UNTYING THE GORDIAN KNOT

PROCESS, REALITY, AND CONTEXT

TIMOTHY E. EASTMAN

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LEXINGTON BOOKS
Lanham • Boulder • New York • London

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Published by Lexington Books
An imprint of The Rowman & Littlefield Publishing Group, Inc.
4501 Forbes Boulevard, Suite 200, Lanham, Maryland 20706
www.rowman.com

6 Tinworth Street, London SE11 5AL, United Kingdom

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British Library Cataloguing in Publication Information Available

Library of Congress Control Number: 2020945463
ISBN 978-1-7936-3916-5 (cloth : alk. paper)
ISBN 978-1-7936-3917-2 (electronic)

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Acknowledgments

This highly integrative work would not have been possible without the prior accomplishments and publications of a vast community of scholars over the centuries. In many cases, research that led to dead-ends has been just as valuable as work resulting in promising new and productive approaches. In particular, I acknowledge the valuable contributions of contemporary scholars, particularly in the fields of quantum physics, American and European philosophy, process philosophy, semiotics and biosemiotics, and information and complex systems.

I am indebted to a wide range of scholars with whom I have dialogued in person including, among others, (Science, philosophy of science) Ian Barbour, Jesse Bettinger, Jeffrey Bub, Reginald Cahill, Geoffrey Chew, Terrence Deacon, Joseph Earley, George Ellis, Lawrence Fagg, David Finkelstein, Leonard Garcia, David Grinspoon, Gary Herstein, William Kallfelz, Stuart Kauffman, Hank Keeton, John Jungerman, Ruth Kastner, Wolfgang Kundt, Eric Lerner, Roland Omnès, Anthony Peratt, Hilton Ratcliffe, Joe Rosen, Robert John Russell, Henry Stapp, and Robert Valenza; (Humanities) George Allen, Randall Auxier, Joseph Bracken, James Bradley, Søren Brier, Milič Čapek, Philip Clayton, John B. Cobb, Jr., David Christian, Herman Daly, Ronny Desmet, William Desmond, Roland Faber, Evan Fales, Lewis Ford, Arran Gare, Herman Greene, David Ray Griffin, John Haught, Brian Henning, George Lucas, Jr., Farzad Mahootian, Derek Malone-France, Leemon McHenry, Thomas Mikelson, Robert Neville, Jorge Luis Nobo, Nicholas Rescher, Franz Riffert, Johanna Seibt, Robert Spitzer, Marjorie Suchocki, Yutaka Tanaka, Thandeka, Michel Weber, Paul Weiss, and Alan White.

Above all, I wish to especially acknowledge the groundbreaking research work of Michael Epperson and Elias Zafiris, whose insights in quantum

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physics and philosophy directly inspired the current work. These advances in turn were earlier made possible by partial support through the Fetzer-Franklin Fund, including critical research and workshops, thanks to coordination efforts by Paul Gailey and Jan Walleczek. And, finally, I am deeply thankful to George Shields of the University of Kentucky for several extended dialogues, during the late stages of this work, that inspired notable improvements in the first dozen drafts.

I am further indebted to my direct human heritage, parents and ancestors, to whom I owe my very existence, and to the loving support of my wonderful children, siblings, in-laws, and their families. Further, I'm indebted to the innumerable persons, institutions, teachers and mentors that enabled my growth, education, and career including, among many others, the University of Minnesota, University of Colorado, Los Alamos Scientific Laboratory, University of Alaska Geophysical Institute, University of Iowa, University of Maryland, NASA Headquarters, National Science Foundation, NASA Goddard Space Flight Center, ADNET Systems, Inc., and Atmospheric Plasma Solutions. Finally, I wish to thank various members of the Fetzer Institute of Kalamazoo, Michigan, for their helpful input and encouragement.

My resources for research were critically dependent on the Library of Congress, especially its John W. Kluge Center which, for over a year, provided research space for my wife, Carolyn T. Brown, following her retirement as director of the Center. We very productively shared that space.

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Chapter 1

Quest

AWAKENING

I was about thirteen years old that seemingly ordinary late May day when I walked down a beautiful hillside overlooking Big Stone Lake in Minnesota. My childhood self was blissfully unaware of my own complexity (10^{26} atoms, 10^{15} cells, 10^{10} neurons, etc.)[1] and of the wider context (gravitational field, electromagnetic field, ecosystems, etc.) in which I was immersed. I was naturally quite clueless about the breadth and depth of the world. Breathing in the fresh woodland air and gazing across the lake to the Dakota hills, beautifully lit by the morning sun, I was seized by a distinct spiritual experience: a sudden awakening to a sense of awe and greater consciousness of the immensity of the natural world; a new recognition of my radical finiteness and humility before an infinite cosmos; and a commitment to learning and understanding what all of this was about.[2] That moment initiated my quest to understand the fundamental nature of the universe and sparked the inquiry that would ultimately result in this book.

Feeling the soil and grass below me, I felt the throbbing life of insects, worms, and plants, and wondered how was I fundamentally like or different from such creatures? How was my radically limited self connected to various possible levels of this wondrous whole? In that unique event, I experienced a heightened awareness of our shared radical contingency, of the immensity of alternative possibilities, of the overwhelming possibility of not existing at all, of the unlikely privilege of being a healthy, sentient entity able to self-reflect, and of being able to examine my privileged perspective in ways far beyond that available to the insects and worms. I meditated on my own ignorance and fears, my radical givenness, and the unlimited possibilities going forward.

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Looking back with maturity through a philosophical lens, I see my younger self then as a radically finite, contingent being of limited perspective looking out over an equally contingent lake. I was a subject with respect to all things available as objects (including my immediate past self), a self giving rise to inevitable object-subject (cognition-dependent) relationships emerging from such finite perspectives, and yet a self acknowledging a universe of cognition-independent "things" beyond any practical reach. At the time, I desperately wanted to be given some "God's eye view" perspective that transcended my own tiny existence,[3] just as my own feeble perspective far surpassed the views of insects and worms.

