy of holistic approaches in evolutionary research.

3.2 Contemporary philosophy of biology and process-to-process relations

Now we've considered some arguments for the primacy of process in biology, I turn to consider some of the fundamental issues for such a view. As we have examined in prior chapters and the preceding section, that processes relate to each other is a core tenet for any process philosophy. In the chapter *Ontological Tools for the Process Turn in Biology: Some Basic Notions of General Process Theory* (2018), Johanna Seibt proposes an approach to classifying processes and describing the various relations that exist between them. This approach uses a process ontological framework known as 'general process theory' (GPT), which has been used predominantly on more general philosophical problems and applies it to the philosophical analysis of processes in biology. Seibt finds a weakness in Whiteheadian process ontology and similar philosophy of biological processes. In her opinion, there is a general inability to organise the process relations in a way that explains the relevant facts.

The basic assumption when using GPT as a method of general classification is to view everything represented in the world as made up of 'general processes' or 'dynamics'. General processes are subjectless or pure, activities. Subjectless statements are descriptive statements that do not denote a subject, for example, "it is snowing" or "it is raining " (CD Broad, 1923, 1925; Sellars, W., 1960,1968). GPT's procedural objective is "…to differentiate the basic [process] into types and sub-types that can form the ontological correlates for true sentences of some theory T (in common sense or science)." (Seibt, 2018, p. 115). This allows for the delineation of processes into their related hierarchies and relationships, which Seibt calls 'Leveling Mereology' (LEM). For

example, referring to fig.1[15] where D3→D2→D1, that is D3 causes or contributes to D2 and D2 similarly to D1. The purpose is to understand the relationships and any causal or other dependencies between processes. When considering the earlier example, in Dupré and Nicholson's case of the "liver" and the "hepatocyte", Seibt would likely view this as a scenario for which GPT is well suited to depict underlying dependencies and relations. To illustrate, D1 is the organism, D2 the Liver and D3 the hepatocyte. Another alternative hierarchy might be D1 as the organism, D2 as an endocrine system, D3 as the liver, and another layer, D4 as the hepatocyte.

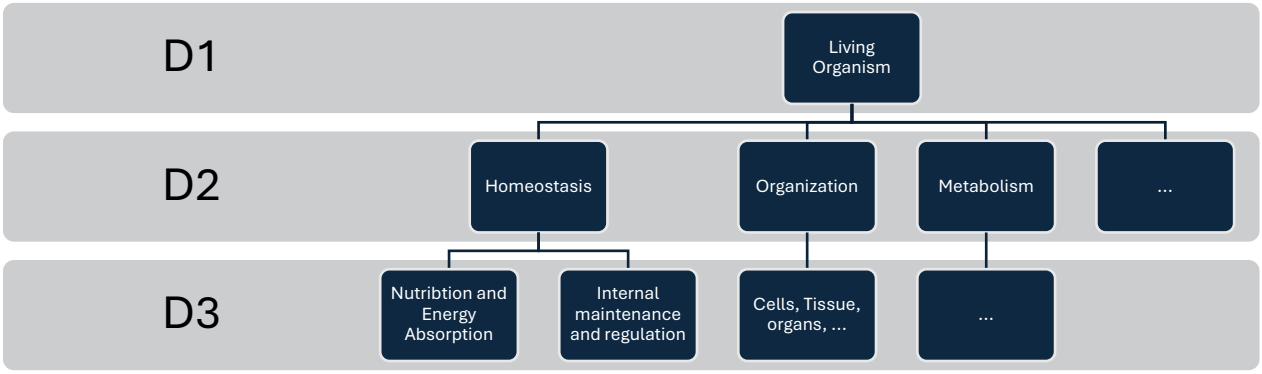

Fig. 1

After gaining an understanding of the general processes and their relationships, the next step in the GPT procedure is to combine this understanding with a 'classification statement' relating to various dynamic qualities. Seibt claims that this is where GPT can help increase the explanatory power of biological processes.

Seibt says that GPT uses five dimensions of dynamic qualities to help define the 'dynamic classification statement'. Dynamic classification statements are required to understand better and explain the characteristics of the processes. It is not enough to have identified a relationship between the liver and the hepatocyte; we also need to understand the dynamics of the relations. Given our example, are hepatocytes transient or sustained? Are there process dynamics such as reinforcing loops in their interactions with the liver, and what are the internal and external conditions that maintain their optimal performance?

[15] Note: the hierarchical diagram approach is influenced by Seibt's work and then populated with relevant researched examples for ease of illustration in this thesis, including Nicholson and Dupré's Liver and Hepatocyte example.

> "…self-maintaining far-from-equilibrium systems like a candle flame, a hurricane, or a biological organism are complex dynamics that emerge from, and constrain, certain interactions and thereby constitute the dynamic system" (Seibt, 2018, p. 125)

Below is a distilled summary of the dynamic classification scheme used in GPT as represented by Seibt in her chapter (Seibt, 2018, p. 125).

i. 'Spatiotemporal signature': This is the unique pattern created by objects as they move and interact with their environment over time, such as an elephant eating. These patterns have different spatiotemporal dynamics by type, such that an elephant eating has a different pattern than a protein folding. Thus, processes of particular types tend to occupy stereotypical patterns of spatiotemporal regions with a particular dynamics. This allows us to recognize certain types of processes on this basis.
ii. 'Participant structures': There are general process participants and roles such as agent, patient and intra-agent.
iii. 'Dynamic constitution': There are a range of particular types of systems dynamics, such as linear and nonlinear mechanics, feedback loops, self-maintaining dynamics, and emergence.
iv. 'Dynamic Shape': The process output over time is often deterministic or chaotic. For example, it may stay in the region of phase, switch between attractors periodically, or chaotically develop in an unpredictable manner.
v. 'Dynamic context': This is the context of the indirect and direct relations relevant to the process. For example, the indirect causal impact on the biology of some organisms from changes in the ecosystem or the direct and likely immediate causal impact to the process from altering airflow.

We have discussed why process-to-process relations are important. However, seeing that these relations are important is not enough. It is the equivalent of saying I understand that there is an electron in the universe, but without the knowledge of quantum mechanics and how the electron

dynamics and interactions with other particles work. In such a case, my understanding of the electron is limited and incomplete. Seibt asserts the usefulness of GPT as a descriptive procedure to help organise the hierarchy of processes proposed by process philosophers of biology such as Nicholson and Dupré. This claim may well have merit and warrants more study.

3.3 Mechanism and Process

As we discussed in section 2.2, Whitehead rejects localised matter and the bifurcation of nature, as he claims that this provides a false mechanistic view of nature. In *A Manifesto for a Processual Philosophy of Biology* (2018), Dupré and Nicholson express a contemporary philosophical view that biological organisms should not be viewed as living machines and provide examples of macromolecules being erroneously viewed as little machines (Nicholson and Dupré, 2018, p. 28-30). We shall now discuss this comparison of mechanism in the context of macromolecules and contemporary process philosophy of biology, first in the context of the general process argument, and then with more specific examples such as olfaction as a process.

Significant progress has been made in biology with the advent of macromolecular biology. This likely has reinforced the traditional view that nature is mechanistic and based in substance. In the chapter *A process ontology for macromolecular biology* (2018), Stephan Guttinger's goal is to change this traditional view. He makes the following claims: (1) macromolecules are fundamentally relational entities; and (2) the relational nature of macromolecules is of a kind that can only be explained by processes (Guttinger, 2018, p. 303-304). For this, Guttinger leverages a framework, an 'Ecological World View' developed by Charles Birch and John Cobb in their book *The liberation of life: from the cell to the community*. The framework assumes that nature can only be explained by processes (Birch and Cobb, 1981). As Birch and Cobb are Whiteheadian philosophers, they turn to the 'Philosophy of Organism' and make two claims:

> "(i) everything – from atoms to organisms to populations is an ecosystem as opposed to some sort of machine or mechanism; and (ii) an ecosystem model of the world goes hand in hand with a process ontology." (Ibid: p. 89)

Guttinger acknowledges the framework's value, but in his view Birch and Cobb's primary example of DNA did not confirm their theory.

Guttinger asserts that the predominant view of philosophy of biology is mechanistic, which presupposes that living beings are distinct and separated from each other. This view acknowledges that there are relations between individuals and the environment but only for resources such as energy (Guttinger, 2018: 305-306). For example, under this mechanistic view, an engine in a car is not affected directly by external relationships for its operation. The engine can wholly rely on its components' internal relations to achieve the engine's purpose.

In support of his claims, Guttinger uses William Bechtel and Robert Richardson's framework as explained in their article, *Discovering Complexity* (1993). In this article they propose a procedure to analyse different types of complex systems, which follows the work done by William Wimsat and Herbert Simon. To summarise this, there are two types of systems in this framework, namely 'aggregative systems', where the components of a system combine in a straight-forward manner to create a whole system. The second is 'composite systems' that are either: (a) component systems; or (b) integrated systems. A component system is governed by its parts; however, their organisation can change the behaviour of the whole system. On the other hand, an integrated system is where the intrinsic functionality of the component is no longer determined, and can change as the whole directs how each component's capacity should function (Bechtel and Richardson, 1993). In the article *Complex Systems* (1970), Richard Levins provides examples of aggregative, composite and evolved or integrated systems. An aggregative system comes into existence where the parts can be viewed statistically and affect the whole, such as an ecological system made up of organisms that together can affect the whole ecology (Levins, 1970, p. 76). An example of a composite system is a circuit board, where the parts are independent, however, their configuration is directly related to the operation and function of the composite circuit (Levins, 1970, p. 77). An integrated system is where the component parts are integrated such as symbiotic organisms, for example, nitrogen-fixing bacteria and leguminous plants (ibid).

