A Computational Theory of World: Mind in Leibnizian Metaphysics

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Bachelor of Arts in Philosophy with Honours

STATEMENT OF PRESENTATION

The thesis is presented for the Honours degree of Bachelor of Arts in Philosophy at Murdoch University.

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I declare that this thesis is my own account of my research and contains, as its main content, work that has not previously been submitted for a degree at any tertiary educational institutions, including Murdoch.

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ABSTRACT

Computational theory of mind (CTM) is a dominant model found in much of the cognitive sciences and neuroscience, with the working assumption that most or all of mental phenomena can be reduced to computation. While this has demonstrated to be an effective working model within such disciplines, there are fundamental philosophical issues with this standard theory. By using a hybrid approach of Leibnizian Metaphysics as the ground on which to develop the emerging field of a computational Metaphysics, we can begin to reconcile this disciplinary gap and grant those fields the epistemic purchase that their assumptions are currently lacking. I will present first the primary concepts of CTM, and the problems which arise from this standard model in terms of understanding the nature of consciousness itself. By then backtracking into Leibniz's Monadology, I will explore the rational foundation of his peculiar computational metaphysics that form his conception of the nature of 'substance'. This will serve as a useful platform to explore the emerging fields of Computational Metaphysics, in which a number of recent theorists are proposing a paradigm shift away from the "myth of matter" to an informational model which seeks to account for physical structures of matter and motion in terms of computation. By combining these theories with Leibnizian metaphysics, in which perception and consciousness are not just explained but are intrinsic to his system, I propose a new, hybrid approach to computational theory of mind which is neither reductive to physical brain states and which accounts for the lived experience of consciousness.

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Introduction

It is the aim of this thesis to outline and explore the various theories of computational metaphysics using a Leibnizian conception of 'substance' in order to provide a metaphysical framework through which to account for human consciousness. The success of computational theory of mind outside of the discipline of philosophy, in the neurosciences and cognitive sciences, leads me to rethink the notion of consciousness. Standard computational theory of mind, which typically adheres to the tenets of physicalism, presents a challenge to explain the role of semantics and the lived experience of human consciousness arising from unthinking, mechanical processes. By explaining mental phenomena solely in terms of the operations of brain structures and chemical and electrical systems, we situate our understanding of mind into a materialist conception of the world. This is problematic given that our classical, Newtonian, physical picture of the world is devoid of any account for mental phenomena or the idea of the conscious observer.

However, in recent years developments in theoretical physics, particularly quantum physics, have undermined materialist assumptions about the natural world. As such, our understanding of physical systems is changing. One of the emerging paradigms to explain physical phenomena in terms of information and computation, as opposed to the traditional matter and energy model, is distinctly reminiscent of Leibniz's peculiar metaphysical scheme. Leibniz's *Monadology*, in particular, provides us with a rationalist exploration of the notion of substance. His ideas about the nature of simple substances, monads, as "incorporeal automata"[1] give us perhaps the first account of the world as being ultimately constituted by computational processes. Adhering to the Aristotelian notion of 'substance',

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[1] G W Leibniz. *GW Leibniz's Monadology: an edition for students*. Ed. and commentary by Nicholas Rescher. Published by University of Pittsburgh. 1991/1714. §18. p.19

Leibniz’s monads are ontologically independent; their existence depends on no other thing than themselves. Using this notion, Leibniz conceived of a metaphysical system in which there are an infinite plurality of these monads, all of which are not only self-sufficient, but which contain within themselves all attributes which might be predicated of them; past, present and future. One of the core notions is that these substantial entities are necessarily incorporeal, without parts nor shape nor dimension, as any material conception of them would result in a dependency of such parts, thus undermining their ontological independence. As such, Leibniz denies them any physical interaction; the relationships between monads are *ideal*, they occur in perfect, mutual conformity with all other monads but are, themselves, the sole source for their internal states. These internal states contain within them their complex, coordinated relations to all other monads, which Leibniz called perception. The changes of these internal states are driven by what Leibniz called appetition, the algorithm contained within any given monad which determines the unfolding of its states. These two concepts, perception and appetition, are crucial for the development of computational metaphysics. And many current informational interpretations of Leibniz’s original text seek to understand these two features of monads, respectively, in terms of information and computation.

One of the problems with computational metaphysics is that there is not, yet, a comprehensive, universally accepted account. As a proposed model for a paradigm shift, it is still a project that is in development by many theorists, not just in philosophy but in physics also. However, I believe that there is potential in exploring these ideas that may better account for the emergence of both life and mind from seemingly unthinking, mechanical processes.

While there are many divergent theories, there are some commonalities between them that warrant exploration. While not all directly credit Leibniz, the ideas put forward reveal a strong resemblance to his metaphysics. All of these theories accept the metaphysical position that the appearance of the processes of physical phenomena are, at their most fundamental level, the expressions of dynamics of information and computation. The term *information*, in this sense, is to be understood as the underlying mathematical geometric relations and qualitative properties of all the constituents of the physical world. The support for this model cannot be proven through empirical evidence, since all investigations into physical phenomena occur in the phenomenal world. Rather, it relies on the efficiency of mathematical and computational models that are already being used to explain the physical world, and then extends those ideas to say that the ultimate nature of reality is computational.

Most of my analysis will be focused not just on Leibniz's original text, but on two theorists in particular that heavily rely on an informational and computational interpretation of the *Monadology*. Steinhart and Uchii advocate what they call "computational monadology" which draws from Leibniz's concept of monads as the ultimate constituents of the physical, natural world. While they do provide differing interpretations, they stay true to most of the core principles of Leibniz's scheme. Their accounts not only provide a current analysis of Leibnizian notion of substance in view of theoretical developments in physics, but also seek to explore the nature of space, time, motion and matter within a computational model of the world. In doing so, they also work to close the explanatory gap between living and non-living systems, and situate consciousness in relation to their corresponding physical bodies.

By exploring these ideas I hope to provide a new account of computational theory of mind which is not reductive to physical brain states and the mechanics of matter. But rather that mental states are product the computational operations of soul-endowed monadic aggregates. As both mental and physical phenomena are explained as the expression of complex, coordinated and unified monadic relations, the computational processes which produce mental states and events are not derived from non-living, mechanical systems. This is a metaphysical scheme which contains, in its most fundamental units, differing degrees of mental-like qualities, from which the properties of consciousness can emerge. In doing so, I hope to bridge the disciplinary gap between philosophy and the cognitive sciences, and provide the epistemic grounds on which a new computational theory of mind can develop.

Computational Theory of Mind: A Brief introduction into its Strengths and Limits

Computational theory of mind (or CTM) is a dominant model found in much of the fields of cognitive science and neuroscience, with the working assumption that most, if not all, mental phenomena can be reduced to computation. Whilst there are many divergent and competing theses that use a computational model in an attempt to understand mental phenomena, there are some commonalities that fall under this, admittedly broad, understanding of CTM.

These accounts typically adhere to a materialist doctrine, which then reduce all mental events to the physical, computational processes of the brain, drawing on the analogy of the human brain as a computer, or the physical hardware for consciousness. That is, the phenomena of mental events can be reduced to and described in both mechanical terms, such as the structures of the human brain; and in computational language, such as the information-processing capabilities and the manipulation of symbolic representations in the mind. Classical CTM is a variant of RTM (representational theory of mind), in which the symbolic representations have both semantic and syntactic properties[2]. This thesis has its roots in the works of Alan Turing who hypothesized his Turing Machine, which begins with its initial state, takes input in the form of symbols on a tape and then, through a specific set of rules or instructions, generates its output in the form of another symbol on the tape, leading to the TM's next state[3]. This led some to equate the syntactic rules

[2] Steven Horst, "The Computational Theory of Mind" in *The Stanford Encyclopedia of Philosophy. Ed. Edward Zalta. 2011.* §1

[3] Bijoy Boruah, "Computation and Cognition: Through the Philosophical Lense" 2006. p.72

followed by humans to the instructions stored on a computer, and the process of applying these rules to the computer's process of executing its instructions.

Central to understanding CTM is formalization, the notion of "formal symbol manipulation", which arose from the works of mathematicians in the late 19th and early 20th centuries to ground reasoning in rules and axioms with non-semantic properties. Computation is the process by which symbols can be encoded with semantic properties, allowing for inferences based solely on manipulations of those symbols in a manner that is receptive only to their syntactic properties[4]. The TM demonstrated that any operation that was sensitive to syntax, or non-semantic properties, could be simulated mechanically, as blind, rote computation. CTM also accounted for features of language such as systematicity and productivity. Systematicity is simply that a person who can understand the sentence "the dog chased the cat" will then also be able to understand the sentence "the cat chased the dog". And productivity refers to the ability that, in mastering language, we are able to form an infinite number of thoughts from a finite set of syntactic rules and (what Chomsky called) "lexical primitives"[5].

The notion of computability began to take hold in the area of philosophy of mind to account for human reasoning, in particular, propositional attitudes. Jerry Fodor linked this classical CTM to his LOTH (language of thought hypothesis), where he saw cognitive representations in the mind as 'tokens'; and propositional attitudes as the relations between the cognitive agent, the human being, to those tokens[6]. The neuroscientist David Marr used a computational approach to human vision using a hierarchy of three explanatory levels. At the highest level is the computational level, where the task specified by the system is

[4] Steven Horst, 2011, §1.1
[5] Steven Horst, 2011, §2.3
[6] Steven Horst, 2011, §2.2

performed. An intermediary level, where the system employs an algorithm, which is how the task is performed. And the lowest level, which involves the implementation of a function by the 'hardware' of a system; in this case it is the human brain.

While this has demonstrated to be an effective working model within the disciplines of the cognitive sciences and neuroscience, there are fundamental philosophical issues with this standard model. The most well-known objections raised against computational theory of mind are Searle's Chinese Room thought experiment and the theory's failure to adequately account for human intentionality and semantics[7]. The Chinese Room thought experiment is presented thusly:

A human person takes on the role of a 'machine' in this scenario. They are locked inside a room with no communication to the outside world except through Chinese symbols, a language the person does not understand. Guided by a rulebook, which tells the person what symbols to write in response to those given, their task is to produce appropriate response, in Chinese symbols, to those symbols that they receive[8].

In this scenario the person may produce meaningful sentences but lacks what we would call any understanding of those sentences. This scenario is designed to mimic the conditions of a digital computer, which can receive symbolic input and generate symbolic output based on its specific set of instructions. The crux of Searle's thought experiment is that one could, through blind rote processes, perfectly simulate human communication in a manner in which lacks any genuine understanding. This thought experiment can be applied to the notion of mental processes being described purely in computational terms; descriptions of the rules or algorithms governing mental processes strictly as syntactical relations cannot account for the crucial role of semantics in lived human experience.

[7] Steven Horst, 2011, §3.4
[8] Steven Horst, 2011, §3.4

While there are significant problems with whether or not standard computational theory of mind can be sustained as a legitimate philosophical position, the benefits of the working model can be demonstrated outside the philosophical domain in the cognitive sciences. Rather than discarding computational theory of mind entirely, I propose a new, hybrid approach to computational theory of mind which is not reductive to physical brain states and which accounts for the lived experience of human consciousness. Rather, this thesis is intended to provide a metaphysical scheme in which a computational understanding of the mind is embedded in the fundamental units of the universe, as a *cosmic computer*. This approach combines the works of Leibniz, in particular his Monadology, and the works of theorists in the emerging field of digital philosophy, to explore the position of computational metaphysics and what consequences this view might have on how we understand the human mind.

The Monadology: The Original Computational Metaphysics

Whilst Leibniz's *Monadology* is not a complete account of his theory of metaphysics it does outline his theory of simple substances and how it fits into his broader metaphysical scheme. For Leibniz, as with his other17th century rational philosophers, the concept of 'substance' is not just crucial to understanding his metaphysics, but is the ground on which his theory is built. The earlier sections of the *Monadology* provide us with a basic overview of the nature of his *simple substances*.

In keeping with other rational philosophers, like Descartes and Spinoza, Leibniz begins with a definition of substance as something which has independent existence. In order for a substance to be as it is, as an ultimate constituent of reality, it must depend on no other thing, except God, for its own existence. This leads directly to the first section of Leibniz's Monadology; in that a simple substance must have no *parts*[9]. Leibniz's metaphysics is diametrically opposed to atomism and other materialist positions, since for a substance to be an ultimate constituent, it must be indivisible, lacking parts, otherwise it would be dependent on those parts for its own existence[10]. Leibniz's issue with atomism here is that he believed all matter, all extended things, in nature are infinitely divisible. Simple substances have their simplicity in that they lack physical components in their make-up, they are quantitatively simple, incorporeal substances. Because simple substances lack parts, they also lack extension; as "true atoms" of nature they have neither shape nor figure, they are immaterial[11]. Unlike any materialist doctrine, Leibniz conceived of the basic, underlying reality for all things which exist as bodiless and incorporeal in nature; that all physical things in the world, all matter and physical processes, are simply the expression

[9] Nicholas Rescher, "G. W. Leibniz's Monadology: An Edition for Students". Published by Pittsburgh University Press. 1991 p.45
[10] Nicholas Rescher, 1991 p.46
[11] G W Leibniz, 1714, §3, p.17

of the basic ‘nature’ contained in these simple substances[12]. This leads us to understand that there are two levels of nature; the micro-level of individual simple substances, or *monads*, and the macro-level of composite matter, the world that we experience, which derives its reality solely from these simple substances[13].