Sitting in that lakeshore woodland, struggling with my own limitations, and filled with an abundance of sense impressions, I unknowingly had stumbled into my lifelong quest, a quest not just for enhanced awareness, not just for understanding the physical world, but ultimately a quest for meaning. Initially I thought that science would provide the key to answering my still inchoate questions and concerns,[4] even while some intuitive part of myself suspected that I might require a broader set of tools. While still in high school I was somehow self-motivated to read through the entire, quite sophisticated section of Western philosophy in the Carnegie Library in Ortonville, Minnesota.

In college at the University of Minnesota, with my bachelor's degree in physics close at hand, I was unclear as to whether I should go on to graduate school in physics or philosophy. My philosophy of science professor, a former member of the famed Vienna Circle of logical positivism, Herbert Feigl, advised me that if I wanted to engage the philosophy of physics, I should first learn the physics and the philosophy could come later. Wise advice! I went to graduate school in space physics, ultimately obtaining a doctoral degree from the University of Alaska. My specialty, space plasma physics, indeed helped me understand the physical world in a practical way. Yet through my college years, both undergraduate and graduate, I nurtured my passion for philosophy by taking courses in philosophy and frequently attending lectures in that field.

As my career unfolded, although pushed to the periphery of my immediate concerns, my lakeside aspirations were never far from the surface. Over the decades I continued to study philosophy as well as many areas of science and the humanities.[5] Although I never obtained a degree in philosophy as such, this runaway avocation led to my giving presentations at philosophy conferences, editing two books, and publishing over thirty papers in the field, most peer reviewed, all while continuing my career in space science.

As a young person, I did not know that a God's eye view is impossible for finite creatures. Indeed, each and every sentient organism (insect, worm, etc.) generates a world-as-perceived *umwelt* (after Uexküll[6]), which requires any perceiving entity to generate some type of stimulus-response modeling of its particular complex of object-subject relationships. We may treat such models

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PROBLEM-SOLUTION-GOALS APPROACH

"One of the main challenges for today's popularizers," reports Anthony Gottlieb, is that "scientific theories are getting weirder" (Gottlieb 2016). Yes, there are real challenges and difficulties; indeed, it can be argued that nearly all technical specialties in the past century have developed such complex levels of terminology, concepts, and application, that specialists in one field encounter serious difficulty and most often do not attempt to learn multiple disciplines. The age of the true multidisciplinary scholar, who is able to understand nearly all known fields, came to an end more than two centuries ago. Further, the creation of new understandings, knowledge, and relatively reliable facts inevitably involves complex "actor-networks" within which, as Bruno Latour states, "facts remain robust only when they are supported by a common culture, by institutions that can be trusted, by a more or less decent public life, by more or less reliable media" (Latour 2018). Such complexities and context are never properly superseded by claims for "facts" discovered from some *View from Nowhere* as Thomas Nagel has labeled it (Nagel 1986).

The principal issue here concerns the wholesale and often unnoticed and unstated migration of modern scientific methods into a domain of thought that is essentially interpretive, and where improved acts of inquiry aim at clarifying and realizing a notion of the good, rather than at simply sifting quantifiable and ostensibly value-neutral information. However limited in implementation, in this work I strive to forward a humanist-interpretive framework, as advocated by Thomas Pfau, in contrast to "strictly naturalist (or deterministic and reductionist) models of human agency" (Pfau 2015, 17). I propose that the most fundamental notions can be inferred from normal human experience; that concepts of contemporary science and philosophy can be woven together in a way that cuts through claims of quantum weirdness; that these concepts reveal a deeper reality that comports well with basic human experience and intuition; and that they move us from a very particular human quest and journey to a promising new synthesis—natural, existential, spiritual.

"Gordian knot" is a metaphor for a seemingly intractable cluster of related problems that can be solved only by thinking creatively in new ways. This book is my attempt to cut through or untie a Gordian knot of multiple fundamental philosophical problems. Although I do not claim to have solved any one of these foundational problems, I propose a preliminary sketch arising from a confluence of research developments (both in science and humanities, especially philosophy) that points to a new, inclusive view of reality. I call this the relational (*Logoi*) framework.[9] My "aha" moment came recently as an insight that numerous fragments of contemporary knowledge are coalescing

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in a coherent way. After decades of reflection and more than five years of concentrated research, I experienced a stunning sense of discovery.

The *Logoi* framework represents a synthesis of several key ideas that each have a long heritage but have not been previously integrated in the way here proposed—a creative synthesis built upon the works of numerous scholars over the centuries. Given the complexity of recent advances in philosophy and science, identifying some unifying framework has appeared more remote than ever, except for those who claim to reduce everything to science and further reduce "reality" to one core equation or a set of Platonic forms.[10] Arguably, such reductions, even if taken at face value, effectively address only a limited domain of discourse. In contrast, the present work attempts to wrestle with all reality—an unlimited domain of discourse.

Going beyond the simplistic reductions of scientism,[11] many scholarly works struggle with the full complexity of the real world, and understandably encounter innumerable complications that are both the glory and the curse of cutting-edge scholarship. These complications have led to a cornucopia of scholarly specialties in science, arts, and humanities over the past centuries, and especially over the past half century. Drawing on some advances achieved within this vast literature, the present work attempts to frame a viable systematic philosophical framework, the *Logoi* framework. I here adopt Alan White's preference for using "systematic" instead of "speculative"as a label for this approach.[12] As Alfred North Whitehead, the British-American scientist-philosopher stated, "Speculative [systematic] Philosophy is the endeavor to frame a coherent, logical, necessary system of general ideas in terms of which every element of our experience can be interpreted" (Whitehead 1978, 3). Similarly Arran Gare, referencing C. D. Broad, states that "the goal of speculative philosophy is to take into account the whole range of human experience—scientific, social, ethical, aesthetic and religious, and to develop a coherent conception of reality that does justice to all of these" (Gare 2017, 113). I will inevitably fail to reach this lofty goal; however, in a spirit of adventure, I will attempt to see how far I can push this quixotic enterprise.