In Guttinger's view, Cobb and Birch represent the DNA macromolecule as having the intrinsic capacity and information for the coding and development of the different cells and relations with the external environment. Cobb and Birch use DNA as an example of their model with emphasis on how the DNA interacts externally with the environment. However, Guttinger argues that the DNA molecule they discuss is operating more like the machine that they reject. This is because they present it as interacting with the external environment in a similar way to the parts in an aggregative system. Guttinger views the DNA macromolecules and external relations as more interdependent, almost symbiotic, as relations between DNA and external processes develop and evolve together over time, and he calls this an integrated system. He discusses termite nests as another example of an integrated system in contrast, as studied and documented by J. Scott Turner (Turner, 2002, 2000). In Turner's example, fungi thrives in the humid conditions created by the termite nest, and the termites rely upon these fungi to break down their food so that they can digest it. As such, the termites have a symbiotic external relation with the fungi and are incentivised to keep the termite nest conducive to fungus growth to survive. Neither the termite nor the fungi have the internal capacity needed to survive alone. Rather, they rely on the whole system, which determines their functions for their respective survival. This was Guttinger's first clue that symbiosis in ecological systems is the norm rather than the exception.

Upon first review, it might appear that macromolecules should be viewed as separate component systems and not integrated. For example, a class of proteins, namely enzymes, are the workhorses that facilitate chemical reactions that the cells require. This is reinforced by the traditional view that proteins follow a substance-based component system known as the sequence-structure-function (SSF) paradigm, where DNA determines the sequence of amino acids, this sequence will determine the protein folding structure, in conjunction with other determining factors, and the protein's structure determines its function. However, the biologist Ross Stein has demonstrated that enzymes likely have many different structures that they rotate through continually, based on the thermal dynamics of the water surrounding the enzyme. Stein's work suggests that proteins act more like integrated systems, enzymes may be reliant on external relations with the water to achieve alternative dynamic 3-dimensional structures rather

than a fixed and rigid structure. This structure then ultimately affects how the enzyme behaves as a catalyst for the chemical reaction.

> "In the end, we will not be able to locate the origins of the catalytic power of an enzyme in a certain 3-dimensional arrangement of active site residues nor in a certain fold of the protein; rather, enzymatic catalysis will have to be analyzed as structurally specific substrates bound to an active site of definite chemical potential embedded in a dynamic protein matrix that is in thermal exchange with the aqueous environment of bulk solvent. This holistic description of enzyme catalysis can be solidly grounded in the metaphysical foundation of Strong Chemical Processism." (Stein, 2004, p. 15)

Another example that exhibits the criteria of an integrated system is 'Intrinsically Disordered Proteins' (IDPs), which lack the three-dimensional structure and can adapt to perform a variety of activities, such as protein-to-protein interaction and regulating gene expression (Dunker, K. et al., 2001).

This discussion regarding integrated systems highlights the distinction between a focus on relations between processes on one hand, and a substance metaphysics based on discrete mechanistic entities on the other. This distinction has been a key theme throughout this thesis. In Chapter 1, we introduced the characteristics of process and the importance of process-to-process relations. In Chapter 2, we examined the importance that Whitehead placed on relations between processes. And again in this chapter we have completed an examination of contemporary process philosophers of biology and biologists who have emphasised relations, making process distinctive from substance approaches. The following section regarding Thomas Pradeu's philosophy of immunology will also take exception to a mechanistic view, this time regarding the immune system. He rejects the idea that the immune system works in a mechanistic manner that is somewhat deterministic. Rather, he argues that the immune system is an adaptive and integrated system, accommodating a changing microbiome and other

biological processes. This is arguably more aligned with Guttinger's view of biology as grounded in relations.

3.4 Contemporary Biological Identity and Process

Biological identity is a subset of the topic of the more general philosophical identity problem: how do we know if an x at one time is the same as x at another time and is not y (Parfit, 1971; Shoemaker,1970). However, for biological identity, there are two issues in the vicinity, and they're not exactly the same. One is biological identity and what determines the whole from the biological parts. The other is biological individuality, and how many biological entities are present. Biological identity is primarily concerned with determining the boundaries associated with where to demarcate living beings. Where biological identities start and stop is challenging for various reasons, such as when considering microbiome and symbiotic organisms. Another related concept is the 'holobiont', which views an organism as a community of symbiotic organisms (Gilbert and Tauber, 2016).

Given the various challenges presented by the substance view of biological individuals, several philosophers of biology have promoted a process approach to this issue. In the article, *Biological Processes: Criteria of Identity and Persistence* (2018), James DiFrisco argues that an individual can be delineated by the processes that lend to its causal cohesion and endurance over time. For example, the strong molecular bonds of a rock provide causal continuity for the rock and endurance over time.[16]

Thomas Pradeu is a philosopher of biology and immunology; however, in my view, he is also likely a process philosopher. In the chapter *Genidentity and Biological Processes* (2018), Pradeu outlines the theory of genidentity. Pradeu is influenced by the article *A matter of individuality* (1978), where David Hull articulates his version of genidentity, claiming that "Identity through time of an entity X is given by a well-identified series of continuous states of affairs." (Hull, 1978).

[16] There are other process theories that are not expanded in this thesis. Some process theories reject the concept of biological individuality, claiming that due to symbiosis and the lack of boundaries, there is no need for a concept of a biological individual (Bouchard, 2018; Meincke, 2018).

Hull is not a process philosopher. However, he does claim the premise that biological boundaries are difficult to demarcate, and that the species made up of the organisms are true biological individuals together forming an "ontological category" that endures over time.

> "In contrast to common sense and intuitive perception, Hull seeks to offer a biologically precise criterion for the diachronic identity of biological individuals; and he finds this criterion in the idea of continuity of change. According to Hull, organisms and species belong to the same ontological category, as both must be understood as spatiotemporal localized entities. More radically, Hull's thesis is that any organism or any species is a portion of space and time. For Hull, because living things can undergo massive and unpredictable change, retention of substance (the idea that something of X remains through time) and resemblance (the idea that X looks sufficiently like itself) are useless criteria for biological diachronic identity. The only satisfying criterion is continuity of change." (Pradeu, 2018, p. 5)

In the book *The Limits of Self: Immunology and Biological Identity* (2012), Pradeu provides what is arguably a process-oriented theory[17] named his 'continuity theory', where he claims that the immune system has a challenge to demarcate what is the organism's biological identity. Pradeu notes that the immune system determines what is a legitimate part of the individual and what is a pathogen. His theory claims that the immune system works as a process that learns over time and adapts to the organism's morphology, such as an organism's anatomy and boundaries. This theory allows the immune system to be less rigid and deterministic regarding the legitimate demarcation of the biological individual. It outlines a possible approach where the immune system changes what are considered legitimate biological boundaries. Pradeu's work builds upon many philosophers of biology.

[17] Pradeu does not explicitly state that his 'continuity theory' for immunology is process-oriented. However, upon review of the qualities of his theory in the context of the detail provided in his book, these qualities likely align with many of the process characteristics outlined throughout this thesis.

The virologist Frank Burnet is accredited as a proponent of the 'self/nonself' theory relating to immunology that has been prevalent for approximately one hundred years in biology (Burnet and Fenner, 1949). Burnet claims that the immune system works like a type of 'white list', which determines early in child development what components are accepted to be part of the organism and what are not. Thus, with this master list of what is 'good' and what is 'bad', pathogens can be identified, and the immune system can react and defend the organism. However, there are several exceptions that pertain to a lack of immune reaction. For example, (1) how do we explain our immune system's lack of reaction or inconsistent reaction to an ever-changing microbiome within our digestive system and on our bodies; (2) why the immune system inconsistently reacts to some cancers which might develop and elude the immune system whereas others do not; and (3) why fraternal twins can exchange transplants such as skin grafts without any immune defensive reaction (Pradeu, 2012, III, p. 85-130). Pradeu rejects the 'self/nonself' theory. His observation is that the immune system does not determine good and bad in the context of what is the self as a demarcated biological individual, rather than what is regarded as the non-self and not the biological individual, such as pathogen (Pradeu, 2012, p. 85). For Pradeu, the immune system is a 'process' that learns over time and adapts based on the experience and intensity of numerous immune system reactions. This is a similar concept to Guttinger's idea of integrated systems. When the immune system has a low-intensity Immune reaction without invoking an immune defence response, this results in the reconditioning of the immune system to accept a new biological part into the organism.[18] If the reaction is high, we might traditionally view this as the attempted immune response to a pathogen. Pradeu develops this into his theory of continuity for biological identity (Pradeu, 2012, IV, p. 131-184). We will revisit Pradeu in the next chapter, where I will argue that Pradeu is likely a process philosopher.