Leibniz determined that while monads, as the most fundamental constituents of reality, are quantitatively simple they must also be qualitatively *complex*. According to the late Aristotelian tradition, a substance is defined as the subject of predication, which cannot itself be predicated of anything else[14]. Leibniz extended this definition further to form what is known as a ‘complete individual concept’. That is, each individual substance must have a concept so complete so as to contain all of the predicates which may be attributable to it, including those that are not currently expressed at any given moment[15]. This understanding of substances as having a complete concept ties into Leibniz’s statement in section 7 that monads have no ‘windows’. By this he means that, since monads are not material they cannot be physically influenced by any other thing, since physical interaction involves a transmission of *parts*[16]. So while monads are quantitatively simple and without parts, they are qualitatively complex in that they contain within them a complete individual concept, an “inner program”, which determines the unfolding of all of its inner states[17]. Monads have no ‘windows’, nothing external can affect its internal states, because all of a substance’s past, present, and future states are already contained within it as its complete concept[18].

[12] Nicholas Rescher, 1991, p.90
[13] Nicholas Rescher, 1991, p.51
[14] Brandon C. Look, "Gottfried Wilhelm Leibniz", in *The Stanford Encyclopedia of Philosophy.* Ed. Edward N. Zalta. 2014. §4
[15] Nicholas Rescher, 1991, p.61
[16] G W Leibniz, 1714, §7, p.17
[17] Nicholas Rescher, 1991, p.59
[18] Douglas Burnham, “Gottfried Leibniz: Metaphysics” in *The Internet Encyclopedia of Philosophy*. §8.a

Unlike Descartes' dualism, or Spinoza's substance monism, Leibniz postulated an infinite plurality of these simple substances. Section 9 of the *Monadology* demonstrates his Principle of the Identity of Indiscernibles. Simply put, this means that no two substances can be qualitatively identical to one another. A crucial feature of monads that will be discussed later, is that they all represent the entire universe from their own unique point of view[19], no two monads can be completely identical in this respect.

In these early sections Leibniz succinctly expresses a fundamentally different concept of substance than his predecessors. The physical world that we experience is one of 'mere phenomena'; true reality lies in the substances of which the world of extension and space and time are derived from. There is an infinite plurality of simple substances, each indivisible and incorporeal but qualitatively complex, which is contained within each monad's complete individual concept.

A central feature to understanding this inner complexity of simple substances is the notion of change. Following on from the Complete Individual Concept, all states of a monad unfold from its own internal principle, which Leibniz calls 'appetition'[20]. Simple substances, or monads, are not static entities, they are ever-changing in accordance with their internal principle[21]. In section 13, Leibniz writes:

> "*This internal complexity (détail) must enfold a multiplicity in unity or in the simple. For as every natural change happens by degrees, something always changes and something remains. Consequently there must be a plurality of properties and relations within a simple substance, even though it has none of parts.*"[22]

[19] G W Leibniz, 1714, §8, p.17
[20] G W Leibniz, 1714, §11, p18
[21] Nicholas Rescher, 1991, p.67
[22] G W Leibniz, 1714, §13, p.18

Leibniz demonstrates through this section that the simplicity of a monad is only a numerical simplicity, in that every simple substance constitutes a true unit and lacks parts. The internal complexity of a monad, however, is not static, but dynamic. Within each simple substance of its properties and relations to all other things which exist outside of it, and this multiplicity of properties within a substance's complete concept is one which unfolds in a predetermined manner according to the substance's internal program[23].

Physicalism is a doctrine which asserts that all mental states are the same as by physical states and processes, a position which Leibniz was firmly opposed to in the *Monadology*. An essential feature of monads is that they have *perception*, which is the set of determinate relations that any given monad has with all other monads in its proximate environment. These simple substances are endowed with some, limited, form of mentality which represents these complex relations. Leibniz demonstrated the insufficiency of mechanical explanations for perception in section 17 of the *Monadology*.

> "*In imagining that there is a machine whose construction would enable it to think, to sense, and to have perceptions, one could conceive it enlarged while retaining the same proportions, so that one could enter into it, just like a windmill. Supposing this, one should, when visiting within it, find only parts pushing one another, and never anything by which to explain a perception.*"[24]

That is to say that if we were to understand perception and mental processes as the result of physical and mechanical operations, then consciousness itself would not be explained.

[23] Nicholas Rescher, 1991, p.74
[24] G W Leibniz, 1714, §17, p.19

There would be nothing of those parts and motions that could account for the complexity and unity of perceptions, only further motions and parts. It is for this reason that Leibniz asserts that perception, and higher levels of consciousness, must be found within the simple substances themselves and not the composites which they form.

Perception, for Leibniz, is the manner in which a simple substance, or monad, contains within itself a "mirror" of the rest of the universe within its own complete concept, as the representation of the many in the one[25]. Each simple substance's complete individual concept contains all of its relations to all other substances, some of which a substance perceives distinctly, but most of which it perceives only confusedly. Perception and appetition, the tendency to move from one perception towards another perception, are the essence of all simple substances. Appetition, which is the striving towards the next state in a monad, is described as "the action of the internal principle which brings about change"[26]. Since all perception states are determined in all monads at the moment of creation, this appetition then is also predetermined, following teleological law[27]. This internal principle of any given monad is then "programmed into its very nature as the individual it is"[28]. This unfolding of this internal program can then be understood as a monad, through its own internal algorithm, computing its next perceptual state[29].

As Since monads are ever-changing, passing from one perception to another in a continuous way, they must have a genuine substantial unity which unifies the manifold of perceptions contained within it[30]. While each monad contains a multiplicity of perceptions which reflect its complex relations to all other monads, they are all contained within a single substance's complete individual concept, forming a single, unitary *one*. Physical

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[25] Mark Kulstad and Laurence Carlin, "Leibniz's Philosophy of Mind" in *The Stanford Encyclopedia of Philosophy*. Ed. Edward N. Zalta 1997 §4
[26] G W Leibniz, 1991, §15, p.18
[27] Nicholas Rescher, 1991, p,79
[28] Nicholas Rescher, 1991, p.81
[29] Nicholas Rescher, 1991, p.80
[30] Brandon C. Look, 2014, §4.2

bodies, as composites, lack this necessary unity as they are divisible and dependent on parts, and as such are unfit for the role of substance[31]. Sections 13, 14 and 16 of the *Monadology* feature the notion of “multiplicity in unity”. That is to say that the continuously changing internal states, or perceptions, of monads are unified within it under a monad’s predetermined complete individual concept.

While all simple substances have vitality or life-force**,** a degree of soul-like qualities, not all possess consciousness. Indeed, in representing the universe as a whole, even conscious beings like animals and humans mostly experience minute **(***petite*) perceptions. These perceptions lie below the threshold of conscious awareness and, as such, are confused perceptions[32]. An example that Leibniz uses to demonstrate this is the act of consciously perceiving the sound of the ocean. The ‘roar’ of the sea is constituted by an infinite number of minute perceptions, parts which make up the whole, that, individually, are indistinguishable from the overall sound that we are consciously aware of[33]. All of the minute perceptions that would lie below the threshold of conscious awareness combine together to form a confused perception that is the roaring of the sea. However, while all monads are always engaged in perception, not all simple substances are capable of perceiving above this threshold of consciousness.

Leibniz lays out a tripartite hierarchy of simple substances, from that which appears to be inanimate to human beings. At the lowest level are *bare* monads, which are only capable of unconscious perception and which have no memory or awareness. On the next tier are *souls*, which consist of some distinct perceptions and *memory*. Memory, for Leibniz, is the operation of a principle of association[34], something which mimics the capacity for reason but which is not reason. This imitation of reason is carried out by an “automatic processes

[31] Mark Kulstad and Laurence Carlin, 1997, §1
[32] Nicholas Rescher, 1991, p,78
[33] Nicholas Rescher, 1991, p.54
[34] Nicholas Rescher, 1991, p.105

associative of thought-transition", or, in computational terms, computing the next state based on previous state-transitions[35].

Animal sentience, and much of the processes of the human mind, function in this capacity as souls. Distinct perceptions are combined with the capacity for memory to form associations regarding the external world. For example, a dog may see a stick and cower or run away due to the memory of previous distinct perceptions in which the stick is now associated with pain of being struck[36]; or we may expect the sun to rise each morning simply because it has every other morning[37]. On this level, souls are capable of sensations and memory and so possess consciousness.

On the highest level of this tripartite hierarchy are *spirits*, monads which possess not only memory and consciousness, but also self-reflexive awareness and reason[38]. Although much of the functions of human beings operate as would a mere soul, we also possess this higher capacity for self-awareness that Leibniz terms '*apperception*'. It is apperception that allows us to reflect on our inner states and perceptions, to think of the 'I', the multiplicity of perceptions in the single, unitary substance[39]. It is this apperception that allows us to come to know eternal truths through the application of reason and self-reflexive thinking[40]. Only those who possess a spirit monad are capable of mathematics and logic, inductive and deductive reasoning, and so are capable of both science and morality.

It is significant to note here that this hierarchal model is one of difference by degrees, and not by kind. All monads, or simple substances, contain perceptions, the difference between a spirit substance and that of a bare monad is the distinctness and clarity of some of their perceptions, and the accompaniment of the capacity for memory. Even at the highest level,

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[35] Nicholas Rescher, 1991, p.105
[36] G W Leibniz, 1714, §26, p.20
[37] G W Leibniz, 1714, §28, p.20
[38] Nicholas Rescher, 1991, p.92
[39] Mark Kulstad and Laurence Carlin, 1997, §5
[40] G W Leibniz, 1714, §29, p.20

that of spirits, Leibniz takes care to establish that for the majority of our actions, we operate on the basis of memory, on the level of souls. We expect the sun to rise tomorrow because it always has, this association is not grounded in reason but only of experience without theory, only an astronomer or similar scientist would base their assertion that the sun will rise again tomorrow on the basis of higher order reason. Even human beings which have a spirit monad will sometimes experience perceptions on the level of a bare monad, such as in a swoon or dreamless sleep[41]. For Leibniz, perceptions can only come naturally from preceding perceptions, so during such a state it is not the case that we are not perceiving at all, but rather that we are not consciously aware of these perceptions. Leibniz understood all change to be *continuous*, rather than discreet, and so conscious and unconscious mental life must not be completely separate, instead bare perceptions are followed by more distinct perceptions, accompanied by reflexive self-awareness[42]. The difference between bare monads, souls and spirits is not one of a difference in kind, but rather the distinctness of perceptions contained within simple substances.

By establishing the ultimate constituents of reality as being incorporeal, self-sufficient and as reflecting the entire universe in its perceptions, Leibniz set up a rather different metaphysical scheme than his contemporaries. In determining the ontological independence of simple substances in their complete individual concept, Leibniz denied the possibility of inter-substantial causality. The ‘windowless’ nature of monads is grounded in the self-sufficiency of a simple substance for all of its internal states and a refutation of matter as a candidate for substance, since for one thing to effect change in another requires a

[41] G W Leibniz, 1714, §20, p.19
[42] Nicholas Rescher, 1991, p.101

transmission of *parts*[43]. In section 22 of the Monadology, we start to develop a picture of the idea of harmony as regards simple substances in their complete individual concept.

> "*As every present state of a simple substance is a natural consequence of its preceding state, so is its present pregnant with the future.*"[44]

That is to say that each substance's entire history, as contained in its complete concept, is predetermined from the moment of its creation. Since every internal state of a monad is a consequent of its antecedent states, at any moment in the unfolding of a monad's internal nature it contains within it all of its previous states[45]. And just as it contains within its complete concept, a simple substance's present state is 'pregnant' with its future states which come from the unfolding of a monad's internal algorithmic "program" alone[46].