Integrative efforts are too often left to reductionists,[13] who tend to neglect broader scholarly advances, and who frequently deploy ever more complex exotica, such as multiple universes, which inevitably depend on, typically unstated, philosophical presuppositions. In contrast, my approach toward a new synthesis is to ask, once again, given the full range of human experience and the universe at large, and given a truly unlimited domain of discourse, can we obtain a relatively simple set of conjunctively coherent fundamental notions that can do the job of integration? That is, can we recursively and dynamically generate from such hypothetical notions a next order set of basic concepts enabling, in turn, the full array of concepts needed to integrate the best of contemporary scholarship? In addition, can these most fundamental

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notions be empirically grounded in basic human experience without initial appeal to highly abstract concepts that are not directly utilized or reflected in such experience? My very preliminary answer to this question is "yes,"[14] provided we follow Whitehead's sage advice: "Seek simplicity and distrust it" (Whitehead 1920, 163). As "tentative formulations of the ultimate generalities," (Whitehead 1978, 8) any such framework of systematic philosophy, including hypotheses about such fundamental notions, is highly fallible. I stress such fallibility because I am a simple sentient being limited to a small planet in a remote neighborhood of an average galaxy at a particular juncture of history. Thus, I offer these suggestions with all humility before the awesome vastness and daunting complexity of the cosmos.

This work is subject to the same kinds of limitations in awareness, much less of knowledge, that Whitehead acknowledged in his defense of systematic philosophy. I strive to focus on inferences from immediate experience, deploying a methodology of testable inferences, scientific method,[15] and when appropriate, more generally scholarly analysis, while always recognizing the limits of deduction, induction, and Peircean abduction.[16] My research has led me to see the inevitable need for philosophical analysis and inference, yet with enhanced sensitivity to problems with globalized claims (e.g., onto-theology, logocentrism, Platonic realms, spatializing, and various "-isms"—see Robert Corrington (2013)) as well as various forms of reduction, both with respect to substance and process (for *substance* forms of reduction, as articulated by Hilary Putnam, see Randall Auxier (2015); for *process* forms of reduction, see Johan Siebers (2002)). Whitehead was persistent in criticizing the false certainties of philosophy: "The chief error in philosophy is overstatement" (Whitehead 1978, 7). Likewise, Isabelle Stengers promotes both moderately deconstructive and constructive conversations, through the exemplars of Gilles Deleuze and Whitehead, in a sustained critique of any one unitary framing (Stengers 2014).

Despite our very human limitations, tendencies for error and overstatement, and frequent entrapment by globalized claims, Auxier and Gary Herstein point out that, nevertheless, we always retain a commitment to some form of realism: "Scientists are almost universally realists" (Auxier and Herstein 2017, 204). Such commitment suggests the need to affirm "that *concrete existence explains the abstract aspects of experience* [such being Charles Hartshorne's credo] and not vice versa. The unexpected characteristic of our experience is that it abstracts from the flux, not that it flows concretely, which we expect" (Auxier and Herstein 2017, 2). George Lucas, Jr. points out that this emphasis on concrete experience was shared as well by both Ludwig Wittgenstein and Whitehead in the form of an "endorsement of common sense and the wisdom of common language and common life" (Lucas 1989, 137). Evan Fales as well emphasizes the centrality of experience: "Whatever

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conceptual distinctions we later impose as we theorize in order to assemble our experiences into a coherent or unified picture, we must begin here, with the experiences themselves" (Fales 1990, 220). Similarly, Whitehead stated that "you may polish up commonsense, you may contradict it in detail, you may surprise it. But ultimately your whole task is to satisfy it" (Whitehead 1917, 112).

The basic approach taken in my quest for understanding, therefore, is to focus on candidate fundamental notions that are empirically based, simple, and intuitive. As an example of a nuanced set of fundamental notions, Gare has offered the following list: "activity, order and becoming; process, structure and event; cause; and spatio-temporal position" (Gare 1994, 313). Inspired by Gare, my method is primarily abductive in contrast to the typical focus on deduction, and includes the goals of coherence, consistency, and applicability, adopted from Whitehead. Nicholas Maxwell argues for a very similar methodology, with emphasis on coherence and the empirical (Maxwell, 2017). All too often, false projections, dualities, or "perfections" (e.g., Platonic forms) are promoted as starting points whether, for example, as "absolute" laws, Big Bang initial conditions, or mathematical Platonism. Various versions of a metaphysics of perfection have a long and continuous history (reflected in both classical theism and much scientific speculation) from Plato's forms and Euclid's geometry to René Descartes's certainty, on to scientism and scientific "theories of everything." As Auxier argues, "The tradition of associating logical (or mathematical), psychological (or cognitive), and ontological necessity with one another, which I call the 'unholy trinity,' was the basis for claiming [necessary] ontological knowledge from Aristotle up to the mid-nineteenth century. As the last 150 years have unfolded, the old assumptions about all types of necessity have come unraveled" (Auxier 2013, 54). As we shall see in chapter 8, this statement is overly strong; it would be more accurate to reference here "numerous claimed necessities" instead of "all types of necessity." Nevertheless, Auxier continues, "Although most philosophy departments have not gotten the news, rationality today is based on the structure of possibility and probability, not on the structure of necessity, and knowledge today does not require necessity of any kind—logical, psychological-cognitive, or ontological" (Auxier 2013, 55). Supporting such skepticism, Lucas has shown how both Wittgenstein and Whitehead "place a heavy emphasis on fallibility" (Lucas 2003, 83). Auxier's disclaimer above arguably applies to numerous claimed necessities, but clearly does not apply to the deductive rigor of much formal logic and does not apply to certain fundamental metaphysical propositions. Overall, however, my approach is consistent with Auxier's skepticism about certainties and leverages the power of sampling alternatives and evolutionary process—harnessing diversity, error, failure, and approximation.

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Finally, the present work overall applies a *problem-solution* approach with the problems being those of the Gordian knot set, and the solution set being this draft proposal of the *Logoi* framework. This framework may also be thought of as an ecological vision, a concept applied by John B. Cobb, Jr. and Wm. Andrew Schwartz (2018), because it emphasizes the interrelatedness of processes at multiple levels.