This concludes the chapter in which we have examined the process philosophies of several prominent process philosophers of biology. The chapter provides the necessary background for

[18] It is interesting to note how similar this is to Whitehead's own view of causation, where, in effect the organism is a process of continual dispositional change with two objects coming together. Rather than invoking a Humean cause-and-effect reaction, they 'become' over time a new object (actual entity) or biological identity.

analysing Whitehead's work in the context of its relevance for these and other contemporary process philosophers of biology.

4. Chapter Four: The case for Whitehead's relevance to process philosophers of biology.

This chapter makes the positive case that Whitehead's Philosophy of Organism should be considered a relevant process metaphysical framework by contemporary process philosophers of biology. The goal of using his framework is to improve their arguments against philosophers of biology who advocate for substance metaphysics. In addition, it will also simply improve and advance the process view. Whitehead has a reputation for being obscure, mystical, and for a few famous unconventional views such as his theist beliefs. Understandably, contemporary process philosophers of biology might be concerned enough to allow Whitehead's reputation to affect their judgement about much of his work. This thesis recommends that they disregard those areas of Whitehead's philosophy they disagree with and take the 'gems' from his work that highlight or resolve the gaps in their own theories. In my assessment, much of Whitehead's philosophy raises the right questions, but I don't agree with all of his responses to these questions. For example, as reviewed in section 2.3.4, it makes sense to ask how a process philosopher accounts for the impetus and amount of change observed in nature. However, his response of using a sort of platonic ideal of an eternal entity, "god", to explain the impetus of nature does not resonate with me for two reasons. First, in my view, it is too easy to solve the problem with reliance on a deity. Second, of more concern is the idea of a supernatural eternal entity contradicts his naturalist account of a physical processional nature.

When I set out to conduct this project my quest was not to argue for process metaphysics, nor to advocate for philosophers of biology to all adopt Whitehead's philosophy. Rather, my goal was to determine if Whitehead's process philosophy is relevant and has value for contemporary process philosophers of biology. Additionally, I haven't taken a traditional Whiteheadian approach to attempt to convince contemporary process philosophers of biology that Whitehead's philosophy should be adopted. My intention is to review Whitehead's philosophy from the perspective of the contemporary philosopher of biology who advocates for process ontology and determine

whether Whitehead's work might strengthen their arguments by highlighting any gaps to be resolved and additional ideas that might be considered.

This chapter identifies three independent but interlinked arguments that make the case that contemporary process philosophers of biology would benefit from considering Whitehead's process philosophy. There are more arguments that have been identified while conducting this research. However, to fully develop these would require considerably more space than is available in this thesis. As such, the case is made by the three points below that will be developed in more detail in this chapter:

i. First, recent challenges by prominent contemporary philosophers of biology that argue for process ontology, such as Dupré and Nicholson discussed in section 3.1, regarding the legitimacy and usefulness of Whitehead's philosophy for biology are overstated and can be overcome. This chapter intends to put these concerns in context, as until there is a rebuttal, they will continue to detract from a serious consideration of Whitehead's work.

ii. Second, as discussed in section 2.4, Whitehead made a case that we need to be explicitly aware of our metaphysics and pay attention to our decisions in this respect when developing philosophical frameworks. Here I am not advocating a specific metaphysical position that philosophers should adopt regarding what underlies everything. Instead, the claim is that philosophers of biology should not neglect the role of fundamental metaphysics in science or be non-committal and 'sit on the fence'. Given that we have a cognitive bias towards substance metaphysics, and that substance metaphysics has been the predominant Western analytic philosophy, taking an attitude of quietude towards fundamental metaphysics will likely equate to an adoption of a substance approach. In turn, this will potentially make it difficult for philosophers of biology who would like to advocate process to move their theories along. We will examine the work of Thomas Pradeu, discussed in section 3.4, where he, similar to Whitehead, asserts the value of metaphysics. The purpose of this is to speculate how he

may have developed his theories faster and more easily if he had been more aware of his own cognitive bias towards substance and wholeheartedly adopted a process position.

iii. Lastly, this research on Whitehead's philosophy has highlighted several gaps of contemporary process philosophy of biology, that if addressed might strengthen the view. In particular, as discussed in section 2.3.3, Whitehead advocated a relations-first approach in his philosophy. He placed importance on an ordered procedure for understanding process-to-process interaction in order to better account for a process ontology. As discussed in section 3.2, Seibt endorses a framework known as 'general process theory' that describes how processes relate to each other and should be adopted in process philosophy of biology. However, an approach to organise how processes develop these relations to each other is otherwise largely absent from the literature. Admittedly, as we discussed in section 2.3.4, the Whitehead approach depends on a god, which is likely hard for most contemporary process philosophers of biology to accept. However, this does not detract from his observation that a method of some kind or other to account for relations between processes is required for any proposed process philosophy for biology to be complete.

This chapter's task is to expand on each of the three points above. As already noted, this research has identified possible other reasons, but these will require more research to determine their potential contribution or otherwise.

4.1 Recent challenges by prominent philosophers of biology to the legitimacy of Whitehead's philosophy are overstated and shouldn't detract from the good parts.

Contemporary philosophers of biology who advocate for process philosophy might be forgiven their assessment that Whitehead's philosophical approach is eccentric and that it is unrealistic to accept all of his philosophical positions. However, in my view, throwing Whitehead out as irrelevant is going too far and fails to appreciate the value of the insights on offer. Additionally, although some of the concerns with his philosophy are reasonable, the majority are arguably over-blown. The basis for this view is expanded in the remainder of this section.

One of the central tasks is to determine whether Nicholson and Dupré are altogether fair in their assessment of the legitimacy of Whitehead's philosophy (Nicholson and Dupré, 2018). The specific concerns raised that arguably impact the credibility of Whitehead's philosophy are as follows: (i) Whitehead's philosophy of organism is too hard to follow given the language that he uses; (ii) Whitehead endorses a 'panpsychism' approach in his philosophy; (iii) Whitehead's philosophy has theist underpinnings with an endorsement of god; and (iv) Whitehead's philosophy presents an argument that supports an atomist and reductionist view that is more aligned with the substance metaphysics that he claims to reject (Nicholson and Dupré, 2018, p. 7-13).

4.1.1 "'Process and Reality' is generally agreed to be opaque and at times so obscure as to verge on the unintelligible" (Nicholson and Dupré, 2018, p. 7).

I admit it isn't easy to interpret Whitehead's Philosophy of Organism as detailed in the 385 pages of his book *Process and Reality* (1929). As discussed in section 2.3, Emmet, a student of Whitehead, speculates that the reason why his work can be difficult to interpret is due to his background as a mathematician, and consequently his metaphysics is written in a manner similar to the development of a logical-mathematical proof (Emmett, 1932, p. 63, 83). Whitehead's use of language is precise, but there is little explanation as to his rationale, and a lack of practical examples and background to support his theories. In my experience, Whitehead's books *Process and Reality* (1929) and *Adventures of Ideas* (1933) are the most complex of his works and are often criticised as difficult and unintelligible. However, as a way to approach Whitehead's ideas, if the philosopher starts with Whitehead's earlier works first then they can follow how the ideas and theories are developed in a logically stepped manner as they progress to his later works. Additionally, secondary literature on Whitehead is helpful (Lucas, 1989; Debaise, 2017; Emmet, 1932; Sherburn, 1965). Admittedly, the investment is considerable and requires, in addition to a meticulous study of *Process and Reality*, a review of Whitehead's other primary works such as *Science and the modern world* (1929) to understand his ideas.

Although I am sympathetic with Dupré and Nicholson's synopsis of Whitehead's philosophy being difficult, I do not agree with their conclusion that contemporary process philosophers of biology should not consider his work on that basis. In fact, they simply admit they won't look at Whitehead's work: "All things considered, we are more inclined to risk reinventing the wheel than to look for the concepts and theses we want in Whitehead" (Nicholson and Dupré, 2018, p. 7). However, even though it is difficult and time-intensive, an investment in understanding his work is rewarded by strengthening the arguments of contemporary process philosophers of biology against substance-based philosophies.

In Chapter 2 we discussed Whitehead's concerns with language and the unintended bias that subject-predicate phrases produce towards substance, and ultimately to the fallacy of misplaced concreteness. Whitehead viewed an object that has attached qualities as promoting the idea of an underlying substance. He considered substance and localised matter to be an abstraction. This meant that relying on such ideas is fallacious, and supports the concept of duality and bifurcation of nature, a view Whitehead rejects (see section 2.2).

The upshot of all of this is that Whitehead needs to avoid subject-predicate language as much as possible. In turn, this means that he is unable to rely on many common terms and ways of speaking. As such, the language he uses is unfamiliar and can be convoluted, as he invented words for the core concepts of his theories that have unfamiliar meanings. Examples of these invented words are given in section 2.3, including prehension, concrescence, actual and enduring entities, nexus and subjective aim. This method has been used by many other philosophers to convey unique ideas that have a new meaning, such as Kant's 'transcendentalism' and Derrida's 'phallogocentric'. However, the extent of Whitehead's use of these newly invented words makes his work very difficult to understand. Despite this, once we work our way through his work in sequence and understand his reluctance to use standard subject and predicate language, his ideas present themselves for our consideration.