Leibniz developed the notion of "pre-established harmony' to account for the nature of the relations between all simple substances whilst denying causality amongst things. All simple substances are programmed at creation in such a manner that all the unfolding states and actions of individual substances are in conformity with those of every other substance[47]. Section 51 of the *Monadology* asserts that any influence of one monad on another is only ideal in nature, lacking any physical causal relation on a monad's internal activity[48]. Whilst all simple substances are self-sufficient in their complete individual concept, they are created in such a way as to be in accordance with all other simple substances. This mutual coordination of all substances in their expression of their

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[43] Mark Kulstad and Laurence Carlin, 1997, §2
[44] G W Leibniz, 1991, §22, p.19
[45] Nicholas Rescher, 1991, p.98,
[46] Nicholas Rescher, 1991, p.98
[47] Mark Kulstad and Laurence Carlin, 1997, §2
[48] G W Leibniz, 1714, §51, p.23

independent internal states is what constitutes the world of phenomena, of matter, space and time which expresses the *appearance* of causal interaction[49]. Within this system of mutual coordination, it can be said that one monad *acts* on another insofar as it has perfection, or *reacts* to another insofar as it is imperfect[50]. The notion of perfection corresponds to the distinctness, or confusedness, of a monad's perceptions, and so is coordinated with its 'actions'[51]. The more 'perfect' a simple substance is, the more it can be said to exert (an ideal) influence on another substance, or can be said to *act* on another[52]. So within this system of mutual coordination of an infinite plurality of independent substances, predetermined at their creation, one thing can be said to act upon another thing if it contains within its complete individual concept a sufficient reason for some characteristic of another substance[53]. And this mutual coordination of all substances in their unfolding of their inner natures constructs a harmonized whole, that is, the universe in its totality.

In section 56 of the Monadology Leibniz connects this idea of pre-established harmony and the complete individual concept that every substance has in relation to all other substances:

> "*Now this interlinkage or accommodation of all created things to each other, and of each to all the others, brings it about that each simple substance has relations that express all other, and is in consequence a perpetual living mirror of the universe.*"[54]

[49] Nicholas Rescher, 1991, p.179
[50] G W Leibniz, 1714, §49, p,23
[51] Nicholas Rescher, 1991 pp.170-1
[52] G W Leibniz, 1714, §50, p.23
[53] Nicholas Rescher, 1991, pp.170-1
[54] G W Leibniz, 1714, §56, p.24

In order for all substances to operate in perfect mutual coordination with one another, each must contain within their own natures all their relations to all other substances which exist, and so each must reflect the entire universe from its own unique point of view[55]. And so every simple substance perceives the whole universe, however confusedly so, and represents “the many in the one”. Thus all simple substances are systematically interrelated to each other from their own unique point of views in such a way that constructs space and time, in which material things are realized[56]. That is to say that spatial position in the extended world is nothing except the perpetual relations between different monads[57]. As is further elaborated in section 60, Leibniz states that “nothing can restrict a monad to representing only on part of things”[58]. All monads perceive the entire universe and so are omniscient, albeit limited in distinctness. However only those things which are nearest or to which a substance is most extensively related to are perceived distinctly, with the majority of perceptions regarding the detail of the entire universe being confused.

From here Leibniz elaborates on the relationship between the immaterial constituents of nature and the extended world of matter and motion that we experience. The mutual coordination and connectedness of all simple substances occurs not just at the monadic level, but at the level of material composites also[59]. As composites are derivative from the relations between individual simple substances, all matter and motion is interconnected to the universe as a harmonized whole.

[55] Nicholas Rescher, 1991, p.202
[56] Nicholas Rescher, 1991, p.211
[57] Nicholas Rescher, 1991, p.211
[58] G W Leibniz, 1714, §60, p.24
[59] Nicholas Rescher, 1991, p.215

On the matter of the connection between mind and body, in section 62 of the Monadology, Leibniz specifies that all monads represent most distinctly the body to which they are "bound"[60].

> "*And even as this body expresses the whole universe through the connection of all matter in the plenum, so the soul also represents the entire universe in representing this body, which belongs to it in a special way.*"[61]

While monads themselves are immaterial, the expression of complex relations between them form the basis of matter and motion in the extended world of phenomena. And, as such, each monad is associated with a particular body of matter to which it has perceptions of most clearly and distinctly[62]. As such there is a hierarchy of organisms in the phenomenal world parallel to the tripartite hierarchy of simple substances. A 'mere organism' is an integrated aggregate, composed of a plurality of monads and their relations, dominated, or unified, by a monad which has bare perceptions. Animals are organisms which are dominated by a soul, and an 'intelligent creature', such as human beings, are animals dominated by a spirit[63]. In this Leibnizian scheme, all monads are associated with some body of matter, and the physical world is subject to the same coordination and harmony as are simple substances. In section 69 Leibniz states:

> "*Thus nothing is fallow, sterile, or dead in the universe; there is no chaos, no disorder save appearance.*"[64]

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[60] G W Leibniz, 1714, §62, p.25
[61] G W Leibniz, 1714, §62, p.25
[62] G W Leibniz, 1714, §62, p.25
[63] Nicholas Rescher, 1991, p.220
[64] G W Leibniz, 1714, §69, p.26

All extended matter, having its substantial basis in these immaterial simple substances, which contain perceptions of their complex relations to all other things, and whose nature is one of constant flux from one state to another, is thus living and in perfect coordination with everything else in the universe. And while each living body has a dominant monad which unifies it as a whole, so too do each part of an organism[65].

So here we have a picture of the metaphysical ground from which all extended matter derives its substantial reality from. All matter, all phenomena, is the result of complex relations of simple substances, unfolding in perfect, mutual harmony. And as every bit of matter is associated with a plurality of these simple substances, the physical world is as interconnected and harmonious as is found at the monadic level. Each simple substance is a reflection of the universe as a whole, and so all matter and organisms are a “living mirror of the whole universe”[66]. Within this scheme there is no problem regarding mind and body interactions; the ‘soul’ and body follow from their own complete individual concepts in pre-established harmony. It is because of this underlying harmony, predetermined at creation of the world whole, that enables the totality of nature, at both a monadic and phenomenal level, to exist. The world of extension, the world that we experience, is the result of complex underlying processes of an infinite plurality of simple substances whose inner natures reflect the whole. And each of these simple substances contains perceptions and appetitions, soul-like qualities in which all of nature is represented and harmonized in a dynamic manner.

[65] G W Leibniz, 1714, §70, p.26
[66] Nicholas Rescher, 1991, p.220

Computational Metaphysics

Current theories of the space-time world as understood in terms of information and computation are highly varied and underdeveloped compared to atomistic or mechanical models. Theorists come from a range of different disciplines, from philosophy to physics, computer sciences, cognitive sciences and biology. Although there are many differences and some incompatibilities between competing theories there are some commonalities that run through the various theories that deserve some exploration. An outstanding example is that an understanding that all physical processes in the world have their basis in reality in terms of informational structures and computational processes, rather than purely in terms of the operations of physical, mechanical structures. Many theories acknowledge the original works of G. W. Leibniz, and later works by Wolfram, Turing and Fredkin in laying the ground on which they develop a computational understanding of the natural world. In particular, they recognize the role of mathematics not just as a tool for understanding the behaviour of physical systems but as essential to the computational nature of those systems.

1. From matter to Information.

The 17th century saw a transformation occur in the natural sciences to understanding the world in terms of the mechanics of matter and motion[67]. While the science of motion reduced the physical processes of the world to mathematical geometric relations, these operations were framed in a material basis where matter would come to dominate our

[67] Ernan McMullin, "From Matter to Materialism… And (Almost) Back" in *Information and the Nature of Reality: From Physics to Philosophy*. Eds. Paul Davies and Niels Henrik Gregerson. Published by Cambridge Univesity Press. 2010. p.18

understanding of the ultimate constituents of reality[68]. The development of classical Newtonian physics further advanced the theory of atomism and the science of mechanics. The scientific view of the world became one where matter, in the form of atoms as fundamental units, and forces, which act on matter produced all the motion and physical processes in the world[69]. As the natural sciences advanced, ultimately the notion of consciousness disappeared almost entirely from the realm of physics; and the belief that we can understand everything in the universe from an investigation into the operations of matter took precedence[70]. This lead to a materialistic reduction of all things in the world in terms of inert, unthinking, particles and deterministic laws which govern the motions of those material parts[71]. Even attempts to understand mental events have been reduced to such physical laws in neuroscience and cognitive sciences. Those fields which, in an attempt to explicate the phenomena of consciousness, look towards physical structures and chemical processes in the human brain. The belief that by understanding the human brain we can then achieve a full account for mind and consciousness has spread into Western culture even outside the scope of those domains which hold that assumption.

However, recent developments in the field of Quantum physics have threatened the metaphysical assumptions of a materialist framework. Several anomalies arise in quantum mechanics that challenge the Newtonian understanding of matter and energy. At the quantum micro level physical particles themselves, previously thought to be unchanging in nature, can convert to energy or waves, thus removing the ontological division between

[68] Ernan McMullin, 2010, p.18
[69] Philip Clayton, "Unsolves Dilemmas: The Concept of Matter in the History of Philosophy and in Contemporary Physics" in *Information and the Nature of Reality: From Physics to Metaphysics*. Eds. Paul Davies and Niels Henrik Gregerson. 2010. p.38
[70] Philip Clayton, 2010, p.38
[71] Paul Davies and Niels Henrik Gregerson, "Introduction: Does Information Matter?", in *Information and the Nature of Reality: From Physics to Metaphysics*. Eds. Paul Davies and Niels Henrick Gregerson. Published by Cambridge University Press. 2010. p.1

matter and energy[72]. This energy and mass conversion undermines the notion of matter as the sole fundamental unit of reality[73]. In subatomic particles position and motion cannot be determined at the same time. The discovery of the indeterminacy of the behaviour of quantum particles directly poses a problem to the determinism of classical physics, which rely heavily on understanding physical processes in cause and effect relations[74]. But even more strikingly is the role of the observer in quantum mechanics. Classical physics eliminates the necessity for a conscious observer internal to the system being observed for the behaviour of physical systems. If indeed there is an observer of physical phenomena their role is held to be external to that system. However, in quantum physics any single phenomenon being observed can be described in multiple, often incompatible ways. An electron can be described as both a particle and a wave; such descriptions are dependent on the observer of the phenomenon and this observer is intrinsic to the system, not ontologically independent of it[75].

The exclusion of mind and consciousness from our framework of understanding the behaviour of physical phenomena itself is problematic. Some argue that it is incompatible to conceive of a universe governed solely by unthinking, mechanical processes, from which we can expect life and even consciousness to emerge. One theorist begins with the question "can mindless objects obey mathematical laws?" to explore the notion of mindfulness in physical phenomena[76]. From this question there are two choices available. Either physical objects are devoid of mind, thereby eliminating consciousness from the physical world and denying the substantial reality of minds. Or there is a degree of mentality, however limited,

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[72] Philip Clayton, 2010, p.54
[73] Ernan McMullin, 2010, p.23
[74] Philip Clayton, 2010, p 55
[75] Philip Clayton, 2010, p55
[76] P. R. Masam, "Mind and Matter: The Question of Primacy" in *Current Science*. Vol. 79, Issue.3. 2000. p.292

immanent in the physical objects and processes of the universe, which manifests itself as laws of nature[77]. By assuming the second position we can then conceive of a world which is, at its most basic level, ripe for the development of living organisms and rational, mindful, conscious beings.

This undermining of the classical, materialist framework demonstrates that, by excluding consciousness and reducing the entire universe to mechanics of matter and motion, we may have formed an incomplete view of the universe. Instead, some are proposing a shift away from matter and motion, towards an informational model of the universe. That is one in which information is the ultimate constituent of reality, manifested in the laws of physics and one from which matter is derived[78]. This is similar to Leibniz's view, which understands the physical world as the result or expression of mathematical, algorithmic relationships based on underlying informational structures.

2. Paradigm Shift: The Epistemic Value of Computational Metaphysics

In addressing the emerging framework of computational metaphysics, we must first lay down the epistemological foundation by which to account for such a paradigm shift. The failures of the classical mechanic model of the universe in accounting for physical (small scale, quantum mechanical) and mental phenomena, I think can be resolved by adopting a metaphysical framework where information and computation are the fundamental constituents of nature. Much of what is addressed in this section, particularly the consequences of computational metaphysics in understanding mental phenomena, will be

[77] P. R. Masam, 2000, p.292
[78] Paul Davies and Niels Henrik Gregerson, 2010, p.3

expanded on later in this theses, but, for now, it is enough to note how these theories might be of epistemic value to us.

One of the core ideas supporting the thesis of computational metaphysic is the notion of “conceptual economy”, in which simpler theories with comparable explanatory power of more complex theories can be used to explain complex behaviours of physical systems. Digital philosophy in particular, a subset of computational metaphysics, firmly asserts a system where there is a lesser conceptual complexity of a set of ideas which produce a description of the universe as both rich and diverse in phenomena[79]. If computation occurs at the most fundamental level of reality and is what ultimately constitutes the physical world, we have a metaphysical scheme in which simple, computational, algorithmic rules generate the complex, phenomenologically rich and diverse behaviours of physical entities and systems. By including informational structures which are carried through computational dynamics, we construct a picture of the world which not only accounts for the effectiveness of mathematical and computation models in describing physical processes, but we also admit for the phenomena of mind and semantics. In doing so we close the gap of our understanding between inanimate, mechanical, non-living systems with those of living organisms.