FROM DUALISTIC THINKING TO A NEW VISION

A major impediment toward achieving a deeper understanding of our world is the tendency toward dualistic thinking, which sets up problems as simplistic "either-or" choices among abstract opposites (mind-body, self-other, black-white, etc.). Of course, there are numerous dualities that we encounter in our everyday world, as J. A. Scott Kelso and David Engstrom have documented; especially notable is their table of complementary pairs (Kelso and Engstrom 2006, 36–37). However, to insist on a particular one-dimensional view of such dualities yields reified dualisms that almost always move us from helpful distinctions to dysfunctional abstractions. Whether analyzing the binaries of the *polis* or Descartes's mind-body distinction, one is well advised to attend to Murray Code's emphasis on how such dualisms often lead to cul-de-sacs of thought.

> Not the least of the problems that the aspiring cultural therapist must tackle, then, concerns the tendency of modern philosophers to turn useful conceptual contrasts (such as body-mind, subject-object, and so on) into vicious dualisms. (Code 2007, 244)

In *Truth and Historicity*, Richard Campbell lays out the historical background for the deep strain between Greek metaphysics and biblical thinking which, although maintained concurrently, albeit fitfully, for over 1,500 years, finally fractured by the seventeenth century. This fracture "decisively occurred with the distinction between real and nominal essences, articulated by Locke" (Campbell 1992, 170) (see *On the Failure of Actualism and Nominalism* in chapter 4). Continuing, Campbell states that

> as a consequence of this split, philosophy from the seventeenth century onwards has been plagued by a series of systematically related dichotomies: of mind over against body (Descartes); of nominal essence over against real essence [nominalism] (Locke); of relations of ideas over against matters of fact (Hume); of the analytic over against the synthetic (Kant and also the positivists); of phenomena over against things-in-themselves (Kant again); of thought and language over

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in both the extent and range of humanistic scholarship. One proxy for such increase is the change in size, and access to, information content, the latter greatly enhanced by new computer and network technologies. Presently, anyone with a computer and internet access has available a vast range of information, which completely dwarfs that available to any scholar prior to the mid-twentieth century. Epstein notes that "in the past 30 years, more new information was produced than in the previous 5,000 years. A single daily edition of the *New York Times* contains more information today than an average person in the seventeenth century encountered in a lifetime" (Epstein 2012, 160).

My approach is to build a creative synthesis, based on what I view as the accomplishments of scholars over the centuries, primarily in philosophy and science. A primary goal of the present methodology is to build on the best of prior thinking and models, incorporate their strengths as much as possible, and formulate a new model that enables greater explanatory power through a constructive approach that incorporates such prior models. Such a new model can hopefully explain both the successes of prior models and their limitations. An important exemplar for such progressive model development is the way in which the strengths and limitations of classical physics have been fully incorporated into modern physics, which also provides explanations of both its own limitations and limitations of the prior model. The present work builds as well on lessons learned from the failure of many scholarly efforts over the past few decades and centuries. For example, a cornucopia of failures in understanding just the concept of time is laid out masterfully by Raymond Tallis (2017). Examples of instructive dead-ends are simplistic forms of monism, dualism, materialism, idealism, nominalism, actualism, and scientism, among others. Indeed, I have come to be skeptical of almost any -ism. One route beyond such dead-ends is that of a pragmatic strategy that is yet realistic, as exemplified in the works of Nicholas Rescher (Pihlstrom 2017). Cheryl Misak summarizes this point about Rescher's oeuvre:

> His kind of pragmatism is an objective truth-and-inquiry oriented pragmatism, rather than a subjective "anything-goes" pragmatism. According to Rescher, the contingency and fallibility of knowledge and belief formation do not entail that our beliefs are simply what our community decides or that truth and objectivity are spurious notions. That is, he offers us a real chance of understanding how it is that beliefs can both be the products of human inquiry and nonetheless aim at the truth. (Misak 2017, ix)

Some criteria for meaning are useful, most often as a critique of abstraction; as Charles Hartshorne stated so concisely, "verifiability (liberally enough construed) is valid as criterion of meaning in general; and falsifiability is

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valid as criterion of empirical meaning" (Hartshorne 1970, 21–22). An even more subtle issue concerns the, often unstated, context and presuppositions of concepts deployed in model making. Nicholas Maxwell stated it well: "Untestable metaphysical[18] [and philosophical] ideas . . . form a vital, integral part of the intellectual domain of science. It's important that such ideas, now implicit, be made explicit within science, so that these ideas can be critically assessed and improved" (Maxwell 1999, 27).

INFLUENCES AND PERSPECTIVES

My primary intellectual influences are broadly process and American philosophy, natural science, and semiotics. My more specific influences include, among others, epistemology, logic and analytic philosophy, metaphysics, intellectual history, empirical observation, and data and information systems. This work is set in context of efforts to grapple with an unlimited domain of discourse, drawing on the structural-systematic philosophy of Alan White and Lorenz Puntel (White 2014) and Charles Hartshorne's neoclassical metaphysics as fleshed out by Donald Viney and George Shields (2020) including integrative metatheories such as those summarized by Paul Marshall (2016) and various ontologies (e.g., Nicolai Hartmann (2013), Roberto Poli, and Johanna Seibt (2010)); philosophy and metaphysics (e.g., Richard Campbell (1992), George Shields (2003), and Raymond Tallis (2018)). In various areas of scholarship, my particular influences include the following: American philosophy and process philosophy (e.g., Nicholas Rescher (2017) and David Ray Griffin (2007)); speculative naturalism (e.g., Leon Niemoczynski (2011), Lawrence Cahoone (2014), and Arran Gare (2017)); information theory and semiotics (e.g., Robert Logan (2014) and Paul Cobley (2010)); and European philosophy (e.g., Richard Kearney (2003) and William Desmond (1995)). More specific areas of influence include biosemiotics (e.g., Jesper Hoffmeyer (2009)), complex systems (e.g., Robert Rosen (2000)), physics (e.g., Roberto Unger and Lee Smolin (2015), and George Ellis (2016)), and mathematics and logic (e.g., Murray Code (1995) and Nicholas Rescher (2014)), among many others.[19]

Raymond Nogar has characterized two important modes of understanding in terms of "picture people" versus "drama people":

> The first looked for a picture of things in order, a cosmic and personal worldview; the second looked for a drama unfolding. The first were restless until they felt that they had grasped something timeless, some eternal verity, and had placed themselves securely into changeless order. The second were impatient and distrustful until they found themselves in the space-time story of reality

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> unfolding, a drama in which they had a part. They wanted to be involved; dynamically identified with all reality. But the picture people wanted just the opposite: detachment, escape from the effort and effect of the sorrows and joys of biographical and temporal existence. (Nogar 1966, 16–17)

Contemporary physical cosmology is often summarized by a picture person, one who seeks and emphasizes cosmic order but in a way that tends to spatialize cosmic systems with tendencies for thing-oriented versus functional descriptions (Eastman 2016). In contrast, some drama people have repackaged their narratives into a cosmic creation story; for example, Brian Swimme's creation story (Swimme 1984) that is part of some "Big History," the latter being explicit about a human role in that story; see David Christian (2019), or William Grassie's applications of Big History (Grassie 2018).