4.1.2 Whitehead is a 'panpsychist'. (Nicholson and Dupré, 2018, p. 7,11)

As an example of Whitehead's use of words in unfamiliar ways, he used the word 'feeling' to represent how actual entities relate to each other. This has created concerns for contemporary philosophers, as it appears to suggest that both small and large-scale objects have a form of consciousness. This is not what Whitehead was suggesting and he was not a panpsychist, at least not in the contemporary sense that consciousness is an inherent feature of everything that exists in the universe. As discussed in section 2.3.3, a key tenet of Whitehead's philosophy is that temporal relations between processes are essential. Process relations are a key differentiating feature for Whitehead's philosophy compared to the substance-based concept of localised matter that is isolated, not continuous and with no temporal relations. Whitehead was influenced by quantum mechanics and the need for process relations, and theorised that, even at the smallest scale, entities must have some minimal 'loci of perspective' of the other entities prior to any relations taking place. Unfortunately, Whitehead uses the words 'prehension' and 'feeling' to explain how processes relate to each other. These words are not intuitive and suggest that there is an agent involved in the 'prehension' and 'feeling' of other processes. What Whitehead intended is that through the process of concrescence there is a prehension of the immediate past and a selection of actual entities (events) towards the future as they combine to make a new actual entity. This selection is not completely random and requires some attractor. Although a difficult concept, Whitehead highlights that process theorists require some form of approach or method that explains how process relations might work (Lucas, 1989; Sherburn, 1965).

4.1.3 Whitehead's philosophy is theistic and not scientific, as it depends on god (Nicholson and Dupré, 2018, p. 7).

As discussed in section 2.3.4 it is reasonable to consider Whitehead to be theistic as he relies on god to explain novelty and creativity. Also as examined earlier, Whitehead's philosophical view of god is not of an anthropomorphic god. In Whitehead's framework, "god" is an eternal part of nature that provides the momentum and impetus for the potentiality of what nature might be in the future.

Contemporary process philosophers of biology might be put off by Whitehead's theistic views. However, Whitehead's conception of god is restrained because he doesn't describe a comprehensive benevolent and omnipotent god. Given his conception of god, it is reasonable to set aside this part of his philosophy. Nevertheless, at some point, it is important to explain how the impetus and momentum that we observe in nature might work. In fact, Whitehead demonstrated that novelty and creativity are features of process philosophy, and so contemporary philosophers need to explain how these features are accommodated in their framework in any case. In short, Whitehead's meagre use of god in his philosophy may be unpalatable for process philosophers of biology, but this should not put them off the whole project of accounting for the drive towards novelty in nature.

4.1.4 Whitehead's philosophy supports atomism and reductionism (Nicholson and Dupré, 2018, p. 13).

Dupré and Nicholson claim that Whitehead's process metaphysics embraces an atomistic view of experiences or actual entities as the basis for what underlies everything, and that this is a reductionist approach (Nicholson and Dupré, 2018, p. 13). Contemporary process philosophers of biology generally view 'holism' as the correct approach, and so the whole organism is considered to be more meaningful than its reduced component parts (Nicholson and Dupré, 2018, p. 8; Moreno et al., 2011, p. 311; Rescher, 2000, p. 22-32). Therefore, there is a concern that Whitehead's approach is not fully distinct from that promoted by substance metaphysics, which endorses both an atomistic and reductive approach.

Given that Whitehead was a physicist and philosopher, he believed that his process philosophy needed to explain the quantum world that we don't observe as well as the macro world and unify both within one overarching theory. Therefore, the first half of *Process and Reality* (1929) explains the basic actual entities that underlie everything, and the second half of this book describes the nexus and becoming of observed objects in the world such as tables, chairs, trees and living beings. In summary, Whitehead's metaphysics is both atomistic and reductionist in the sense that it accounts for the very small. Still, it is also holistic, as it accounts for the macro world we observe.

He is attempting to unify these two different worlds as is the goal of physicists and philosophers of science. A substance metaphysician might make similar atomistic and reductionist claims. However, as we reviewed in section 2.3.3, the underlying approach is different as Whitehead's approach is processional based on the concrescence of different events that form into new actual entities, not an arrangement of building blocks of some underlying atomic homogenous substance. Like Guttinger's idea of an integrated system we reviewed in Chapter 3, Whitehead asserts a holistic view that everything in the universe is related and interconnected (Sherburn, 1965, p. 7, 77-79). Whitehead's philosophy is not atomistic and reductionist in that it attempts to unify and provide a holistic view of the universe.

4.2 Contemporary philosophers of biology should consider Whitehead to make them aware of their metaphysical commitments and pay attention to the decisions they make when developing their philosophical framework.

Whitehead provides an approach that can be used to assess metaphysics, that contemporary philosophers can apply to their own proposed metaphysics. Additionally, he makes the case that philosophers should be aware of their metaphysics commitments and pay attention to their decisions when developing their philosophical framework. Also, as discussed in section 2.4, he suggests that it is not sufficient to be non-committal regarding one's metaphysical positions, as we are affected by cognitive bias and will likely assume a substance framework as the default position. As a consequence, this will make the development of process metaphysics more difficult and slower. This remaining section will argue for Whitehead's view. To achieve this, we will revisit Thomas Pradeu, whom we introduced in section 3.4, and contend that he is in fact a contemporary process philosopher of biology. I will argue that Pradeu may be influenced by a cognitive bias stopping him from wholly embracing a process metaphysics. Furthermore, I speculate that if he had wholly adopted process metaphysics this likely would have allowed him to develop his theories associated with immunology and biology more quickly and easily.

In section 2.4 we examined Whitehead's views on the necessity of metaphysics in science and his belief that metaphysics should adhere to a set of standards to make our philosophy well-behaved. It is this method that contemporary philosophers of biology, whether they endorse substance, process or something else, can use to assess the quality of their metaphysical positions.

a) The Metaphysics of science should be grounded in contemporary science, not the inverse where metaphysics dictates the science and worldview.
b) Metaphysics should conform to intuitive experience.
c) Propositional content requires clarity and should attempt to minimise ambiguity.
d) Propositions in metaphysics should be logically consistent.

In his book *Process and Reality* (1929), Whitehead made a case for speculative philosophy in biology. According to Whitehead, philosophers who rejected process ontology or took a non-committal metaphysical position might default to the substance metaphysical bias standardly associated with Western analytic philosophy. This might be fine for substance-based philosophers of biology. However, it may be a problem for those who recognise the value of process to explain biology, and yet don't believe they need to take an ontological process position. For this reason, Whitehead wrote about metaphysics and particularly 'abstraction' to caution philosophers about the influence of cognitive bias in science (Whitehead, 1929, p. 11).

As outlined in section 3.4, there are a number of reasons why Pradeu might adopt a metaphysics for science and biology that embraces process primacy over substance primacy. As a recap, Pradeu has been able to rethink the traditional immunological theories that are based on a substance cause-and-effect mechanism, which reacts to anything deemed foreign to the individual. As an alternative, he proposes that the immune system is less binary, by learning and adapting what is and is not considered a pathogen through a continuous feedback loop (Pradeu, 2012; Guay & Pradeu, 2020). Additionally, similar to Whitehead's view, Pradeu clearly states that metaphysics is important for scientific progress, as it helps inform scientists of possible theories for what the world is like. And finally, he acknowledges that cognitive bias affects science. However, despite each of these commitments, Pradeu has not been prepared to fully commit to

process metaphysics. He takes a non-committal ontological position regarding process (Guay & Pradeu, 2020). The below sub-sections i-iv summarise Pradeu's journey and provide evidence that illustrates Whitehead's concerns regarding the bias that many scientists and contemporary philosophers of biology have towards substance.

i. *Pradeu as a contemporary philosopher of biology is likely a process philosopher.*

As discussed earlier in section 3.4 Pradeu is influenced by Hull's 'genidentity' work where the boundaries of an individual are ambiguous. For Hull, the species is a biological individual that lasts over vast time periods (Hull, 1978). Although Hull is unlikely to be regarded as a process philosopher, some might consider his views on biological identity as aligned with the process view that boundaries between processes are difficult to determine and are fuzzy (Dupré, 2012, 2020). Pradeu has built upon genidentity theories proposed by Hull and others to develop a unique process and systems view of how immunology might work in his 'theory of continuity'. His theory of continuity challenges a hundred years of development of the non-self theory for immunology (Pradeu, 2012). In his book chapter *Genidentity and Biological Processes* (2018), Pradeu asserts that there are good reasons to use processes to explain living beings.

"…it is possible to give good arguments in favor of the adoption of an epistemological process view and to show that, from this epistemological point of view, the decision to interpret the living world in terms of processes…". (Pradeu, 2018, p. 105)

ii. *Metaphysics is important to science and metaphysical decisions should be a conscious choice*.

In their article, *Right out of the box: how to situate metaphysics of science in relation to other metaphysical approaches* (2020), Guay and Pradeu assert that metaphysics is important to science and that metaphysical commitments in our theories should be a conscious choice. Next, they assert that philosophers should be open-minded about the possibility that this metaphysics might be based on process (Guay and Pradeu, 2020).

Furthermore, when we are non-committal about our metaphysical commitments, philosophers are likely to unwittingly default to substance ontology; a clear mirroring of Whitehead's views on the topic (Guay and Pradeu, 2020; Whitehead, PR, 1929).