One of the key theorists in developing several other arguments for the epistemic value of a computational view of the universe is Gordana Dodig-Crnkovic. Dodig-Crnkovic attempts to lay out not only a development of the notion of a computing universe, but also the ways in which these ideas can be used to fundamentally change the way in which we understand the physical world. Inspired by the work of Galileo in overturning the

[79] Gregory Chaitin, “Epistemology as Information Theory: From Leibniz to Omega”. 2005. p.5

geocentric model with the Copernican worldview, Dodig-Crnkovic, along with Vincent Muller, begin a dialogue contrasting the classical, mechanical understanding of the universe with the new model of information-computationalism.

Gordana Dodig-Crnkovic also raises the most important criticism of the materialist doctrine relevant to this thesis, and that concerns the exclusion of mind and mental phenomena from the broadly mechanical picture of the physical world. Henry Stapp comments on the impact of this view on our picture of mind:

> "*Neither the character of the basic description of the brain, within classical mechanics, nor the character of the classical dynamical laws that supposedly govern the brain, provides any basis for considering the brain correlate of a thought to be, at the fundamental as distinguished from functional level, a single whole entity*."[80]

The argument is that since physical systems within a classical mechanical framework are understood in terms of a collection of material interacting parts, there is then no way to account for the experience of thoughts on the level of a single, unified mind[81]. The only way to account for the human mind in a mechanical universe is then to introduce another conception equivalent to the "ghost in the machine", an appeal to a different type of (mental) phenomena[82]. The problem with this is that it introduces a dualistic notion into classical mechanics, which it fundamentally opposes by describing the world solely in

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[80] Henry P. Stapp, "Why Classical Mechanics Cannot Naturally Accommodate Consciousness But Quantum Mechanics Can". 2008. pp.6-7
[81] Henry P. Stapp, 2008, p.3
[82] Henry P. Stapp, 2008, p.5

terms of physical constituents, matter, and natural physical laws[83]. This necessity for the addition of non-mechanical explanations, which contrast from the main metaphysical and physical understanding of the universe itself, removes the epistemological simplicity of the original doctrine.

One of the strengths of an informational-computational framework is that, within the natural sciences, we already use such a model to describe much of the operations of the physical world with a reasonable degree of accuracy[84]. Even if one were to reject the overall thesis that the universe is in fact a cosmic computer, it's still true that a computational model of the universe is useful as an explanatory tool until a more developed metaphysical and physical framework is discovered[85].

Much like Leibniz, to contrast the classical mechanistic perspective, Dodig-Crnkovic lays down the general principle of the model of the universe as a cosmic computer: the physical world is ultimately constituted by structures of information and dynamics of computation[86]. This is an interactive, dynamic model of the universe in which all physical systems are operating within a context-dependent network, relying on communication with a system's environment[87]. Within this open system model, observers are not external to the system being observed, they are engaging with information processing that operates on all levels throughout the physical world[88]. And within this system, Dodig-Crnkovic argues, we can begin to account for emergent properties that supervene over physical structures; since

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[83] Henry P. Stapp, 2008, p.7
[84] Hector Zenil, "Introducing the Computable Universe: Understanding and Exploring Nature as Computation" in *World Scientific* 2012. p.5
[85] Hector Zenil, 2012, p.5
[86] Gordana Dodig-Crnkovic and Vincent Miller, "A dialogue Concerning Two World Systems: Info-Computationalism vs. Mechanistic" in *Information and Computation*. 2009. p.3
[87] Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3
[88] Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3

the properties of physical entities are no longer solely derived from the properties of their parts but also of the interactive network formed between the parts constituting the whole[89].

Whilst the model laid out in this dialogue is not a complete, comprehensive account of an emerging model of computational metaphysics, the points that Gordana Dodig-Crnkovic lays out directly contribute to what she argues about the epistemic productivity of this scheme. As it is an emerging model, she takes note that it is still in development, but still argues that if we were to pursue such a paradigm shift it would not simply offer a more complete explanatory account for physical processes but might begin to reconcile some of the issues that arise from the contrasted model. The most prominent of these she identifies as the explanatory gap between living and nonliving systems in the world.

Gordana Dodig-Crnkovic believes there is an explanatory gap in in understanding complex, living organisms in terms of lifeless mechanics of matter and motion. Instead she argues for the explanatory power of adopting the information-computationalist framework to unifying the living and nonliving world, accounting not simply for complex biological processes but even for a more comprehensive account of mind[90]. In this she identifies complexity not just as important for the occurrence of much of the physical phenomena, but as an essential characteristic of life[91]. More than just aggregates of inanimate matter, determined by mechanical laws, living organisms are “complex, goal-oriented, autonomous information-processing systems with [the] ability of self-organization, self-reproduction and adaptation”[92].

By understanding computational processes in nature, Dodig-Crnkovic believes that we can understand not just the systems of inquiry in physics, but also biology, sociology,

89 Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3
90 Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3
91 Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3
92 Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3

economics, and other fields where informational complexity is fundamental[93]. Using this framework we can understand the evolutionary process of natural selection as information-processing adapting across generations and DNA as informational instructions for the development of organisms[94]. The DNA "code" in biological organisms is an excellent example of the applicability of this particular framework. Within each cell of an organic body there are a sequence of instructions which govern the way in which the organisms develops. This code determines all of the biological attributes of the organism, it is the "information in a seed"[95]. DNA contains both informational content and the "program", the sequence of instructions, which underlies the physical development and processes within every living body.

But more than just these biological processes we can also understand social dynamics within this unifying framework. That by understanding natural computation as an open system adapting dynamically to its environment, we can examine the self-organized behaviour of groups of organisms in terms of networks of complex information-processing interactions[96]. This extends to the behaviours of small living organisms, like the operations of ant colonies, all the way to complex social relations among human beings.

Gordana Dodig-Crnkovic twice mentions the promises of the framework in explaining life as a "network of information processing structures"[97].

> "*[The] integration of scientific understanding of the phenomena of life (structures, processes) with the rest of natural world helping to achieve "the*

[93] Gordana Dodig-Crnkovic and Vincent Miller, 2009, p.3
[94] Dodig-Crnkovic, 2011, p.311
[95] Edward Fredkin, "An Introduction to Digital Philosophy", in *International Journal of Theoretical Physics*. Vol.42, issue.2. 2003. p.198
[96] Gordana Dodig-Crnkovic, "Significant Models of Computation, From Turing Model to Natural Computation" in *Minds and Machines*. Vol.21. 2011. p.311
[97] Gordana Dodig-Crnkovic and Vincent, p.24

unreasonable effectiveness of mathematics" such as in physics even for complex phenomena like biology that today lack mathematical effectiveness."[98]

In this, she is seeking to unify scientific theory of natural, physical processes with an account for living organisms. There have already been comparisons between the structures and processes of life to such an information-computational framework. In biology, DNA can be understood as a "code of life"[99] where the development of living organisms is determined by the underlying unfolding of algorithms encoded in complex protein structures. Such an approach takes the passing on of genetic traits as an information transfer across generations, containing instructions for biological developments.[100] Dodig-Crnkovic suggests that, even though we have not yet developed a full understanding of these processes due to the complexity of the structures of living organisms, we may eventually be able to achieve the same degree of mathematical effectiveness as we find in other natural sciences, like chemistry and physics. She is not just focusing on how an info-computational model might change our current understanding of life, but in the potential future applications that it might yield.

> "*Of all manifestations of life, mind seems to be information-theoretically and philosophically the most interesting one. Info-computationalism (pancomputationalism + paninformationalism) has a potential to support our effort in learning about mind.*"[101]

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[98] Gordana Dodig-Crnkovic and Vincent, p.9
[99] Hector Zenil, 2012, p.7
[100] Hector Zenil, 2012, p.7
[101] Gordana Dodig-Crnkovic and Vincent Muller, 2009, p.10

For her, both brains and computers are dynamical systems which manipulate symbols, and this symbol manipulation occurs in higher levels of organization in which the symbols represent something significant for a living organism, they function as carriers of meaning[102]. For most living organisms, this response to symbol manipulation is unconscious, it is "built into their genes" for an organism to respond to their meaningful environmental input in such a way as to serve vital functions, such as getting food, avoiding harm and reproducing[103]. As such, meaning is embedded within this interactive model, even when its operations occur below the level of consciousness. Dodig-Crnkovic argues that this inclusion of semantics, through the universe's fundamentally informational structure and the dynamic, interactive networks of any system operating within the world, has the potential to develop a view of semantics of information within a naturalist account.

> "*Understanding the semantics of information as a part of data-information-knowledge-wisdom sequence, in which more and more complex relational structures are created by computational processing of information. An evolutionary naturalist view of semantics of information in living organisms is based on interaction (information exchange) of an organism with its environment*."[104]

If life is to be understood as a network of information processing structures, then any account of the human mind or consciousness does not need to make an explanatory leap. Cognitive agents in the world like human beings are not mechanically determined by natural laws of cause and effect, they are adaptive, learning, anticipative beings engaged in

[102]Gordana Dodig-Crnkovic and Vincent Muller, 2009, p.12
[103] Gordana Dodig-Crnkovic, "Where do new ideas come from? How do they Emerge? – Epistemology as Computation (Information Processing)" in *Randomness and Complexity, from Leibniz to Chaitin*. 2007. p.5
[104] Gordana Dodig-Crnkovic and Vincent Muller, p.9

complex information processing through computational dynamics[105]. There is much left to be said about the hierarchy of complexity of nonliving entities and living organisms, and what consequences this might have for our understanding of mental phenomena, which will be discussed later in this thesis; but Dodig-Crnkovic's argument here is about the explanatory value that rethinking our metaphysical assumptions may have for future understandings of the human mind. These ideas are reminiscent of Leibniz's *Monadology*, in which life permeates the whole world at every level through complex relations between monads and the bodies that they correspond to.

One of the other central arguments for the epistemic productivity of info-computationalism that Dodig-Crnkovic puts forward is that of developing unified framework which encompasses diverse disciplines. In listing the promises of info-computationalism, she writes:

> "*The synthesis of the (presently alarmingly disconnected) knowledge from different fields within the common info-computational framework which will enrich our understanding of the world. Present day narrow specialization into different isolated research fields has gradually led into impoverishment of the common world view*."[106]

By narrowing fields of inquiry within different disciplines, we do not possess a unified, interdisciplinary framework by which to understand the natural world. Many different disciplines make different metaphysical assumptions about the world: from classical physics working from a materialist doctrine, to mathematicians understanding the world in

[105] Gordana Dodig-Crnkovic, 2007, p.6
[106] Gordana Dodig-Crnkovic and Vincent Muller, 2009, p.9

terms of numbers, geometrical representations and algorithms, to psychology and neuroscience which account for mental phenomena either in terms of behaviours, some inner mental life or just as structures of the human brain. Dodig-Crnkovic suggests that, by understanding nature as ultimately constituted by the computational dynamics of information structures, we can create a unified framework which accounts for many disparate research fields. The epistemic value is that it can account for a vast array of different phenomena under a simpler scheme of information and computation. She also writes that info-computationalism can provide:

> "*A unified picture of fundamental dual-aspect information/computation phenomenon applicable in natural sciences, information science, cognitive science, philosophy, sociology, economy and a number of others*."[107]

By altering our framework, we can account for not just physical phenomena of the natural sciences, in which a mechanistic model can be understood as operating within the info-computational framework, but we can also provide explanatory power to the fields of cognitive science, psychology, sociology, et cetera. In creating a unified explanation of living and nonliving entities, and in developing an account of mind within this information processing scheme, the gaps between the fields of physics and chemistry and biology lessen.

Muller concludes that these general principles of an information-computational metaphysical scheme, in which the universe is conceived as a cosmic computer, is underdeveloped to justify a paradigm shift. Gordana Dodig-Crnkovic, while acknowledging that this newly emerging framework still has some strides to make, argues

[107] Gordana Dodig-Crnkovic and Vincent Muller, 2009, p.9

for the epistemic productivity of info-computationalism. She reasserts several justifications, like the unified framework of understanding, a unification of living and nonliving systems, and an understanding of semantics of information to develop a more comprehensive view of the mind and mental processes. Within a scheme in which all systems in the universe are complex, interactive networks of information processing, the gap between inanimate physical entities and complex living organisms begins to narrow; and, with an inclusion of semantics for informational structures and symbolic representations that occur with computational changes, this leads to an account of mental phenomena which is inclusive within the broader metaphysical scheme.

3. The Intellectual legacy of Leibniz

Most theorists in computational metaphysics pay some credit to Leibniz, some going so far as to call the transition in understanding from matter-energy relations to information-computation relations as ‘Leibniz’s legacy’[108]. As laid out in Leibniz’s *Monadology*, his descriptions of simple substances (monads) are resonant with most computational metaphysical schemes. Leibniz laid out the rational foundation by which to consider the ultimate constituents of substantial reality as immaterial, computational processes, rather than physical structures. Even those thinkers that do not directly credit Leibniz share many of the themes he raised in the *Monadology*. The relationship between Leibniz and computational metaphysics will be explored in depth later in this thesis, under the heading ‘computational monadology’.