The *Logoi* framework works with both of these perspectives yet endeavors to avoid any simplistic God's eye view framing. In both "picture" and "drama" (or story form), my quest has become both a systematic philosophical framework and an *Adventure of Ideas* (Whitehead 1933).

SUMMARY OF CHAPTERS

In this first chapter, Quest, I have laid out the motivation for this study and sketched my own half-century journey, from a childhood enlightenment experience, through decades of readings and research in philosophy, physics, space science, and related fields, to the realization of a possible new synthesis that has the promise of untying a Gordian knot of problems. Recommended readings for each chapter are provided in Appendix 1. The core of the proposed approach, the *Logoi* framework, as sketched in chapter 2, is the notion of process from the Latin *processus*—a going forward or advance. Process incorporates succession—"one darn thing after another"—and partners with two other fundamental notions: logic and relations. Each of these fundamental notions has at least two aspects: process (local/global; imbedded), logic (binary/nonbinary; triadic), and relations (part/whole; internal/external, extension, information,[20] semiotics[21]). Key components of the *Logoi* framework are the models of Relational Reality[22] inspired by recent developments in quantum physics, as discussed in depth by Michael Epperson and Elias Zafiris (2013), and augmented by Ruth Kastner and colleagues (Kastner, Kauffman, and Epperson, 2018) and Hans Primas (2017); along with process-based theories of required basic concepts, suitably updated for multiscale processes, emergence, and complex systems, especially as discussed by Campbell (2015), Seibt (2004), Siebers (2002), and Auxier and Herstein (2017). Several cross-cutting concepts are introduced along the way,

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including, among others, how our world is permeated by both information and signs.

The Gordian knot set of problems is laid out in chapter 3, and the *Logoi* framework is applied to suggest possible approaches to resolving these problems. Resolving the critically important Gordian Knots can only be accomplished through both humanistic scholarship (here, especially philosophy) and science, not science alone. As both Ludwig Wittgenstein and Alfred North Whitehead argued, "scientism" is specifically rejected.[23]

Building on this approach, I lay out tentative solutions in chapter 4 for the fundamental problems of causation, physical relations (aka "law"[24]), and emergence. Chapter 5 summarizes the intellectual history that ties together information and semiotics, the theory of signs, with process thought and speculative [systematic] naturalisms. It is important to note that the *Logoi* framework is not a logocentric metaphysics, which Jacques Derrida criticized, and which, Arran Gare points out, is "the quest for an origin or foundation in truth, reason, or the Logos . . . to find some fixed, permanent center, a transcendental signifier that will give meaning to all other signs" (Gare 2002, 42–43). Instead, my approach seeks to leverage the deconstructive critique of such modernism, opening space for a third way[25] that incorporates both fundamental logic and a semiotic and relational perspective. That is, my approach is neither modernism or simplistically post-modern, but rather seeks a coherent and integrative positive philosophy, such as that characterized by Friedrich Schelling, as argued by Gare, in his speculative naturalism (Gare 2002, 38). Gare also argues for the importance of applying such speculative naturalism in current efforts to address the environmental crisis. Finally, the *Logoi* framework incorporates elements of both Western and Eastern culture, both rational order and aesthetic order, both rational thinking and correlative thinking, both abstract relations and concrete particulars—all these imbedded in a most general science of order which, as noted by David Hall and Roger Ames with respect to the Chinese tradition of thought, can be characterized as the "art of contextualizing."[26] Arguably, there is a correlation as well between the above distinction of rational thinking and correlative thinking with the distinction of sequential and nonsequential modes of knowing (per Primas's discussion). These latter modes of knowing are based on complementarity in quantum physics which, in turn, reflects the distinction between two fundamental kinds of logic, Boolean and non-Boolean (Primas 2017), which are discussed in detail in chapter 2.

Chapter 6, which addresses the complex whole, both incorporates multiple ways of knowing and attempts to provide a philosophically grounded synthesis. My way of framing the complex whole is inspired, in part, by recent attempts to be both compatible with recent scientific results, yet skeptical of any scientific "theory of everything." The essential triadic logic that permeates

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the several fundamental notions is brought out as a centerpiece for chapter 7, which discusses a convergence of Peirce's triads and Whitehead's process, especially as outlined by Campbell (2015) and Auxier and Herstein (2017).

The final chapter provides reflections on the overall quest and focuses on the questions of ultimate context and meaning. I argue for the immense value of scholarly research in a wide variety of fields that could contribute to enhanced human self-awareness, other-awareness, and deeper understandings of reality.[27] This final chapter 8 connects new scientific results to that humanistic scholarship, which is yet again expanding the human context, historically, humanistically, and spiritually. These recent developments clearly indicate the need for updated worldviews[28] that can avoid the nihilism of mechanistic materialism and simplistic reductionisms, and that can open up space for new perspectives on human meaning and the spiritual dimension. Taken together, such research has the potential to overcome the tendency toward false dualities, false -isms,[29] made-up facts, scapegoating, racism, and the resulting strife and wars, all being largely preventable illnesses of the human condition. At a time of reduced support for the humanities, as a scientist I concur with Epstein's persuasive argument (Epstein 2012) about the singular importance of humanistic discourse in enabling the transformative work that is so critically needed.

NOTES

1. Powers of 10 are typically represented as an exponent of 10 so that 10^6 represents 10 multiplied by itself 6 times to yield one million. The number 10^{26} is an inconceivably large number for which we require abstract representation.