Guay and Pradeu promote an openness towards considering various metaphysical commitments and not disregard metaphysical alternatives without good reason. They take a broad conception of what may be a workable metaphysical framework, allowing the need for "…an open-minded metaphysics of science" (Guay and Pradeu, 2020, p. 1853).

To recap, Whitehead asserts that the default position for philosophers in the Western tradition is likely substance (Whitehead, PR, SMW, 1929). Guay and Pradeu are aligned with Whitehead's view that we cannot do science without being influenced by our cognitive structures which may be considered biased.

"In our view, …If it is true (as seems likely) that we cannot do science without being influenced by entrenched cognitive structures, then it becomes crucial, for both philosophy and science itself, to investigate the way descriptive metaphysics and metaphysics of science may dialogue, and influence each other.**"** (Guay & Pradeu, 2020, p. 1862)

iii. *Pradeu likely has good reasons to adopt a process ontology for living beings.*

In the chapter *Genidentity and Biological Processes* (2018), Pradeu does not rule out the possibility of process ontology; he merely challenges process philosophers to provide evidence for the view.

"I do not think that it is possible to prove the ontological claim that the biological world is 'really' made of processes; and, if this is indeed the claim that process philosophers of biology want to make, then they must give an argument for it." (Pradeu, 2018, p. 105)

Based on Pradeu's comments, it seems reasonable to assume that he does not fully commit to a process ontology. His non-commitment is because he believes there is a lack of evidence to support an argument for process ontology. Of course, a similar challenge perhaps could be placed on the substance-based philosopher to provide evidence and make a positive argument for substance ontology. Given Pradeu's earlier comments about cognitive bias, it is plausible to suggest that his ontological default position might be substance-based. At the very least, his position would mean that not committing to a process view would run the risk of defaulting to a substance metaphysics. As discussed, Pradeu also claims he has good reasons for this to consider process from an epistemological point of view to explain the living world (Pradeu, 2018, p. 105).

Therefore if we only consider process or substance metaphysical frameworks, it is reasonable to suggest that Pradeu likely has good reason to ontically commit to process. At the very least he has better reasons than to default to substance metaphysics.

iv. *Pradeu would benefit from acknowledging that he is likely a process philosopher and adopting wholly process metaphysics.*

If Whitehead and Pradeu are correct that metaphysics is important for the development of philosophy of biology, then one can only speculate about the benefits that might have been realised if Pradeu wholly adopted process metaphysics. He likely would have been more able to develop his theories further whilst being aware of the pitfalls pointed out by Whitehead associated with substance metaphysics. Secondly, he might have developed his past and future theories more quickly. Another more speculative concern is that Pradeu's views might have been limited by this potential bias towards substance ontology.

To recap the points covered in this section. Guay and Pradeu assert that metaphysics is important to science and that it should be a conscious choice. Next, they assert that philosophers should be open-minded about the possibility that this metaphysics might be a process ontology. Furthermore, when we are non-committal about our metaphysical commitments, philosophers

are likely to unwittingly default to substance ontology. Lastly, Pradeu's own assessment aligns with Whitehead's: that one can't 'sit on the fence', as we are likely biased to default to substance metaphysics, given the predominance of this view in Western philosophy. Pradeu claims that process is superior for epistemic reasons, which is aligned with his views regarding genidentity and the immune system. All of these points support the argument that Pradeu has good reason to adopt a wholly process metaphysical framework.

This thesis is not making the case for process metaphysics, nor is the intention to frame Pradeu as a Whiteheadian process philosopher. Rather, the intention is to highlight that both Whitehead and Pradeu are aligned on some topics and as such Pradeu may want to make this connection more explicit. These include the importance of metaphysics for science and philosophy of science and biology, and to be aware of the entrenched cognitive bias that likely influences the development of philosophical theories. It is this last point, as illustrated by Pradeu's work, that is important for contemporary process philosophers of biology. While developing their philosophical theories they should consider Whitehead's urging to be aware of their own bias towards substance metaphysics.

4.3 Whitehead's philosophy highlights several gaps in the work of contemporary process philosophers of biology. If they considered Whitehead's work, it would likely strengthen their arguments for process in biology.

We have seen that Whitehead put forward a number of views that are off-putting to contemporary philosophers. Certainly, Whitehead's philosophy of organism may not be a correct representation of reality, and this thesis does not intend to wholeheartedly defend all of his claims. However, in my view to disregard Whitehead and what he has to offer based on these anomalous claims is a mistake, as much of his philosophy could enrich the framework of process ontology. For example, when we compare the work of prominent contemporary process philosophers of biology such as Dupré and Nicholson with Whitehead's process metaphysics, we

can identify significant gaps in their theories. The task of this section is to better understand how Whitehead may be helpful for these contemporary process philosophers by pointing out these gaps.

First, this section will recap and summarise the major substance and process philosophical systems relevant to this analysis. This is intended to highlight some overarching differences in these projects, much of which has already been detailed regarding Whitehead in Chapters 1 and 2, and in Chapters 3 for Dupré, Nicholson and Seibt.

Next, the task will be to compare the contemporary philosophers of biology, Dupré and Nicholson, and their process philosophy with Whitehead's Philosophy of Organism. The comparison will be performed against the major defining characteristics of process taken from Table I in Chapter 1. This analysis does identify gaps in Dupré and Nicholson's work, and demonstrates that contemporary process philosophers of biology consider Whitehead's work with regard to their own process theories.

Lastly, one particular identified gap in contemporary process philosophy, is how to explain how processes relate to other processes. Much of Whitehead's work is dedicated to understanding how processes relate to other processes, temporal relations, and becoming the very small to the largest objects we observe in the universe, including living things. As discussed in section 2.3.3, the absence of a method for establishing ordered relations between processes might arguably result in an inability for process metaphysics to account for why the world isn't chaotic with disordered and randomly related processes. Contemporary process philosophers generally agree that process-to-process relations are an important component of any process philosophy. However, there appears to have been surprisingly little discussion regarding how to understand the relations between processes. Seibt is an exception to this, and she understands the importance of a method for understanding process-to-process interactions and uses a system for process categorisation that moves in a similar direction as Whitehead.

4.3.1 Recap of major accounts for process and substance metaphysical frameworks in the context of philosophy of biology.

As reviewed in Chapter 1, there has been a lineage of process metaphysics in the Western philosophical tradition, although the predominant metaphysical framework adopted by most philosophers has historically been substance-based. Table III provides a recap of the major differences between substance metaphysics and process metaphysics alongside the more modern versions of these theories in philosophy of biology. Using this table, we can identify a number of contrasts between these metaphysical positions. Note, however, that there are exceptions to these views, as Table III has purposefully simplified the major differences between substance and process metaphysical frameworks and philosophy of biology for ease of contrast. To begin, the substance view claims that living beings are best explained as a multitude of functional components with fundamental underlying biological mechanisms. In contrast, contemporary process philosophers of biology such as Dupré and Nicholson view processes as having superior explanatory power.

Philosophical System	Argument	Basic	Philosophical view of Nature	Simple localization	Process Owner
Substance (Aristotle)	Substance has primacy over process. Substance explains biology.	Matter that causally relates to each other.	Uniform	Matter located in space and time.	Agent
Substance (Mainstream philosophy of biology & Biologists)	Substance has primacy over process. Substance explains biology.	Living things made up of parts, i.e., macromolecules. Parts predictably interact.	Mechanistic	Biological identity located in space and time, i.e., genetic identifier.	Agent
Process (Whitehead)	Processes underly everything there is in the unverse. Objects in nature are abstracted from experience/events.	Actual entities (events). Relations between events required.	Rejects the Bifurcation of Nature & Mechanism. Nature is processional not static or uniform. Approach for process relations detailed.	Rejects notion of isolated discrete localized matter.	No owner
Process (Philosophers of biology that advocate process - Dupre and Nicholson)	For living things process has primacy over substance. Process explains biology.	Processes. Simple process categorization.	Mechanism has less explanatory power than process. Relations between processes observed as important and not explained.	Boundaries of one organism to the next is often fuzzy.	Unclear

Table III

Next, it should be noted that Whitehead's process metaphysics and Dupré and Nicholson's process metaphysics are different in scope. Whitehead's philosophy of organism is intended to be relevant to the science of the quantum world as well as making sense of the macro world we observe in nature, including living beings through the science of biology. Additionally, his project's scope relates to what underlies everything in the universe, including living beings as well as the planets and stars. On the other hand, as reviewed in section 3.1, the scope of Dupré and Nicholson's process philosophy is constrained to living beings. In spite of this difference, there is some overlap and alignment between Whitehead's philosophy of organism and Dupré and Nicholson's process philosophical views.

4.3.2 Comparison between Whitehead and Dupré and Nicholson frameworks.

To recap what was covered in section 3.1, Dupré and Nicholson make the following claims regarding the applicability of process to living beings:

i. Living beings are not made up of 'substantial particles'.
ii. Living beings comprise 'processes' and are "dynamic through and through".
iii. There is a hierarchy of processes, stabilised at different timescales.
iv. Processes in this hierarchy include processes of various sizes, intensities and magnitudes, and support the conditions for objects to persist.
v. The fact that an entity exhibits stability over time does not entail that it is a substance, as processes can present like this.
vi. If there are substances, they are likely processes that exhibit stability over time. (Nicholson and Dupré, 2018, p. 3-5)

It is important to note that a significant portion of their process philosophy is dedicated to the concept of 'hierarchy of processes', which they explain is to view dynamic processes of different sizes moving in and out of priority in a complex web of interactions and integrations. However, upon review of their work, it is unclear how they propose this hierarchy of processes works. They observe that process hierarchies and process-to-process interactions exist, but do not explain how these interactions are supposed to happen. This point will be expanded upon in section 4.3.3 to better understand why addressing this gap might strengthen their process theories.