[108] Gregory Chaitin, “Leibniz, Information, Math and Physics” 2003. p.11

One theorist, Chaitin, draws parallels between the emerging fields of digital philosophy and digital physics, placing philosophy in a central role regarding the questions raised by modern physics. Describing digital philosophy as "Leibniz's legacy"[109], Chaitin develops an 'algorithmic information theory', converging the disciplines of mathematics, theoretical computer science and theoretical physics using the concepts of information and computation[110]. Using Wolfram's "A New Kind of Science", Fredkin's cellular automata and Bekenstein-t'Hooft's holographic principle, Chaitin argues for a theory of quantum information and quantum computation that takes precedence over the old models of matter and energy to form the foundation of the physical world[111]. This model can be used to question whether or not the entire universe is a computer, drawing an analogy between the way in which DNA "programs" living beings and the way in which God programs the universe[112].

Allan Randall, across several of his papers, attempts to reconcile current scientific advances in theoretical physics with the metaphysical axioms of Leibniz which predate it. Randall uses Leibniz's principles of Sufficient Reason and Identity of Indiscernibles to demonstrate their applicability in understanding the "weirdness" of quantum theory[113]. Even though Randall ultimately rejects Leibniz's assertion that there only exists *one* world out of an infinity of possible worlds, he remains confident that Leibniz's theory of monads can provide an alternate account on such things as quantum superposition[114].. He argues that quantum mechanics can be understood within an a priori, rationalist framework,

[109] Gregory Chaitin, 2003, p.10
[110] Gregory Chaitin, 2003, pp.1-2
[111] Gregory Chaitin, 2003, p.9
[112] Gregory Chaitin, 2003, p.9
[113] Allan Randall, "Quantum Superpostition, Necessity and the Identity of Indiscernibles" 1996. p.1
[114] Allan Randall, 1996, p.10

understanding the laws of nature as tautologies of pure reason[115]. In doing so, he not only demonstrates the relevance of Leibniz's work with contemporary physical theories, but also outlines a shift away from mechanistic accounts of the physical world and towards a mathematical model which corresponds to a computational view of the universe.

Tagliabue, much like Chaitin, uses Wolfram's "A New Kind of Science" and Fredkin's concept of cellular automata to rethink our basic metaphysical assumptions about the world, supporting a new scientific paradigm of digital physics. His core principle centers around the notion that simple rules can lead to complex, phenomenally rich behaviours, and that these simple rules form the computational foundation of the physical world[116]. Much like other theorists Tagliabue argues for the 'finite nature hypothesis', which rejects the Leibnizian notion of change as continuous, and argues that every quantity of physics, including space and time, will turn out to be both discrete and finite. Tagliabue attempts to utilize the concept of cellular automata as tools for understanding pattern formation and complexity found in the physical world, at one point comparing the basic substrate of physics to the operations of these cellular automata[117]. Within this new digital framework for understanding natural laws, Tagliabue resituates philosophy at the frontier of science, in which a theory of a digital universe may be used to model and "debug" existing philosophical theories[118].

Jonathan Edwards, in his paper "21st Century Monadology" reworks Leibniz's *Monadology* to draw parallels between this and modern field theory. While Edwards departs from some of Leibniz's ideas, namely that matter is infinitely divisible and monads

[115] Allan Randall, 1996, p.1
[116] Jacopo Tagliabue, "A New Kind of Philosophy: Manifesto for a Digital Ontology" in *Irreducibility and Computational Equivalence*. Springer Berlin Heidelberg. 2013. p.4
[117] Jacopo Tagliabue, 2013, pp.6-7
[118] Jacopo Tagliabue, 2012, p.10

as enduring, he argues that the dynamicism found in Leibniz's works is compatible with advanced theoretical science. Most notable of which is that the ultimate constituents of the universe are increasingly seen as units of *force* rather than units of matter[119]. That is, that the phenomena of matter is not rooted in the material structure of things, but rather in units of force in dynamic relations. He uses a Leibnizian understanding of how each monad represents the universe to describe how the energy bearing modes in modern physics are dynamic patterns which are made possible by the rest of the universe; such as an electron orbital[120]. Edwards also draws parallels between Leibniz's grades of monads (bare monads, souls and spirits) to ideas about neurocomputation. One of the strengths of Edwards' paper is what he calls "graded panexperientialism", where an interpretation of the *Monadology* in terms of modern field theory renders redundant the 'hard problem of consciousness'[121]. In Leibniz's account, all of the basic constituents of the physical world have some degrees of perception, all things are endowed with some basic, limited, unconscious mentality, and consciousness is simply a threshold above which things are reflexively aware.

Nakagomi is concerned with the internal world of monads. While all monads represent the entire universe to some degree, each monad has its own unique perspective. He identifies the primary content of a monad's internal world as including 'self-image' and 'other-images'; that is the degree to which a monad is self-reflexive, and its degrees of distinct perceptions[122]. Like Leibniz and others, Nakagomi does not think that material explanations can completely account for the experience of human consciousness. Instead he accounts for human volition in terms of a monad's changing its own internal state by acting on its self-image, where this action itself is deterministic in accordance with the monad's internal

[119] Jonathan Edwards, "21st Century Computational Monadology" 2014. p.37
[120] Jonathan Edwards, 2014, p.38
[121] Jonathan Edwards, 2014, p.37
[122] Teruaki Nakagomi, "Quantum Monadology: A Consistent World Model for Consciousness and Physics", in *Biosystems*. Vol.69. 2003. pp.28-9

principle[123]. Nakagomi asserts the necessity for Leibniz's pre-established harmony in such as system, through which the individual monads internal worlds are synchronized to a "common world" which does not exist in the monadistic world; the common world is virtual[124]. While Nakagomi does not directly refer to digital physics or digital metaphysics, it is clear that his interpretation of Leibniz's Monadology is in line with that of Uchii and Steinhart's, rejecting material accounts for the occurrence of natural phenomena in favour of an information-computationalist interpretation. The physical, material world is *virtual,* a product of the harmony of a plurality of monads whose 'coding' form the foundation of space, time, matter and motion.

4. Cellular Automata

Stephen Wolfram, a scientist known for his advancement of theoretical physics, established in his 'A New Kind of Science' a model for a digital computational universe understood in terms of mathematical relations. Wolfram proposed that digital information underlies the quantum level, creating a shorter description, or 'compression' of the universe[125]. This digital information model argues that simple, computational, rules produce the rich, complex behaviours of physical phenomena[126]. For Wolfram, the goal of "digital physics" is to develop a minimal model to describe the universe in order to create a unified theory[127].

Edward Fredkin's work on cellular automata also contributes to an understanding of computational metaphysics. He proposed that our universe is one, complex, single

[123] Teruaki Nakagomi, 2003, p.28
[124] Teruaki Nakagomi, 2003, p.29
[125] Hector Zenil, 2012, p.4
[126] Hector Zenil, 2012, p.3
[127] Hector Zenil, 2012, p.4

automaton which is always digitally computing its next state[128]. He posits that every physical object and their motions are just patterns on this complex cellular automaton, the universe[129]. He posits four laws of 'Digital Physics"; that information is conserved; that the fundamental process of nature is computational; that the state of physical systems must have digital representations; and that change is only produced via a digital information process[130]. He argues that all information can be thought as digital, and so must have a digital means of representation; as such, then all changes in information must necessarily be the consequence of these digital information processes[131].

The works of both Wolfram and Fredkin are mentioned in various works arguing for digital philosophy and digital physics. This understanding of physical objects and their relations is fundamentally digital, in the sense that discrete computational structures underlie these physical events[132]. However, the view of these discrete processes is incompatible with Leibniz's understanding of change, at both the phenomenal and monadic levels, as continuous. The 'finite nature hypothesis' that both Wolfram and Fredkin support, along with some of the theorists of digital metaphysics, argues that every quantity of physics, including space and time, will turn out to be both finite and discrete[133]. For the sake of expediency, the question of whether the universe and the computational processes within it are finite and discrete or infinite and continuous will not be addressed in depth in this thesis. Computational metaphysics has theorists that support either a digital (discrete) hypothesis or a continuous (analogue) hypothesis. Both theories set information and computation at the center of metaphysical and physical inquiry in a manner appropriate to Leibniz's monadic scheme; unavoidable incompatibilities are dealt with by other theorists.

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[128] Berto, Francesco and Tagliabue, Jacopo, "Cellular Automata", *The Stanford Encyclopedia of Philosophy*. Ed. Edward N. Zalta. 2012 §3
[129] Berto, Francesco and Tagliabue, Jacopo, 2012, §3.4
[130] Edward Fredkin, 2003, p.206
[131] Edward Fredkin, 2003, p.197
[132] Berto, Francesco and Tagliabue, Jacopo, 2012, §3.4
[133] Berto, Francesco and Tagliabue, Jacopo, 2012, §.3.4

5. Features of Computational Metaphysics.

Already we have seen that, across diverse theories, the push towards computational metaphysics is dominated by an understanding of the physical world as fundamentally informational and computational in nature. This has implications not just in the field of physics, but in biology and neuroscience, whose goal is to understand living organisms and the mind. Some of the computational models used to demonstrate these theories assume the ‘finite nature hypothesis’, with the underlying presupposition that, at the most fundamental level, the computational operations of the universe will be both finite and discrete, violating Leibniz’s notion of the continuum. Other models use either analog processes or a hybrid of the two. While this is an interesting problem within this field, whether nature is ultimately ‘digital’ and discrete or analog, this is not a central concern for this thesis. The notion of computational metaphysics is still in development, and as such disputes over which models are more effective are still yet to be resolved.

At the core of most of these theories is that the physical world, all of matter and motion, are the result of more fundamental computational processes. These theories account not only for the motions of material objects but also seek a more comprehensive account of living organisms and the experience of consciousness. The use of computational descriptions may enable us to better understand the idea of life as an emergent property of complex, though seemingly mindless, systems. If the ultimate constituents of nature are informational structures undergoing dynamic computational processes, then living organisms can be understood as an increasing complexity of these existing processes … and this can be extended to a concept of the mind. Through these informational structures some degree of mentality underlies all material bodies and physical systems in the world.

Computational Monadology

While there are many different theories regarding computational metaphysics, I primarily focus on those developed closely with Leibniz's *Monadology* in mind. The work done on computational monadology retains the rational foundation of Leibniz's peculiar exposition into the essence and nature of substances, yet remains pliable enough to resonate with current developments of modern science. These theories focus on the features of Leibniz's simple substances (monads), which function as fundamental units of computation and whose relations generate the spatio-temporal world of matter and motion. And the peculiar properties, or 'qualities' that these monads possess as giving rise to mental phenomena such as consciousness, memory, self-consciousness and reason. There are two dominant theorists that I explore in this scheme, Eric Steinhart, a strong proponent of digital philosophy, and Soshichi Uchii who takes on an informational interpretation.

1. General characteristics of Monads

In line with Leibniz's *Monadology*, the monads of a computational scheme are quantitatively simple, incorporeal basic units whose relations generate complex physical objects and processes. They consist of a system of qualities that can be described as a system of equations, or, rather, a *program*[134]. It is the programs of monads, defined in terms

[134] Abir U. Igamberdiev, "Physical Limits of Computation and Emergence of Life" in *Biosystems*. Vol.90. 2007. p.342

of mathematical equations, which form the logical basis for the physical world as an embodied, logical machine[135].

Soshichi Uchii draws attention to how Leibniz likened a monad to an automaton, even using the phrase ‘incorporeal automata’[136]. He explores the basic features of monads using an informational interpretation of Leibniz’s metaphysical scheme. As computational units, monads are immaterial, ultimate substances which produce all physical and mental phenomena in the world[137]. Without mass, nor shape, nor parts, monads are defined by their complex, qualitative internal states. These internal states within a single monad reflect the internal states of all other monads, and so contain within themselves perceptions of the entire universe[138]. Far from being static, unchanging entities, monads are dynamic, they contain within themselves the striving towards change, which is identified as the state-transition function[139]. In Uchii’s interpretation, monads function as ‘bearers of information’, and so changes to the internal states of any monad is actually a change in the informational content of the monad[140]. This informational content directly correlates with the perceptual content of a monad in any given state; changes to this informational content are a computational process, taking Leibniz’s monadic appetition as the state-transition function of a monad[141]. This state-transition function governing a monad’s series of changes is determined at the moment of creation in line with Leibniz’s pre-established harmony[142]. All phenomena, physical and mental, which arises in the world are a result of the informational content and computational processes of monads, and the “coding” which

135 Abir U. Igamberdiev, 2007, p.341
136 Uchii, informational interp, p.2
137 Soshichi Uchii, "An Informational Interpretation of Monadology". 2009. p.2
138 Soshichi Uchii, 2009, p.2
139 Soshichi Uchii, 2009, p.2
140 Soshichi Uchii, 2009, p.2
141 Soshichi Uchii, “Monadology, Information, and Physics Part 1: Metaphysics and Dynamic”. 2014. p.3
142 Soshichi Uchii, 2014, p.2

produces the pre-established harmony of all monads[143]. As with Leibniz, Uchii identifies God as the source of this coding which governs the state-transition function of all monads[144]. As such, the whole series of changes of the informational content of any monad is given at the moment of creation, in such as manner as to ensure that its changes are compatible with those of all other monads[145]. And Uchii argues that, to completely understand the world, we would have to have a full account not only of the informational content of each monad and their state-transition functions, but also of "God's coding" of the pre-established harmony which enables the *formal* relations of monads to produce complex physical, and mental, phenomena[146]. As such, God alone can comprehend the entire universe, we have only limited access through the world of phenomena and the capacity to reason through eternal truths.