2. My most vivid spiritual experiences have been rare; in contrast, as documented by Kathleen Duffy, Pierre Teilhard de Chardin's spiritual experiences were frequent and well integrated into his life journey (Duffy 2014).

3. For the purpose of this work, in general, I am not distinguishing "existence" and "reality," broadly interpreted. Philosophical analyses of these terms is essential but varied; see Milton Munitz (1974).

4. Science is a highly diverse enterprise that, at its core, aspires to develop quantitative, context-independent models of natural systems. At the same time, there is a vast network of practices of science that incorporate context dependence, normative constraints of policy, resources and domains of reference that often transcend science issues *per se*; for example, see Stephen Norton and Frederick Suppe (2001).

5. Unless otherwise specified, "philosophy" in this work refers primarily to Western philosophy, even while recognizing that there are great schools of philosophical inquiry in East Asia, South Asia, and Persia, among others.

6. John Deely argues that for Jacob von Uexküll the *umwelt* is above all "a lattice and network of ontological relations between organism and environment, elevating

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Ames attempts to demystify the distinction by pointing out that Peirce's abductive reasoning is "a more familiar form of correlative thinking" (Ames 2016, 40).

27. When discussing levels of reality, Basarab Nicolescu distinguishes the real, which is always hidden, from reality "that *resists* our experiences, representations, descriptions, images, and mathematical formulations" (Nicolescu 2014, 105). Here I simply use the term "reality" to refer to that which exists and resists, independently of ideas concerning it, without any hypothesis about ultimate hiddenness.

28. Worldviews are fundamental conceptual frameworks for human interaction, most often not articulated. They can range from core philosophical presuppositions to active models for world encounter. A Christian worldview and some alternatives have been summarized by James Sire (2014) and J. P. Moreland and William Lane Craig (2003). Mehdi Golshani has recently articulated why "Science Needs a Comprehensive World View" (Golshani 2020). My use of the term is independent of any particular religious or philosophical framework—everyone by definition has a worldview, including atheists and agnostics.

29. Standard -isms often depend on false dualities or partial framings of basic philosophical positions. In particular, the *Logoi* framework does not fit any of the standard "-isms" typically discussed as, for example, in *The Ism Book* by Peter Saint-Andre (2017).

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Chapter 2

Relations—*Logoi*

In this chapter, I will introduce core elements of the *Logoi* framework, first using a phenomenological analysis of immediate experience, second laying out fundamental questions and complementary philosophical analyses, and third leveraging recent interpretive advances in contemporary science, especially quantum physics. For the latter, quantum physics is our most fundamental theory concerning the nature of matter and energy. Further, it is the most successful theory ever formulated, rigorously tested for almost a century. Unresolved issues are primarily matters of interpretation, which I will address in this and the next chapter.

FROM EXPERIENCE TO MULTILEVEL CONTEXT

The immediacy of my youthful, lakeside spiritual experience inspired in me a strong intuition of elemental succession in the universe. I felt this experience to be radically contingent, just one among a near infinity of possibilities, most of which excluded any account of my very being. Thus, I directly felt and affirmed possibility as part of reality[1] along with the actuality of my hands clutching the grass and soil of the hillside.[2] Simultaneously, I felt the radical finiteness and localness of my perspective on the world, my world-as-perceived—my *umwelt*. Yet that highly localized perspective was not merely self-contained; it felt clearly linked to a larger context. Over the years, through both scientific research and personal experience, I have come to affirm that such local-contextual framings have a basis in reality, reflected in any and all input-output-context relationships. Scientific description and approximations, and various tools of model making, frequently employ simple input-output pairings because that methodology is useful and effective.

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However, as I noted above, real-world interactions, considered in their ontic fullness, always involve sequences of triads (input-output-context).

Applying a phenomenological analysis to my lakeside experience suggests the following fundamental notions: (1) process—succession,[3] (2) logic of both actuality and potentiality,[4] and (3) relation, including local-global relations,[5] all associated with the concept of process. Eva Brann, who studied the particular Greek usages of the term *logos*, as well as its particular Greek origins, argues in her work, *The Logos of Heraclitus*, that for her *logoi* implies both flux (process) and relations (Brann 2011). Tallis points out that "there are many translations of *Logos* . . . The register of its tentacular meanings would include ratio, proportion, principle, standard; reasoning power; hypothesis, grounds for belief or action . . . to gather together, to arrange, and to put in order . . . that which results in a world picture" (Tallis 2018, 32). My *Logoi* framework works with all of these meanings and in multiple ways, and can be characterized by a term that William Desmond has emphasized, *metaxu*,[6] the Greek word for "between."[7]

> Metaxological philosophy holds that to be is to be between. Nothing is defined purely through itself alone; all that is is in relation; this relatedness encompasses being in relation to other things, as well as self-relation. Metaxology refers us to a logos of the between. The between is hospitable to plural intermediations. (Desmond 2016, 423)

The elements of experience articulated by the *Logoi* framework are so fundamental that they may, as Griffin argues, represent cases of hard-core common sense (Griffin 2007), that is, concepts that are presupposed in practice. Does anyone ever have an experience—without a concurrent sense of succession?—without some sense of alternative possibilities?—without some awareness, however indirect, of a more encompassing global context for that immediate local experience?

ELEMENTS OF THE *LOGOI* FRAMEWORK

Succession can be simply thought of as "one darn thing after another." Consider then all events as asymmetric sequences of discrete actualizations ordered by a definite logic (two-valued, Boolean logic[8]). "That production is an asymmetric relation," as Fales states, "is something we experience. We do not merely experience forces as having location, magnitude, and direction. We experience them as acting upon something—in the case at hand, upon our bodies" (Fales 1990, 34). For the *Logoi* framework, the overall context for succession depends on *both* the above standard (Boolean) logic

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of actualizations (Latin *res extensae*) *and* a logic of potentialities (Latin *potentia*, plural—*potentiae*), which is multivalued, non-Boolean logic.[9] As Randall Auxier has stated, "The actual and possible together effectively form what [Josiah] Royce means by the 'real,' and the order we hypothesize for those relations is the universally mediating relation of time. The 'possible' is associated with the future and the 'actual' with the past, while the present moment is an indefinite duration that links what is actual to what is possible in overlapping . . . nested hierarchies of time-spans" (Auxier 2013, 59). Fundamental process incorporates such hierarchies of events through relentless input-output succession within context (constraints and *potentiae*), and such process is both local and contextual, a multilayered whole, the "local-global." Emergent temporality is built into such process and mediates the temporal modalities by providing basic ordering relations.