To further the analysis, Table IV below compares the qualities of processes that Dupré and Nicholson discuss with those qualities examined in section 1.1. The arrows map qualities that Dupré and Nicholson view as important with those identified in Table I. To recap, the process qualities in Table I are generally accepted by various process philosophers, including prominent mainstream process philosophers Nicholas Rescher and George Lucas (Rescher, 2000; Lucas, 1989).

As expected, there are many one-to-one mappings. However, some of the qualities generally accepted by process philosophers don't have counterparts in Dupré and Nicholson's framework, such as creativity, novelty and the method of becoming. The quality of process relatedness is mapped with a dotted line to reflect Dupré and Nicholson's observation that "Many processes exhibit activities that are causally interconnected." (Nicholson and Dupré, 2018, p. 13). The rationale for the dotted line is that this statement only notes that this connection exists and that, similar to the statement pertaining to the 'hierarchy of processes', it is not clear what their proposed method or approach is regarding how process-to-process relations and interconnectedness work. This does not refute Dupré and Nicholson's work. Rather, it suggests that their work regarding process relatedness is incomplete. Whitehead saw the need to describe both a method of relating processes to processes, and how new processes are created. Again, this gap and its implications will be examined next.

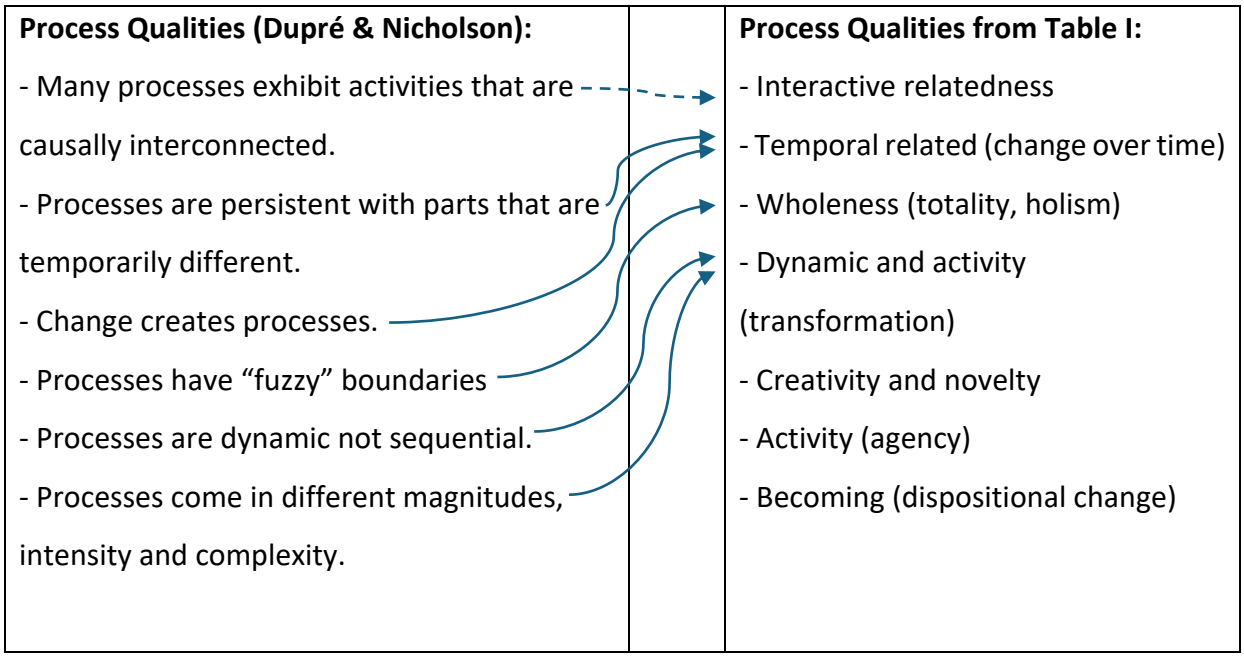

Table IV

In contrast to Dupré and Nicholson, Whitehead has a detailed explanation in his proposed system to address all of the process qualities depicted in Table I. To see this, Table V shows that Whitehead's philosophy of organism fills the identified gaps in the process philosophy of Dupré and Nicholson. With the exception of 'relating', the implications of the other identified gaps will

not be fully examined, as they cannot fit within the confines of this thesis. For reference, a description of Table I qualities is contained in Chapter 1, and how Whitehead addressed qualities such as creativity is contained in Chapter 2.

Process Category / Philosophical System	Interactive Relatedness & Order (processs to process relations)	Temporal Related (change over time)	Wholeness (totality and holism)	Dynamic and Activity (transformation)	Creativity and Novelty	Becoming (dispositional change)
Process - (Whitehead)	Yes	Yes	Yes	Yes	Yes	Yes
Process - Conteporary philosophers of biology that are or may be process philosophers (Dupre and Nicholson)	No	Yes	Yes	Yes	No	No

Table V

4.3.3 The implications for any process philosophy for biology that does not accommodate an approach for process-to-process relations.

As we examined in section 3.1 and again in section 4.3.2, Dupré and Nicholson have identified that processes are most probably hierarchical and interconnected in some manner. Furthermore, they point out that processes come in different magnitudes, intensities and complexity, and they can also be causally dependent on each other. As reviewed in section 3.2, Seibt extends this idea by proposing the use of 'general process theory' (GPT). Seibt's contribution is that a complete process metaphysics requires a method to understand how process hierarchy and interactions can be observed and categorised. Seibt's work is aligned with Whitehead's level of specificity and need for categorical description regarding process relations, although Whitehead did take the further step of explaining how processes might interact to create new processes. As discussed in Chapter 3, Dupré, Nicholson and Seibt have not provided us with a method and catalyst for how process-to-process relations take place. This is a subtle but pivotal concept. For Whitehead, it was not enough to see that processes in nature and biology appear to interact. He went further to provide an explanation as to why and how processes interact through his 'theory of occasions' and 'concrescence'.

As identified in section 2.3.1 and specifically the method of becoming, relating and order in sections 2.3.3 and 2.3.4, Whitehead took significant care to outline a process metaphysics that accounts for how processes relate to each other and how they interact to become new processes. This incorporates how processes come into being with novelty and creativity over time through a procedure of dispositional change. Whitehead observed that processes cannot underlie everything in an ordered manner if there is no system by which they can relate with other processes, including those in the past, present and future. Dupré and Nicholson's discussion of a multitude of processes with various sizes, intensities, magnitudes, and complexity that sometimes causally interact, without a method for how they might interact, is incomplete.

In summary, Whitehead's observation is that any process theory for biology should account for an approach to process-to-process relations. In his view the absence of this approach for ordered process relations, in any process philosophy, makes it difficult to account for why the universe is not disordered or composed entirely of random processes. Again, this thesis is not suggesting that Whitehead's method for this is correct. Rather, the claim is that he proposes a comprehensive process metaphysics that, in my view, should be considered by contemporary process philosophers of biology in the development of their theories. Even if philosophers don't agree with his views, they should see his thoroughness as a template to demonstrate what is required for a fully complete metaphysics of process. Seibt has paved the way using global process theory (GPT) to be more specific about the different categories of process-to-process relations. Further work is required to better understand the potential of GPT applied to philosophy of biology. For process to be a viable alternative to substance for the philosophy of biology, it cannot be incomplete. As such, it is important that further work is conducted, following the path that Whitehead laid before us to better understand the applicability of process ontology for philosophy of biology.

References

1. Agar, W. E., (1936), Whitehead's Philosophy of Organism an Introduction for Biologists, *The Quarterly Review of Biology*, Vol. 11, No. 1, pp. 16-34, University of Chicago Press

2. Anjum, R. and Mumford, S., (2018), Dispositionalism : A dynamic theory of causation, in Daniel J. Nicholson, and John Dupré (eds), *Everything Flows: Towards a Processual Philosophy of Biology*, Oxford Press

3. Anscombe, G. E. M., (1958), On Brute facts*, Analysis*. 18 (3): 69–72

4. Aquinas, Thomas., (~1265/1273), *Summa Theologiae*, Translated. Alfred J. Freddoso, (2023), ret. Dec, 2024, URL = <www3.nd.edu/~afreddos/summa-translation/TOC.htm>.

5. Barnes, J. and Dupré, J., (2008), *Genomes and What to Make of Them*. Chicago: Chicago University Press

6. Bechtel, W., (2016), Mechanists Must be Holists Too! Perspectives from Circadian Biology, *Journal of the History of Biology*, 49(4), 705–731

7. Bechtel, W., & Abrahamsen, A., (2005), Explanation: a mechanist alternative, *Studies in History and Philosophy of Biol & Biomed Sci*, 36(2), 421–441

8. Bechtel, W., & Richardson, R. C., (1993), Discovering complexity: Decomposition and localization as strategies in scientific research. Princeton, NJ: Princeton University Press.