Eric Steinhart adopts another perspective in his 'Computational Monadology', where he also explores the basic features of monads in developing a digital metaphysics. He describes monads as immaterial, algorithmic entities and the spatio-temporal world as virtual, a 'software' program running from the incorporeal 'hardware' of monads. He defines the internal changes of monads as the "inner logical-mathematical transformations" of their internal qualities[147]; these transformations are essentially algorithmic in nature. As such, the changes of qualities, or informational content, of monads are the result of monads computing their own algorithm and generating their next state[148]. The informational contents of monads are described as a system of mathematical qualities whose equations are

143 Soshichi Uchii, 2014, p.2
144 Soshichi Uchii, 2014, p.2
145 Soshichi Uchii, 2014, p.3
146 Soshichi Uchii, 2014, p.2
147 Eric Steinhart, "Computational Monadology". 1999. p.4
148 Eric Steinhart, 1999, p.5

the program which a monad executes, through the algorithmic transformations[149]. And these qualities are understood as variables which are able to take on different values, and whose patterns, through the ideal relations between monads, produce material things in the world[150]. Using Leibniz's Principle of the Identity of Indiscernibles, Steinhart agrees that these internal qualities are different for each monad, all containing many complex relations and properties[151]. While each monad may be able to simulate the entire universe from their own unique point of view, it is the differentiae between monads which produces the entire world, including space, time and motion[152].

Steinhart agrees with Leibniz that perception, an essential feature of all monads, cannot be explicated on mechanical grounds[153]. Computing monads are not physical machines, they are informational computing structures which underlie all matter and motion. As such, the interactions between monads are purely formal, or ideal in nature, there is no mechanical interaction by which the internal states of a monad are altered by any other[154]. The formal relations between monads, in Steinhart's digital metaphysics, do not create matter as such, rather they algorithmically generate the appearances of matter and motion, which are virtual, i.e. higher-order properties which specify the relevant property, material.[155].

Both Steinhart and Uchii accept the preliminary description of Leibniz's monads as immaterial, computing automata. Their focus on the basic descriptions of monads form the basis for their later metaphysical claims about the nature of space, time and motion; the character of perception; the relationship between monads and physical bodies; and the

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[149] Eric Steinhart, 1999, p.5
[150] Eric Steinhart, 1999, pp.5-6
[151] Eric Steinhart, 1999, p.6
[152] Eric Steinhart, 1999, p.5
[153] Eric Steinhart, 1999, p.10
[154] Eric Steinhart, 1999, p.10
[155] Eric Steinhart, 1999, p.10

exploration of mental phenomena. In both of their accounts the entire universe is generated by mathematical algorithms or programs executed by monads in accordance with the pre-established harmony of the monadic whole. The qualities of each monad in any given state are the informational content of the universe from a unique perspective, and the changes to these states is governed by each monad's internal, computational program.

2. Space and Time

The programs of all monads, from their unique perspectives, is what defines the spatio-temporal world[156]. Rather than space and time existing independently, and through which matter and motion of physical phenomena can be understood, this computational monadology posits that it is the relations between monads themselves which generate space and time. Since monads are the logical basis for the physical world, the internal states of a monad are always coordinated with all other monads in pre-established harmony. It is this harmony and mutual coordination which results in the actualization of those programs which generates space and time[157]. Space and time are relational constructs, the medium generated by monads through mutual coordination, and in which physical phenomena are defined[158].

Steinhart demonstrates that monads are neither in space nor time, but rather that both space and time are virtual and the product of the coordination of monadic transformations[159]. As the basic features of monads include the lack of extension as

[156] Abir U. Igamberdiev, 2007, p.341
[157] Abir U. Igamberdiev, 2007, p.342
[158] Abir U. Igamberdiev, 2007, p.342
[159] Eric Steinhart, 1999, p.1

immaterial automata, monads cannot exist in space[160]. And since monads are programmed at creation, the start and end of the world are the "logical limits" of the world, and are not in the world as such[161]. From this, Steinhart argues that monads are substantially real and that both space and time are virtual; they are digital representations that result from the mutual relations among monads based on their internal properties[162]. The coordination of internal qualities of monads interrelated by geometric relations produce immaterial patterns which give rise to the spatial structure of the world[163].

Uchii also examines the relationship between the reality of monads, which are conceived of as existing without space or time, and phenomena which occur in space and time[164]. This extends not only to physical processes, but also mental phenomena, such as sensation and thought, which need spatial and temporal concepts in order to be exemplified.[165]. To say that there is a pain in my head is both to give a spatial location to the sensation being experienced, and the time through which the sensation is experienced. It is the collection of sets of monads which produce any physical body in the phenomenal world[166]. And since monads possess only qualitative properties, Uchii argues that the quantitative properties of the phenomenal world are added through encoding in the realm of phenomena[167]. In other words, it is not just the algorithms within individual monads that produce phenomena, but the mutual coordination by way of pre-established harmony, or "God's coding".

[160] Eric Steinhart, 1999, p.1
[161] Eric Steinhart, 1999, p.1
[162] Eric Steinhart, 1999, p.1
[163] Eric Steinhart, 1999, p.5
[164] Soshichi Uchii, 2014, p.4
[165] Soshichi Uchii, 2014, p.4
[166] Soshichi Uchii, 2014, p.4
[167] Soshichi Uchii, 2014, p.4

Space and time, in which the phenomena of matter and motion reside, do not have independent ontological existence in computational monadology. They are the structures in which the appearances of physical phenomena are perceived by us, which arise only from the mutual coordination of all monadic entities. Spatial structures are formed by mathematical geometric relations expressed in the internal states of monads, and time is an order of succession by which the spatial relations are determined by the coordinated unfolding of a monad's inner algorithm[168].

3. Dynamics of Motion in physical phenomena

Uchii's metaphysical scheme of computational monadology explores the notion of force and dynamics in both the monadic and phenomenal realms before developing a full account of the relation between monads and bodies. While the term "force" was largely neglected in Leibniz's *Monadology,* compared to his earlier works, Uchii explores the concepts in terms of activity and passivity. Uchii emphasizes the informational features of this force relation, primarily that the distinction between activity and passivity as one of perceptual distinctness[169]. Since there is no intersubstantial interaction between monads the idea that one monad 'acts upon' another is purely an ideal relation, not one of mechanical interaction. One monad is said to 'act upon' another when it contains within it more distinct perceptions; and is said to 'be acted upon' when it contains more confused perceptions[170]. So the source of monadic action and passivity is found within the informational content of the perceptions, as more distinct or obscure[171].

[168] Soshichi Uchii, 2014, p.4
[169] Soshichi Uchii, 2014, p.24
[170] Soshichi Uchii, 2009, p.9
[171] Soshichi Uchii, 2009, p.9

Uchii identifies the primitive forces as the transition function of monads, i.e. their striving towards change, or appetition[172]. As such, primitive force persists within a monad itself as the determined sequence of operations that takes place consecutively in a monad[173]. This transition function represents the totality of all possible combinations of internal states that any monad will undergo[174]. However, each individual operation of the transition function of a monad can be understood in terms of derivative force, a modification of primitive force[175]. A single operation of the transition function of a monad determines, through the present internal state and the present input, the next internal state of the monad[176]. Since the changes which occur in the phenomenal world must have their ultimate basis in the changes of underlying monads, the activity and passivity of physical phenomena originates in the transition function of monads[177]. Just as time and space are not substantially real, motion in the phenomenal world does not *really* exist[178]. The physical dynamics of motion are a phenomenon that we are able to see in our conscious perception, it does not have a basis in reality except as the notion of force expressed in monads[179]. In the physical phenomena of collisions, for example, there is no real transfer of force as appears to our conscious perception. Each body is moved by its own derivative forces governed by the set of monads which correspond to it[180]. And it is because of the pre-established harmony that its motions correspond to the motions of other bodies as aggregates of monads[181].

[172] Soshichi Uchii, 2009, p.9
[173] Soshichi Uchii, 2009, p.9
[174] Soshichi Uchii, 2009, p.10
[175] Soshichi Uchii, 2009, p.10
[176] Soshichi Uchii, 2009, p.10
[177] Soshichi Uchii, 2014, p.26
[178] Soshichi Uchii, 2014, p.8
[179] Soshichi Uchii, 2014, p.8
[180] Soshichi Uchii, 2009, p.11
[181] Soshichi Uchii, 2009, p.11

4. State Transition Function of Monads

As we've mentioned already, the computational processes which underlie all worldly phenomena occur in the state-transitions of monadic internal qualities. While all monads reflect or represent the entire universe in its perceptions, the transition function, or appetition, refers to the internal striving towards change in its own internal state. If perception is viewed as the informational content of monads, then the transition function is a monad's algorithmic execution of its own internal program, computing its next internal state.

The notion of change in Steinhart's digital metaphysics is somewhat incompatible with the Leibnizian scheme. By subscribing to the finite nature hypothesis advocated by Wolfram and Fredkin, Steinhart has to reconcile this with his interpretation of Leibniz's monadic scheme. Rather than seeing change as continuous, Steinhart argues that the changes in monads over time occur in discrete stages[182]. However, this does not lead Steinhart to dispense with the Leibnizian metaphysical scheme.

Steinhart argues that since physical change in the phenomenal world is mathematically ordered, one can then assume the existence of mathematical structures and dynamics within monads themselves[183]. And the changes to a monad's internal states are driven by their "inner logical-mathematical transformations", what Leibniz calls appetition, and what Uchii calls their transition function[184]. The set of qualities which forms the complete concept of any given monad is described as a system of equations which form the logical basis for the structure of the universe, putting mathematics into motion[185]. Steinhart also identifies the algorithmic function of the changing of a monad's internal states as a recursive program.

[182] Eric Steinhart, 1999, p.4
[183] Eric Steinhart, 1999, p.5
[184] Eric Steinhart, 1999, p.4
[185] Abir U. Igamberdiev, 2007, p.342

The internal state of a monad at any given moment is entirely determined by its previous states and by the internal program that it is executing. As such, the qualitative detail of a monad's state is the function of its previous states in a recursive program[186].

Unlike Steinhart, Uchii's computational monadological system does not strongly adhere to the finite nature hypothesis model and maintains the Leibnizian claim that all change is continuous. However, like Steinhart's model, Uchii describes the state-transition function of monads as the spontaneous, mathematical computing of a monad's own internal states. And the entire series of changes, the transition function, of all monads are predetermined at the moment of their creation[187]. It is 'primitive' force which governs the operations of this function in the realization through a monad's execution of its computational program[188]. This primitive force contains both active and passive relations which form an essential role regarding the informational content of monads[189]. As described earlier, monadic activity, in which one monad can be said to 'act upon' another monad, is explained via the distinctness or confusedness of perceptual content. Since there is no mechanical interaction by which monads can impart force to one another, and since all the operations of a monad originate internally from their predetermined transition function, the activity and passivity in monads is purely ideal, or formal[190]. This 'dual nature' of the active and passive forces contained within a monad's internal computational program is then reflected in the behaviour of physical phenomena derived from the complex relations in the monadic realm[191]

Because monads, to some degree, reflect in their internal qualities the totality of the world and their relations to all other monads, any changes of the internal state of any given

[186] Eric Steinhart, 1999, p.4
[187] Soshichi Uchii, 2014, p.3
[188] Soshichi Uchii, 2014, p.40
[189] Soshichi Uchii, 2014, p.40
[190] Soshichi Uchii, 2014, p.40
[191] Soshichi Uchii, 2014, p.13

monad also includes the state changes of all other monads[192]. As such, both active and passive primitive forces must be contained within the transition function of all monads; when any monad is said to 'act upon' another in an ideal relation, another monad holds within its program the relation of 'being acted upon'[193]. The only way to achieve perfect, mutual coordination through these complex ideal relations between monads, which are the sole causes of their own operations, is through the pre-established harmony determined at the moment of creation. As such, the transition function of monads follows from teleological law; they are not bound by the constraints of cause and effect that appears to us in the phenomenal world, but operate self-sufficiently towards their own ends[194].