Potential Relations (*potentiae*)—Most importantly, the "real" is constituted by both the actual and the possible or, more fully expressed, potential relations (*potentiae*). This distinction has a long history for, as Michael Epperson points out, "Aristotle held that potential and actuality are two species of reality . . . that actualities give rise to *potentia*, which give rise to actualities" (Epperson 2016, 62). Ronny Desmet highlights the Whiteheadian idea, going back to the *Organization of Thought* (1917), that "all thought—common sense thought, scientific thought, and mathematical thought—is propositional, and always involves both concrete actuality and abstract potentiality, even though the share of the former component decreases, while the share of the latter component increases, as we shift from common sense to science to mathematics" (Desmet 2010a, 152). In his work *Logic in Reality*, Joseph Brenner shows in multiple ways how the real is both the actual and the possible (Brenner 2008). To appreciate the reality of potential (yet not actualized) relations, consider how the many paths that you did not follow are important for who you are now; consider the multiple scenarios (some that you consciously filter out; many that you don't) under which you would have hit an oncoming car with just a small, careless change of steering. Such alternative scenarios indicate how paths not taken can make a "real" difference. Paths not taken are effectively infinite; actualized paths are finite, unique, and sequential.

The concept of relations, whether actual or potential, incorporates part/whole, internal/external, relations of relations, and algebras of relations, this last concept being addressed in contemporary mathematics through category theory (for details, see five sections below beginning with *The Relational Reality Model*, and the section on *A Theory of Relations for Modeling and Process—Category Theory* in chapter 6). Fundamental relations are either triadic (semiotics) or dipolar (part/whole—mereology). As Duane Voskuil states, "Any whole/part relation is necessarily dipolar—one side of a dipolar relationships, and *potentiae* for their realization—all features foundational to contemporary field theory in physics.[16] Temporality and spatiality are coextensive with such process, and the asymmetry of time emerges from the inevitable successiveness of such process. Arguments for the bidirectionality of time are based on models, effectively of pre-space trajectories in *potentiae*, not directly on measured physical parameters.[17] Symmetry applies to pre-space *potentiae* and trajectories but the measurement process and successive actualizations break such symmetry.

Alternative *potentiae*, framed in terms of alternative trajectories in pre-space, which can be thought of as "pre-space paths," can be modeled as sums of action parameters. Optimizing such sums (either to obtain a minimum or a maximum, depending on the representation used) enables the derivation of most physical relationships (laws of physics)[18] (for details, see *"Law"—From Entailment to Constrained Processual Histories* section in chapter 4). I am here speculatively expanding on the constraint interpretation for emergence, which James Blachowicz proposed to encompass the emergence of all physical relations (Blachowicz 2012, 205).

Process/logic/relations are the most fundamental notions; physical relations, although basic (for science), are derivative relative to this most fundamental (philosophic) level. Nevertheless, very high levels of predictability can arise from such probabilistic law with constraints (boundary conditions, initial conditions, context), but they are not entailments (viz., involved by necessity) as in deductivist accounts.[19] The ultimate basis of such physical relations, within multiple levels of constraint on *potentiae*, may be revealed when further imbedded in constraints of metalogic. For example, recent research in fundamental logic by Nick Rossiter and Michael Heather (2005, 2018) indicates that the "arrow" in category theory[20] is a promising key concept for an ultimate logic. In turn, this result is compatible with both fundamental triadicity and the above discussion of fundamental notions focused on process, logic, and relations, as well as inevitable context.

Summarizing once again, this time in terms of logic, one can conclude from the fundamental theory of relations (category theory), and semiotics, that triadic relations (e.g., input-output-context) are most fundamental and that dyadic relations (e.g., input-output only) are derivative even though they often provide useful abstractions and approximations. "Symmetry is immunity to a possible change," as Joe Rosen stated (1995, 2), and many dyadic relations can be represented in a symmetric way. Yet adding a third term to create a triad will most often create an asymmetry. This important result arises from fundamental logic as shown by logician George Shields.

> The *most* definitive of functions, the only functions capable of defining all others in singular fashion, are the Sheffer functions, which possess a triadic

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asymmetry that yet *includes* dyadic symmetry . . . symmetry *within* an all-embracing asymmetry. (Shields 2003, 20)

This result is supported as well by Rosen, a leading expert on symmetry theory in physics. Reflecting on Hartshorne's identification of an ultimate pattern of "symmetry within an all-embracing asymmetry," Rosen states that "asymmetry is a necessary condition for symmetry. For every symmetry there is an asymmetry tucked away somewhere in the world" (Rosen 2004, 134). Further details are provided in the *Symmetry in Science* section of chapter 4.

As part of the *Logoi* framework, I hypothesize that these results point to the conclusion that dyadic relations do not, in fact, ever exist in the real world (versus the world of abstract modeling) because of the inevitable involvement of context; thus, the triad input-output-context is completely general.[21] Importantly, this result, as well as other elements of the *Logoi* framework, effectively denies key metaphysical claims of scientism,[22] which Don Ross, James Ladyman, and David Spurrett (2007) argue for in their work *In Defense of Scientism* as part of a naturalistic metaphysics. However, they presuppose actualism and their discussions of the basic physics fail to include reference to the Boolean/non-Boolean logic distinction, which is central to my analysis and, arguably, central to quantum physics itself. Further, they call "the synthesized empiricist and materialist—and resolutely secularist—stances the scientistic stance" (ibid. 64). They argue that living out this stance "requires, most importantly of all, paying close attention to the actual progress of science" (ibid. 65). Yet, ironically, this "scientistic" practice should cause them, in light of the fact that the domain of the real encompasses both the actual and *potentiae* (given the latest developments of quantum physics), to re-think such materialist and scientistic commitments!