9. Bechtel, W., & Abrahamsen, A., (2011),'Complex Biological Mechanisms: Cyclic, Oscillatory, and Autonomous', Philosophy of Complex Systems, Handbook of the Philosophy of Science, Ed. Hooker, Cliff, North Holland, pp. 257-285

10. Bechtel, W., & Richardson, R., (1993), *Discovering complexity*, Princeton, Princeton University Press

11. Bergson, Henri., (1911), *Creative Evolution*, tr., Arthur Mitchell, (1998), New York: Dover

12. Bertalanffy, L. von., (1941), Die organismische Auffassung und ihre Auswirkungen, *Biologie,* [The organismic view and its implications, *Biology*],10: 247–58 and 337–45

13. Bickhard, M., (2011), Systems and Process Metaphysics, in C. Hooker (ed.) *Handbook of Philosophy of Science. Philosophy of Complex Systems*, Vol. 10, Amsterdam: Elsevier, 91–104.

14. Birch, C. and Cobb, J. B., (1981), *The Liberation of Life. From the Cell to the Community*, Cambridge: Cambridge University Press.

15. Bird, Alexander., (2007), *Nature's Metaphysics: Laws and Properties*, Oxford: Clarendon Press.

16. Bouchard, Frédéric., (2018), Symbiosis, Transient Biological Individuality, and Evolutionary Processes, in Daniel J. Nicholson, and John Dupré (eds), *Everything Flows: Towards a Processual Philosophy of Biology*, Oxford Press

17. Braeckman, A., (1985), Whitehead and German Idealism, *Process Studies 14*, no. 4 (Winter)

18. Broad, C. D., (1948), Alfred North Whitehead (1861-1947), *Mind*, 57(226), 139–145.

19. Broad, C. D., (1925), *The Mind and Its Place in Nature*, London: Kegan Paul.

20. Broad, C.D., (1923), *Scientific Thought*, London: Kegan Paul.

21. Burnet F. and Fenner F., (1949), *The production of antibodies*, 2nd ed., Melbourne : Macmillan

22. Chakravartty, Anjan., (2007), *A Metaphysics for Scientific Realism: Knowing the Unobservable*, Cambridge: Cambridge University Press.

23. Clarke, B.L., (1992), Logical Construction, Whitehead, God, J. F. Harris (ed.), *Logic, God and Metaphysics,* 131-149, Kluwer Academic Publishers.

24. Cohen, M., Curd, P., and Reeve, C. D., (2016), *Readings in ancient Greek philosophy : from Thales to Aristotle,* ed. Cohen, Curd, Reeve., fifth ed., Indianapolis, Hackett Publishing Co

25. Debaise, Didier, (2017), *Nature as Event: The Lure of the Possible*, Durham: Duke University Press.

26. Descartes, Rene., (1596-1650), *Meditations on First Philosophy*, ed. John Cottingham, 2nd ed., Cambridge, United kingdom ; New York : Cambridge University Press]

27. Johnathan Delafield-Butt, (2008), *'Biology', from the M. Weber, J. Seibt & N. Rescher (Eds.), 'Handbook of Whiteheadian Process Thought'*

28. Delafield-Butt, Jonathan., Koutroufinis, Spyridon A. (ed.), (2014), "Process and Action: Whiteheads Ontological Units and the Perceptuomotor Control Units", *Life and Process: Towards a New Biophilosophy,* Boston: De Gruyter.

29. Dewey, John., (1940), *Time and Its Mysteries*, New York, NY University Press, p. 155

30. DiFrisco, James., (2018), Biological Processes: Criteria of Identity and Persistence, in Daniel J. Nicholson, and John Dupré (eds), *Everything Flows: Towards a Processual Philosophy of Biology*, Oxford Press

31. Diderot, Pensees sur l'interpretation de la Nature (1754), Dream of d'Alembert (1769), Elements of Physiology (c. 1780)

32. Dunker A. K., Uversky V. N., Davidov e. N., A. R. Gillespie, et al., (2001), Intrinsically Disordered Protein, *Journal of Molecular Graphics and Modelling*.

33. Dupré, J., (1993), *The Disorder of Things: Metaphysical Foundations of the Disunity of Science*, Cambridge, MA: Harvard University Press.

34. Dupré, J., (2002), *Humans and Other Animals*, Oxford: Oxford University Press.

35. Dupré, J., (2008), *The Constituents of Life,* Amsterdam: Van Gorcum.

36. Dupré, J., (2010a), It Is Not Possible to Reduce Biological Explanations to Explanations in Chemistry and/or Physics. In J. Ayala and R. Arp (eds), *Contemporary Debates in Philosophy of Biology* (pp. 32–47). Oxford: Wiley Blackwell.

37. Dupré, J. (2012), *Processes of Life: Essays in the Philosophy of Biology*, Oxford: Oxford University Press.

38. Dupre, J., (2017), Metaphysics of Metamorphosis, *Aeon,* ret. Sept. 4th, 2023; URL = <https://aeon.co/essays/science-and-metaphysics-must-work-together-to-answer-lifes-deepest-questions>

39. Dupré, J., (2020), 'Processes within processes: a dynamic account of living beings and its implications for understanding the human individual', *Biological Identity: Perspectives from Metaphysic and the Philosophy of Biology.* Edited by Anne Sophie Meincke and John Dupré, pp.149-166

40. Dupré, J. and Guttinger, S., (2016), Viruses as Living Processes, *Studies in History and Philosophy of Biological and Biomedical Sciences,* 59: 109–16.

41. Dupré, J. and O'Malley, M., (2009),Varieties of Living Things: Life at the Intersection of Lineage and Metabolism, *Philosophy and Theory in Biology* 1: e003.

42. Eastman, T., E.,(2020), *Untying the Gordian Knot: process, reality, and context*, Lexington Books, UK, London

43. Emmet, Dorothy M., (1932), *Whiteheads Philosophy of Organism*, Macmillan & Co, St Martins Street, London,

44. Gilbert, Scott F. and Alfred I. Tauber, 2016, Rethinking Individuality: The Dialectics of the Holobiont, Biology & Philosophy, 31(6): 839–853

45. Godfrey-Smith, Peter., (2003), *Theory and reality : an introduction to the philosophy of science* (1st ed.). Chicago: University of Chicago Press

46. Godfrey-Smith, Peter., (2014), *Philosophy of Biology*. Princeton Foundations of Contemporary Philosophy. Princeton: Princeton University Press.

47. Guttinger, Stephan., (2018), A Process Ontology for Macromolecular Biology, in Daniel J. Nicholson, and John Dupré (eds), *Everything Flows: Towards a Processual Philosophy of Biology*, Oxford Press

48. Gunter, Peter., Koutroufinis, Spyridon A. (ed.), (2014), Quantum Biology: a Live Option, *Life and Process: Towards a New Biophilosophy,* Boston: De Gruyter.

49. Guay, A. and Pradeu, T., (2020), Right out of the box: how to situate metaphysics of science in relation to other metaphysical approaches. *Synthese* 197, 1847–1866

50. Gruszczynski, Rafal., (2022), *MATHEMATICAL METHODS IN REGION-BASED THEORIES OF SPACE: THE CASE OF WHITEHEAD POINTS*, Department of Logic, Nicolaus Copernicus University in Toruń, [Acknowledgements: This research was funded by the National Science Center (Poland), grant number 2020/39/B/HS1/00216 "Logico-philosophical foundations of geometry and topology"]

51. Haldane, J. S., (1917), *Organism and Environment, as Illustrated by the Physiology of Breathing*, New Haven: Yale University Press

52. Haldane, J.S., (1935), *The Philosophy of a Biologist*, Oxford, Clarendon Press

53. Hartshorne, Charles and William L. Reese, (eds.), (1953) [2000], *Philosophers Speak of God*, Amherst, New York: Humanity Books.

54. Hempel, C. G., (1973), Science unlimited, *Annals of the Japan Association for Philosophy of Science* 14, 187-202

55. Howard. R., (2021), Substance, *The Stanford Encyclopedia of Philosophy* (Fall 2021 Edition), Edward N. Zalta (ed.), ret. May, 2023, URL = <https://plato.stanford.edu/archives/fall2021/entries/substance/>.

56. Hume, D., (1999) [1748 1st ed], *An Enquiry concerning Human Understanding*, edited by Tom L. Beauchamp, Oxford/New York: Oxford University Press

57. Hull, D. L., (1976), Are species really individuals? *Syst. Zool*, 25:174-191.

58. Hull, D. L., (1978)., A Matter of Individuality, *Philosophy of Science* 45 (3): 335–60

59. Hull, D. L., (1965), The Effects of Essentialism on Taxonomy: Two Thousand Years of Stasis, *British Journal of Philosophy of Science* 15: 314–26 and 16: 1–18

60. Hull, D. L., (1976), Are Species Really Individuals?, *Systematic Zoology* 25: 174–91.

61. James, William., (1912), "A World of Pure Experience", *Essays of Radical Empiricism*, New York, Longmans Green, p. 54

62. Kim, Jaegwon., (1999), Making Sense of Emergence, *Philosophical Studies*, 95: 3–36

63. Kuhn, Thomas., (1962), *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press (1970, 2nd edition, with postscript)

64. Koutroufinis, Spyridon A. (ed.), (2014), *Life and Process: Towards a New Biophilosophy*, Boston: De Gruyter.

65. Ladyman, James, and Don Ross, (2007), *Every Thing Must Go: Metaphysics Naturalized*, Oxford: Oxford University Press.