5. Perceptions as Informational Content

In computational monadology, as with Leibniz's original conception of monads, the other essential feature of monads are complex, internal qualities contained within each monad as its perceptions. If the transition function of a monad is the computational, immaterial process of changing its internal states, then the perceptions contained within these states can be described as the informational content of each monad. These two fundamental characteristics form the informational-computational nature of the ultimate reality on which physical phenomena is derived. In Leibniz's *Monadology*, monads as simple substances contain within themselves a reflection of the entire universe through their perceptions of the infinite plurality of all other monads. No two monads can have the same qualitative perceptual content; rather, each monad represents the entire universe from its own unique position, which contains both distinct and confused perceptions. A monad at

[192] Soshichi Uchii, 2014, p.40
[193] Soshichi Uchii, 2014, p.40
[194] Soshichi Uchii, 2014, p.3

any given state contains this representation of the universe, and the transition function is what computes the next internal state of the monad, altering the distinctness and obscurity of the perceptions a monad has of the universe. This notion of perception as the informational content of a monad is what ultimately gives rise to the conception of mind and consciousness in the phenomenal world. Monads, as the fundamental units of the world are conceived of as "points endowed with mentality", however limited, through the distinctness of their perceptions[195]. This is the mindfulness immanent in the cosmos; hence, no object in the world is without some minimal mentality[196].

As such, the notion of perception is crucial to Steinhart's digital metaphysics framework. He describes this "perpetual living mirror" of the universe as the set of mathematical structures which form the ideal relations between monads[197]. These internal representations of the whole contained within each monad are what he calls the "structure-preserving functions", in which the formal relationships between monads act as "structure-preserving maps"[198]. For Steinhart, space, time and matter are all virtual, whose common "worldspace" is derived from the formal relations between monads[199]. Since each monad has its own unique perspective of the world in its complex perceptions, as internal mathematical points, the perceptual content of each monad is the basis for the informational structure of the phenomenal world. The common worldspace is structured by these formal relations which supervene over monads as immaterial patterns which constitute virtual space, time and matter[200]. So it is the coordinated, formal relations between all monads which preserve the informational structure of the universe, expressed as the spatio-temporal physical world that we experience.

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[195] P. R. Masam, 2000, p.293
[196] P. R. Masam, 2000, p.293
[197] Eric Steinhart, 1999, p.23
[198] Eric Steinhart, 1999, p.23
[199] Eric Steinhart, 1999, p.25
[200] Eric Steinhart, 1999, p.25

Steinhart describes the concept of perception at the monadic level in information-computational terms. He refers to perception as the “perceptive subprogram” of each monad which not only represents the entire universe, but functions to comprehend those representations[201]. The informational content contained within each monad in its perception of the universe is then not simply mathematical relations, but there is a limited degree of mentality immanent in the monadic realm. Monads do not simply generate virtual space and time in which the motions of matter are governed by mathematical algorithms, but are also the substantial reality for the occurrence of mental phenomena. This relationship between mental and physical phenomena is crucial for the explanation of both of how bodies are manifested in the phenomenal world, but also to explain the phenomena of the emergence of mental life and consciousness.

As I have already discussed, in Soshichi Uchii’s informational interpretation of the *Monadology*, his conception of monads are as the “bearers of information”, whose state changes are described as changes in the informational content. It is changes in the informational content of a monad, computing its next state that form the substantial basis for the dynamics of force. So the perceptions of a given monad are transitory states which are determined by the transition function (appetition) of that monad[202]. Uchii asserts that the phenomenal world is the result of higher order perceptions which are produced in organic bodies operating in harmonious formal relations[203]. The correspondence between the activities of monads and the world of phenomena is determined by the pre-established harmony coordinating the perceptions of the monadic aggregates whose relations constitute physical bodies[204]. Uchii discusses the role of perception in terms of the ‘flow of

[201] Eric Steinhart, 1999, p.9
[202] Soshichi Uchii, 2014, p.26
[203] Soshichi Uchii, 2009, p.6
[204] Soshichi Uchii, 2009, p,6

information' in a hierarchy of programs, illustrated with Leibniz's own example of how it is that we hear the roar of ocean waves.

When we hear the ocean's roar, our bodies' monadic constituents receive 'petite perceptions' of the actions of innumerable small waves, the effect of which we can only perceive confusedly as a 'roar'; one cannot distinguish these petite perceptions individually[205]. In Uchii's interpretation, the flow of information of this phenomenon transfers from each innumerably small wave to the sensory organs of our ears, to the conscious perception of our anima (soul) through a hierarchy of programs governing organic bodies[206]. In order to understand petite perceptions, Uchii extrapolates from the original imagery: imagine that there are thousands of observers at various locations on the sea, and that each of those individual observers correspond to the petite perceptions that lie below the threshold of conscious perception. As such, Uchii says that the flow of information through monadic relations which underlie physical phenomena becomes less distinct as it propagates to a distant place[207]. By this he means that the bodies in the physical world corresponding to those small, innumerable waves have more distinct perceptions of their relations than an observer whose perception of this activity cannot distinguish those minute perception and can only hear the confused roar of the sea. Monads have more distinct perceptions representing the bodies to which they correspond, and the substantial structure of those phenomenal bodies can be understood in terms of a hierarchy of monadic programs[208]. Since the governing monadic relations constituting the observer's body do not directly correspond to those representing the individual innumerable waves, they cannot have distinct perceptions of them.

[205] Soshichi Uchii, 2014, p.35
[206] Soshichi Uchii, 2014, p.35
[207] Soshichi Uchii, 2014, p.35
[208] Soshichi Uchii, 2014, p.35

6. Bodies in the Phenomenal World

Before we can understand the emergent phenomena of consciousness and higher order mental capacities such a reason within this computational monadological framework, we must first explore the relationship between the monadic realm and the behaviours of bodies in the phenomenal world. This was briefly touched upon by Uchii in the understanding of conscious perceptions of the phenomenal world as the operations of a hierarchy of programs, but deserves further analysis. I have already established that, within this framework, space and time are the results of immaterial, monadic relations coordinated via Leibniz's notion of pre-established harmony. The dynamics of motion in the phenomenal world are governed by each monad's internal state, in the distinctness of perception, and the transition function, as containing within itself both active and passive forces. Within these complex processes, I now explore the relationship between monadic entities and the phenomenal bodies to which they correspond and whose logical basis for existence lies in monads themselves.

In Steinhart's computational monadology, each monad's program is focused on the body to which is corresponds. Steinhart describes this correspondence using an example of the a person's vision of surroundings in relation to their walking. As the body moves through space it remains at the center of its perceptual field; the external phenomena of other bodies in the visual field grow in distinctness or confusedness depending on their proximity to the body[209]. As such, a monad's body is defined by Steinhart as the pattern at the center of the monad's "grid" that represents the entire universe[210]. This, together with the program of the

[209] Steinhart, 2005, ss56-81, p.28
[210] Steinhart, 2005, ss56-81, p.29

monad is what constitutes the unity of an organism[211]; a body is composed of the formal interrelations between an aggregate of monads unified under a dominant entelechy. In the case of a living animal, this entelechy is called a ‘soul’ (or ‘anima’) which allows for the emergence of consciousness as the expression of mental-state patterns supervening over the set of unified monads[212].

There is a hierarchy of programs in which the dominant monad, the ‘entelechy’, unifies and governs the programs of all other monads whose computational processes constitute the body. The members of the set of aggregated monads that form any complex living body are themselves filled with other living things, each with their own dominant entelechies.

> “*Every animal’s body is a pattern centered on its focal cell. So this pattern is distributed over the material world. These bodies grow and decay, unfolding and enfolding their complexities. These bodies are infinitely complex. They vary in size from what we see to microscopic (even infinitesimal). The arrangements of parts of bodies change over time, but bodies never entirely perish, at worst, they simply become infinitesimal microscopic seeds*.”[213]

The infinite complexity and continuity in Leibniz’s *Monadology* that Steinhart refers to is incompatible with Steinhart’s stance that all of nature is discrete and finite. However, he retains the crucial features of the relationship between monadic entities and phenomenal bodies, and the notion that there is no ontological distinction between inanimate objects and living organisms; that it is only a difference by degrees in perception. The body which corresponds to a monad as its governing entelechy can thus never entirely perish. The dominant entelechy governing any collection of monads that form a complex body can be

211 Eric Steinhart, 1999, p.29
212 Eric Steinhart, 1999, p.29
213 Eric Steinhart, 1999, p.32

said to 'act on' the other monadic members of the collection. And while these other monads are all dominant entelechies of their own over their corresponding aggregate bodies, they are said to 'be acted upon' by the unifying monad to which they are subordinate. So the unity of organic bodies in the phenomenal world are the products of the pre-established harmony of the activities and passivity found within each monad as a member which constitutes these bodies[214].

Uchii's interpretation of the relationship between monads and phenomenal bodies uses computational descriptions as a hierarchy of programs in a many layered structure. As Uchii does not subscribe to the finite nature hypothesis, he argues that the infinite divisibility of matter means that there are an infinite number of sublayers of programs underlying any material body[215]. Any complex, material body is the result of the organization of an innumerable number of monads, with a central governing monad that acts as the body's central processing unit (CPU)[216]. Each of these individual monads whose relations constitute organic bodies have been individually programmed, at the moment of the creation of all monads, to coordinate harmoniously in view of the whole organization[217]. At the top of the hierarchy of programs is the program of the dominant monad which unifies and governs the operations of the whole organism; a role analogous to the operations of a computer's CPU[218]. From this dominant program, various subprograms follow ad infinitum, each computing their own state-transition functions in accordance with all other monadic programs running within the organized whole[219]. So any organic body is an organized collection of programs, containing within themselves a sequence of instructions for executing their various state transitions, operating as a harmonious whole

[214] Eric Steinhart, 1999, p.32
[215] Soshichi Uchii, 2014, p.32
[216] Soshichi Uchii, 2009, p.2
[217] Soshichi Uchii, 2014, p.32
[218] Soshichi Uchii, 2014, p.32
[219] Soshichi Uchii, 2014, p.32

under the active program of the dominant monad. As with Steinhart's model, the governing entelechy is the active program insofar as more reasons can be found within the monad's own complete concept for the behaviours of the other monads acting in accordance with the dominant monad's own program[220]. As such, it is this dominant monad which forms the most distinct perceptions of the organic body to which it corresponds with[221].

As with Steinhart, Uchii also describes the nature of organic bodies in the phenomenal world in terms of cellular automata. As the universe is filled with matter, eliminating any notion of a vacuum or a void, each body is in direct contact with all of its neighbors in the plenum[222]. So the universe is filled with an infinite number of "cells", where their spatial relations are defined by the monadic coordination of mathematical geometric relations[223]. The informational flow through this cellular space is then transferred through a chain of immediate contacts[224]. Uchii explains that this is why the conscious perceptions that a body has of itself are more distinct than the perceptions of those things occurring at a distance to the body in this cellular space[225]. The flow of information in the perception of the sound of the ocean can only occur to our consciousness as a confused roar since the petite perceptions of each innumerable small wave has to be transferred through the cellular space as it propagates to the distant observer[226]. Within this conception, all bodies which occupy the phenomenal world are the products of monadic aggregates which function as cellular automata, whose universal coordinated harmony produce the whole world as a single, cellular automaton[227]. Uchii refers to the organized structure of a group of monads that correspond to a particular body as its "collective state" and the coordinated unfolding of

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[220] Soshichi Uchii, 2014, p.32
[221] Soshichi Uchii, 2014, p.32
[222] Soshichi Uchii, 2014, p.38
[223] Soshichi Uchii, 2014, p,38
[224] Soshichi Uchii, 2014, p.38
[225] Soshichi Uchii, 2014, p.38
[226] Soshichi Uchii, 2014, p.35
[227] Soshichi Uchii, 2014, p.36

their state-transitions as the “common force”[228]. The collective state produces the place of a body in the phenomenal world relative to all other bodies, and the common force of the monads in any given set corresponding to a body contribute to the changes of the body as a whole[229].

The body of any set of monads is thus always in a state of perpetual change, and the relations between dominant and subordinate monads change over time[230]. Monads are not just the source from which physical bodies in the phenomenal world are derived, but are also the source for mental phenomena. As such, there can be no material body that is completely devoid of some limited semblance of mental life, since these bodies would then have to be devoid of monads, something incompatible with this scheme[231]. Thus there is no sharp ontological distinction between “inanimate” matter and living, organic bodies[232]. In line with Leibniz’s original account, in computational monadology there is no difference in kind between unconscious and inanimate bodies and living organisms, the difference is only one of degree in the complexity of the monadic organization and the distinctness of its overall perceptions.