66. Leibniz, Gottfried Wilhelm., (1714), *The Monadology, translation*, Robert Latta, (1898), Oxford : Clarendon Press

67. Levin, R., (1970), Complex systems, In C H Waddington (ed.), *Towards a Theoretical Biology*, vol.3, Aldine, Chicago, 73-88

68. Levins, R. and Lewontin, R., (1985), *The Dialectical Biologist*. Cambridge, MA: Harvard

69. Locke, John., (1690), *An Essay concerning Human Understanding* (London: Penguin Books, 1997), book 2, Chpt. 8, pp. 135

70. Lucas, George. R., (1989), *The Rehabilitation of Whitehead: An Analytical and Historical Arsenal of Process Philosophy*, Albany, NY: SUNY Press

71. Meincke, Anne Sophie., (2018), Persons as Biological Processes: A Bio-Processual Way Out of the Personal Identity Dilemma, in Daniel J. Nicholson, and John Dupré (eds), *Everything Flows: Towards a Processual Philosophy of Biology* , Oxford Press

72. Moreno, A., Ruiz-Mirazo, K. and Barandianran, X., (2011)., The impact of the paradigm of complexity on the foundational frameworks of Biology and Cognitive science, *Philosophy of Complex Systems, Handbook of the Philosophy of Science,* Ed. Hooker, Cliff, North Holland, pp.311-333

73. Muraca, Barbara., Koutroufinis, Spyridon A. (ed.), (2014)., Teleology and the Life Sciences, *Life and Process: Towards a New Biophilosophy*, Boston: De Gruyter.

74. Mumford, Stephen, and Matthew Tugby, eds, (2013), Metaphysics and Science, *Mind Association Occasional Series,* Oxford: Oxford University Press.

75. Nagel, T., (1971), Brain Bisection and the Unity of Consciousness, *Synthèse*, 22: 396–413

76. Newton, Isaac,. (1999) [1687] *Philosophiae Naturalis Principia Mathematica* ("*Mathematical Principles of Natural Philosophy*"), London, 1687; Cambridge, 1713; London, 1726. *The Principia: Mathematical Principles of Natural Philosophy: A New Translation*, tr. I. B. Cohen and Anne Whitman, preceded by "A Guide to Newton's *Principia*" by I. B. Cohen, Berkeley: University of California Press, (1999)

77. Nicholson, Daniel J. and Dupre, John., (2018)., A Manifesto for a Processual Philosophy of Biology, in J. Dupré and D. Nicholson (eds.), *Everything Flows: Towards a Processual Philosophy of Biology*, First Edition, Oxford: Oxford University Press

78. Nicholson, Daniel. J., (2013), Organisms are not machines, *Philosophy of Biological and Biomedical Sciences* 43: 152–63.

79. Nicholson, Daniel. J., (2014), The Machine Conception of the Organism in Development and Evolution, *Studies in History and Philosophy of Biological and Biomedical Sciences*, 44: 669–78.

80. Parfit, D., 1971, 'Personal Identity', *Philosophical Review*, 80: 3–27

81. Pepper, S., (1938), *Aesthetic Quality*, New York: C. Scribners, p.71

82. Plotinus., (tr. 2018), *The Enneads*, Translated (2018) Gerson, Lloyd P., et al., UK : Cambridge University Press

83. Powell, A. and Dupré, J., (2009), From Molecules to Systems: The Importance of Looking Both Ways, *Studies in History and Philosophy of Biological and Biomedical Sciences* 40: 54–64.

84. Pradeu, Thomas and Edgardo D. Carosella, (2006a), The Self Model and the Conception of Biological Identity in Immunology, *Biology and Philosophy*, 21(2): 235–252

85. Pradeu, Thomas, 2012, *The Limits of the Self. Immunology and Biological Identity*, New York: Oxford University Press.

86. Pradeu, Thomas, 2016, Organisms or Biological Individuals? Combining Physiological and Evolutionary Individuality, *Biology & Philosophy*, 31(6): 797–817

87. Pradeu, Thomas, 2018, Genidentity and Biological Processes, in J. Dupré and D. Nicholson (eds.), *Everything Flows: Towards a Processual Philosophy of Biology*, First Edition, Oxford: Oxford University Press, p. 96–112

88. Rescher, Nicholas., (2000), *Process Philosophy : A Survey of Basic Issues*, University of Pittsburgh Press

89. Rescher, Nicholas., (1996), *Process Metaphysics : An Introduction to Process Philosophy*, State University of New York Press.

90. Russell, E. S., (1930), *The Interpretation of Development and Heredity: A Study in Biological Method.*, Oxford: Clarendon Press

91. Russell, E. S, (1916), *Form and Function: A Contribution to the History of Animal Morphology*, London: John Murray.

92. Russell, B., (1929), *Our Knowledge of the External World*, (New York: The New American Library, 1960), p. v.

93. Russell, B., (1919), *Introduction to Mathematical Philosophy*, London: Routledge

94. Russell, B., (1918), *On Scientific Method in Philosophy*, Herbert Spencer lecture delivered at Oxford Nov 18 1914 and published by the Clarendon Press as a pamphlet the same year, Repr. in *Mysticism and Logic and Other Essays*, London, Longmans, Green, and Co., pp. 33-25

95. Seibt, J., (2018)., 'Ontological Tools for the Process Turn in Biology: Some Basic Notions of General Process Theory', in J. Dupré and D. Nicholson (eds.), *Everything Flows: Towards a Processual Philosophy of Biology*, Oxford: Oxford University Press

96. Seibt, Johanna., (2024), Process Philosophy, *The Stanford Encyclopedia of Philosophy* (Spring 2024 Edition), Edward N. Zalta & Uri Nodelman (eds.), ret. March. 2024, URL = <https://plato.stanford.edu/archives/spr2024/entries/process-philosophy/>.

97. Seibt, J., (1996), The Myth of Substance and the Fallacy of Misplaced Concreteness. *Acta Analytica* 15: 119–39.

98. Sherburn, D. W. (ed), (1965). *A Key to Whitehead's Process and Reality*. New York: Macmillan, pp 224-225

99. Shoemaker, S., 1970, Persons and Their Pasts, *American Philosophical Quarterly*, 7: 269–285.

100. Spinoza, Benedictus, (1985, 2016) *The Collected Writings of Spinoza*, 2 vols., Edwin Curley, translator (Princeton: Princeton University Press, vol. 1: 1985; vol. 2: 2016). The *Ethics* is in vol. 1; the *Theological Political Treatise* is in vol. 2.

101. Stein, R. L., (2004)., Towards a Process Philosophy of Chemistry. *HYLE: International Journal for Philosophy of Chemistry* 10: 5–22.

102. Strawson P.F., (1959), *Individuals: An Essay in Descriptive Metaphysics*, London, Methuen

103. Turner, J. S. (2000), Architecture and morphogenesis in the mound of Macrotermes michaelseni (Sjöstedt) (Isoptera: Termitidae, Macrotermitinae), in *northern Namibia*. 16: 143-175.

104. Turner, J. S., (2002), *The Extended Organism: The Physiology of Animal-Built Structures*, Harvard University Press.

105. Wimsat, W., (1972). Complexity and Organization, *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association,* Vol. 1972, pp. 67-86

106. Wimsat, W., (2000)., Emergence as Non-Aggregativity and the Biases, *Foundations of Science* 5: 269–297

107. Whitehead, A.N., (1905), On Mathematical Concepts of the Material World, *Alfred North Whitehead: An Anthology,* 008. F. S. C. Northrop and Mason W. Gross (New York: Macmillan, 1961.

108. Whitehead, A. N., (1910, 1912, 1913) (with Bertrand Russell), *Principia Mathematica*, 3 volumes, Cambridge: Cambridge University Press.

109. Whitehead, A.N., (1919)., *An Enquiry Concerning the Principles of Natural Knowledge* (Cambridge: Cambridge University Press).

110. Whitehead, A. N., (1920) [1964], *The concept of nature : The Tarner lectures delivered in Trinity College November,* (1st pbk. ed)., Cambridge University Press

111. Whitehead, A. N., (1922), *The Principle of Relativity*, London: Cambridge University Press

112. Whitehead, A. N., (1929), *Science and the modern world*, Cambridge University Press

113. Whitehead, A. N., (1929) [1985], *Process and Reality*, (Gifford Lectures 1927–28), New York: Macmillan. Corrected edition, David Ray Griffin & Donald W. Sherburne (eds.), New York: The Free Press, 1985.

114. Whitehead, A. N., (1933), *Adventures of Ideas*. Cambridge University Press

115. Whitehead, A. N., (1934) [2011], *Nature and Life*, Chicago: University of Chicago Press. Reprinted Cambridge: Cambridge University Press, 2011.

116. Whitehead, A.N., (1948), Analysis of Meaning, *Science and Philosophy* (New York: The Wisdom Library), p. 140.

117. Woodger, J. H., (1929), *Biological Principles*, London, pp. 268-272

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