7. Body-Mind Correspondence

Having established the complex relationship between material bodies and the monadic organizations from which they are derived, we can now explore the concept of mind within this computational monadological scheme. Both Steinhart and Uchii follow Leibniz’s hierarchy of monads; from bare monads, to ‘souls’, those governed by an ‘anima’, to

[228] Soshichi Uchii, 2014, p.45
[229] Soshichi Uchii, 2014, p.45
[230] P. R. Masam, 2000, p.294
[231] P. R. Masam, 2000, p.294
[232] P. R. Masam, 2000, p.294

spirits. One of the principal advantages of this computational monadological framework is to reduce the explanatory gap between non-conscious inanimate matter and animate material beings which manifest consciousness[233]. Since mental life permeates through the physical world via the underlying immaterial monadic structures, consciousness can be explained as an emergent phenomenon above a certain threshold of complexity.

Uchii’s account of the mind-body relation, while not as highly developed as Steinhart’s, follows from his informational interpretation of Leibniz’s *Monadology*. In living organisms, it is only the governing program unifying the whole that has the most distinct perceptions and is capable of consciousness[234]. A living body, itself the result of the organization of an infinite number of monads, is controlled by the ‘soul’, or ‘anima’[235]. This ‘anima’ of the body “controls” the body via its program (its transition function); according to Uchii’s view this control is not causal in the mechanical-efficient sense we use with regard to middle-sized things. The dominant program of any body is active insofar as it has more distinct perceptions and has more reasons within itself for the movements of the body than the subprograms which operate under it[236]. With his ‘flow of information’ example regarding the roar of the sea, the conscious perception of the confused roar is produced by the ‘anima’ as a product of the various, unconscious, subprograms operating under it[237].

In Steinhart’s digital interpretation of Leibniz’s *Monadology*, he follows the hierarchical scheme laid out. Bare monads, while representing the entire universe, only contain within themselves indistinct perceptions. While these monads are endowed with some limited

[233] Abir U. Igamberdiev, 2007, p.345
[234] Soshichi Uchii, 2014, p.32
[235] Soshichi Uchii, 2014, p.32
[236] Soshichi Uchii, 2014, p.35
[237] Soshichi Uchii, 2014, p.35

mentality they lack any higher-order mental properties that we associate with consciousness or mind. The informational content of these monads have no self-reflexive awareness, nor memory; their transition functions are executed by blind, rote, mathematical algorithms[238]. These bare monads are members of organized collections which form living organisms, performing as subprograms under a dominant soul monad, and are the governing entelechies of living *and* non-living things in the world.

Animals are those living organisms whose dominant entelechy can be called a ‘soul’ or ‘anima’. They are capable of more distinct perceptions, corresponding with their body, and have the capacity for memory. Steinhart defines memory in mathematical and computational terms, as a sort of ‘consecutiveness’ of the mental phenomena of an animal[239]. He describes memory as a mathematical pattern in which the intensity, frequency and regularity of repetition of the perception of stimuli on the body affect how strongly associations are made in the ‘soul’ of an animal[240]. As such, the capacity for memory necessarily requires the consecutiveness of previous internal states. Even while unconscious and operating on the level of that of a bare monad, each given internal state of a soul-endowed monad is a function of all of its previous states[241]. Steinhart’s use of the phrase “information presupposes information” captures his view that the internal states of all monads contain informational content. The movement from unconscious to conscious is then understood at the “reflexivity of the recursive operation of the monad”[242]. That is to say, the capacity for consciousness arises out of an ensouled monad’s ability to make associations through retention of sequenced information about its previous internal states. This is made possible since the recursive structure of any given monad’s program is a function of all of the monad’s previous internal states. The operations of this function can

[238] Eric Steinhart, 1999, p.10
[239] Eric Steinhart, 1999, p.13
[240] Eric Steinhart, 1999, p.13
[241] Eric Steinhart, 1999, p.12
[242] Eric Steinhart, 1999, p.12

then be understood as mathematical patterns which represent the unity of the effects of the body to those of the soul[243].

At the highest tier are spirit monads (human beings) which possess all the capacities of more simple monads, as well as the ability to engage in self-reflexive acts that give rise to our faculty of reason and access to eternal truths[244]. What Leibniz called 'apperception', Steinhart describes as a special sort of program able to determine its own algorithm and data structures[245]. In doing so, we are then able to make computational models of ourselves through the rational reflection with our internal state contents[246]. It is important to note here that not all of the operations of human beings occur at this spirit level. While the dominant entelechy of our being is at the spirit level, that is simply the type of monadic program which unifies an innumerable number of perceptions and governs the coordinated structures and changes of all other monads which make up the human being. Most of our daily activities function on the level of a soul monad, as "empirical physicians" rather than at the level of reason[247]. Indeed, as our living bodies are composed of an innumerably large number of monads in their complex coordinated relations, most of our functioning is comprised of these unconscious computational changes in our petite perceptions. The dominant program of the spirit monad is simply that which possesses apperception and which unifies the coordinated computational processes and informational content of immensely complex monadic relations that make up the living body of human beings.

Steinhart takes care to highlight that the relationship between the mind and the body is not one of efficient causation since there is no intersubstantial interaction as such.

[243] Eric Steinhart, 1999, p.13
[244] Eric Steinhart, 1999, p.13
[245] Eric Steinhart, 1999, p14
[246] Eric Steinhart, 1999, p.14
[247] Eric Steinhart, 1999, p.13

> "*The body does not cause effects in the mind during perception, nor does the mind cause effects in the body during action. Rather, both perception and action are (inverse) isomorphisms between body and mind*."[248]

The operations of monads are what give rise to all mental and physical phenomena within the spatio-temporal "virtual" world. And since monads are self-sufficient in the sense that they alone are the cause of their internal states (via their transition function), there is no true communication between monads, except as their formal relations already contained within each monad's complete concept. As such, the appearance of causal relations in the phenomenal world is strictly that, of an *appearance*. While each monad corresponds with a material body in the phenomenal world, and is the source of its existence, the body is simply an expression of these complex monadic relations, and has no substantial realty in and of itself[249]. So there can be no interaction as such between mind and body; rather, they are coordinated by the pre-established harmony, through which a soul, or mind, and an organic body can be said to be in mutual conformity[250]. As Steinhart explains further:

> "*The mind is a cellular automaton whose states are just these formal mental structures. Both states and transitions of the mental automaton correspond to those of the bodily automaton. This is the pre-established harmony between body and mind. Mind and body are coordinated, but they do not interact*."[251]

[248] Eric Steinhart, 1999, p.32
[249] Eric Steinhart, 1999, p.32
[250] Eric Steinhart, 1999, p.32
[251] Eric Steinhart, 1999, p.33

Thus the relationship between the mind and the body, particularly the brain, is one of perfect mutual coordination. The occurrence of a bodily sensation such as pain can be described as the change of the informational content in the formal structure (the program) whose states correspond to the states of the nervous system[252]. The visual experience of seeing involves an intentional 'object' which corresponds to a complex pattern of impulses within the nervous system[253]. In this framework, the complex computational features of the mind are not determined by physical brain structures and their electrical and chemical processes. Mind is not reduced to the mechanical operations of matter; but nor can mind 'act on' the body in anything other than a purely formal sense. The dominant program of the mind can only be said to control its body insofar as the subprograms it governs are coordinated in such a way that they can be said to 'be acted upon'. This activity and passivity is programmed into each monad's transition function from the moment of their creation as per the pre-established harmony.

8. The Broader Picture

In this section I've examined two theorists that have used Leibniz's Monadology to support their computational metaphysical schemes. This is not an exhaustive list of the themes and arguments for computational monadology, but these two thinkers, Steinhart and Uchii, represent clearly the strong relationship between the original work of Leibniz and the push towards rethinking our understanding of the material world. Each offers their own information-computational approach to the original work, but adhere to much of Leibniz's dominant principles. Their views are in keeping with interpretation of Leibniz's monads in

[252] Eric Steinhart, 1999, p.32
[253] Eric Steinhart, 1999, p.32

terms of computational programs. In the *Monadology* descriptions such as the fundamental units of reality being “incorporeal automata” has enabled his peculiar metaphysical scheme to be taken up by current theorists, not just in philosophy but in physics also.

By using a computational framework, they have established a metaphysical picture of the world in which the divide between non-living physical systems and living organisms is not of a different kind. Emergence of life is better understood as arising from complex systems whose most fundamental units can be said to have life-like qualities. And the divide between unconscious processes and conscious, even rational, organisms is simply a difference in degrees, not in kind. By describing these fundamental units of reality as necessarily endowed with some, limited, mentality, we then reduce the explanatory gap for the emergence of consciousness from seemingly unthinking, material systems. And by thinking of the entire world as the product of a cosmic computer, we can better situate a computational theory of mind which is not reduced to the structures and operations of the brain.

Conclusion: A Leibnizian Computational Theory of Mind

Throughout this thesis I have explored the movement away from materialist systems in which the world is explained in mechanical terms of matter and motion. The development of classical physics is one in which the explanations of physical structures and systems are devoid of the mental properties that we associate with mind. They are blind, mechanical systems, composed of interacting parts which obey physical laws. The traditional ideas in computational theory of mind rests on those physicalist assumptions; that the mind is analogous to a computer whose operations are governed by physical brain structures and their interacting parts. However, this view of consciousness is problematic in accounting for exactly how consciousness, embedded with meaningful experience, can emerge from such physical systems.

In the advancement of theoretical physics, however, there is a movement away from this standard mechanical model. The theories that I have explored in this thesis focus primarily on the exploration of computational metaphysics as a new paradigm through which we can understand the natural world. In this, I see Leibniz's role as crucial for this new development, and I have focused on the works of theorists like Steinhart and Uchii who have based their computational metaphysics scheme using an interpretational analysis of the *Monadology*. Such interpretations of the ultimate nature of reality as information-computational are not without its difficulties. Strict adherence to Leibniz's *Monadology* would cause contradictions with contemporary scientific theories; most notably regarding the 'finite nature hypothesis' and whether or not his infinite plurality is even possible. However I find that these reinterpretations of this text, which predates modern field theory and quantum physics, may provide us with a more comprehensive account for both physical and mental phenomena.

In describing their ‘computational monadology’, Steinhart and Uchii view Leibniz’s monads as computational programs, whose coordinated executions produce space, time, matter and motion. Monads are not in space or time, rather these structures, in which physical objects exist, are the products of coordinated monadic programs. The whole universe can be conceived of as a cosmic computer, the result of an innumerable number of these programs computing their own individual algorithms. A crucial feature of this interpretation is the role of information. Both Steinhart and Uchii preserve the Leibnizian notion of perception in monads. That each computable monad contains within it a representation of the entire universe from its own unique point of view, albeit one which is mostly indistinct and confused. This presents the idea of panexperientialism; that, at the level of reality, the ultimate units of reality are endowed with some mental-like qualities. The perceptions of these fundamental units, which represent their proximate monadic relations, are the informational content of the universe, from each possible unique perspective. And the changes in this informational content occur through the computational processes of the state-transition function in each monad. Just as all physical phenomena is the result of monadic encoding, as is all mental phenomena.

As such, there is no ontological distinction between non-living systems and living organisms, both are the products of monadic programs, differing only in their complexity. The emergence of life does not develop out of ‘inanimate’ physical matter, but rather through the same complex, dynamical, computational processes that underlie all physical systems. At the very essence of these computational processes is the informational content undergoing those changes. The emergence of properties that we associate with mental phenomena arise from those informational structures and computational processes that occur through all of the natural world at the level of these monadic units.

Leibniz's work laid down the foundation to shift away from the "myth of matter" and explore the idea of an immaterial, computational basis for reality; an explanation of space and time, motion and matter, and even human consciousness that is compatible with current empirical investigations into both physics and neuroscience. By retaining a Leibnizian understanding of perception and consciousness, we can form a new computational theory of mind in which semantic relations are intrinsic in any system performing computation, thereby answering criticisms like those raised by Searle's Chinese Room thought experiment. Mental states and events are then not just the products of blind, rote symbol manipulation, governed purely by syntactical rules alone. These processes are embedded with some limited degree of mentality at the most fundamental level. Within this idea of the universe as a cosmic computer, while the computational processes of the brain and the mind do correspond to one another, the occurrence of mental phenomena are not reduced to, nor derived from, these physical brain states and operations. Rather, they are both the result of the complex computational operations embedded in the most fundamental units of reality.

By resituating a computational theory of mind within a framework of computational metaphysics, I hope to bridge the disciplinary gap between philosophy, physics, biology and the cognitive sciences. In working to create a unified framework to understand the natural world, and thereby granting computational theory of mind its explanatory purchase, a computational metaphysics model demonstrates how this might be achieved. Although this framework is not without its difficulties, and is not fully developed, the aim of this thesis is to explore the possibilities of a new paradigm shift, and the consequences this might have to our understanding of physics, the emergence of life and consciousness.

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