Potentiae, or potential relations, characterize all domains of process. My overall argument for the *Logoi* framework correlates with three roles for *potentiae*:

1. *potentiae* or potential relations, along with actuality, is an essential component of the "real"; this hypothesis derives from both human experience and philosophical analysis, with their multiple forms of creative emergence, and from recent results of quantum physics;
2. *anticipatory logic*, associated with such *potentiae*, enables important new understandings in the analysis of causation, physical relations, biological anticipatory systems, and human experience (see *Complex Systems* section of chapter 4);
3. *correlations of potentiae* can enable the coherence of physical relations as observed at astronomical scales (the "principle of universality"[23]) (see chapter 4); among human systems, such coordination could even help us to understand evidence for archetypal phenomena (see Harald Atmanspacher

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and Christopher Fuchs, 2014) and certain psychic phenomena (see Griffin, 1997) including anomalous cognition (see chapter 8).

The *Logoi* framework incorporates both fundamental principles of relation and concepts relating both the contingent, as focused on naturalistically by William Wimsatt (2007) and more theologically by Hartshorne (Viney and Shields 2020) and Roland Faber (2018), as well as the non-contingent dimensions of being and becoming, which is Lorenz Puntel's focus (2008). The contingent dimension includes both the entirety of Boolean logical actualizations and non-Boolean *potentiae*. Yet, as we will see in chapter 8, it is impossible for everything to be simply contingent. Augmenting such argument, Whitehead's ontological principle affirms that any reality that accords to an abstraction must depend on actual entities upon which it is composed or grounded. By this principle, only actual things can act; thus, *potentiae*, although demonstrably real, can only act via some embodiment in one or more actual things. From this we infer that there must be some ground for *potentiae*; concurrently this provides a basis for both logical truths, mathematical forms and ethical norms, potentially solving fine-tuning problems as well as both the Platonic and the Benacerraf problems[24]—see Griffin (2007, 56) (also the *Systematic Philosophy and Ultimacies* section of chapter 8).

The importance of metaphysical possibility is also emphasized by Nicholas Rescher as follows:

> To account for the being of contingent existence at large, one has to impose the burden of explanation on something that is itself entirely outside the realm of contingent existence and of existential fact. But where can one possibly look for explanatory resources if the realm of actuality, of "what there is," is not available? The answer is clear: we must look to the realm of possibility, of what *can possibly be*. For if reality is to have a basis, then *possibility* is the only available prospect . . . What is thus called for here is a principle of explanation that can effect a transit from possibility to actuality. (Rescher 2017, 15–16)

The *Logoi* framework enables this transit from possibility to actuality in multiple ways, via our analyses of time and causation, and quantum physics, among others. Indeed, such transitions are reflected as well in our fundamental tools for analysis. As Ronny Desmet points out, Whitehead "conceived both algebra and logic as symbolic tools to support the mathematician's essential activities of recognizing, entertaining, and applying relational patterns; and that both led Whitehead to disentangle pure and applied mathematics, and to illuminate that the essential pure-applied interplay of mathematics and physics is a high-level expression of the potential-actual dialectics of human thought" (Desmet 2010b, 225). As the fundamental tool for the analysis of

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pattern, mathematics works basically with potential relations (*potentiae*) in combination with supporting hypotheses about modeling the world and correlating measurements.

LEVERAGING INTERPRETIVE ADVANCES IN CONTEMPORARY SCIENCE

As noted above, the *Logoi* framework is leveraging a combination of scholarly advances that includes, among others, progress in understandings of quantum physics, logic, philosophy, and semiotics. Such progress has clarified the concepts of physical relations, functions, temporality, causal orders, and logics, including the distinction of the logic of actualization and the logic of *potentiae* in terms of the Boolean/non-Boolean logic distinction. Advances have been made as well in understanding local-global relations and multilevel relations of input-output-context (see section *Causal Orders, Form and Fact, Potentiae and the Actual* later in this chapter).Up through the nineteenth century, it was plausible to take the sequence of events as just that,

> a simple sequence, and to map such onto rulers or the number line, thus, effectively spatializing time and presuming simple entailment. The multiple problems with spatializing time have been systematically raised by Milič Čapek (1991) and more recently surveyed by Tallis (2017). Further, with the advent of James Clerk Maxwell's field theory, and modern physics based on such field theory (indeed, the core of modern physics), the interpretation of both the concept of mathematical function (for physics) and thus the understanding of sequences in nature (and of time) have required a much richer conception that involves process and relations at multiple levels, as John Jungerman (2000), Leemon McHenry (2015), and others have argued. As Tim Maudlin states, "Contrary to common belief, relativity does not *spatialize time*, it rather *temporalizes space*" (Maudlin 2016).

The mathematical function is a concept central to modern physics, and such is notably exemplified in Whitehead's work as a mathematical physicist, initially in his 1884 thesis at Cambridge University on Maxwell's new field theory, and continuing through his *Principles of Relativity* (Whitehead, 1922). Whitehead recognized in his work three key features of relation in general, namely, activity (~*potentiae*), differentiation (~actualization), and ordination (~law-like relation). Further, physical relations can arise from optimizations in *potentiae* "space," as with the principle of least action[25] (see discussion on physical "law" in chapter 4.) In addition, these three key features map as well to the Peircean triunity (firstness, secondness, thirdness).[26] Thus, the heart of modern physics,

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which includes the mathematical concept of function, and modern field theory, builds into itself a framework of relation that is highly flexible regarding the nature of the variables deployed. Indeed, Bradley's generalized functional analysis enables a "universal account of instantiation in terms of three, irreducible or subsistent, elements, which are necessarily nonconceptual in nature because they are the irreducible elements of activity: namely, infinite mapping activity, free difference or singularity, and free synthesis or individuality" (Auxier and Herstein 2017, 79). Using the notion of an iterative map,[27] Bradley explains this framework of relation in more detail as follows:

> The principle of iterative mapping activity can thus be regarded as a ontological generalization and constructivist reinterpretation of the Plato-Frege theory of numbers as serial relations or connectives in series. Its general significance can be stated this way: subject and object, as well as subject and predicate, are not here fixed ontological opposites. They are not fundamentally different in nature or kind. Rather, they are the basic states or sequential relations of finite instances of iterative mapping. For in the infinitely iterative, threefold series of mapping, a finite instance switches roles from being a successor mapping, or synthetic subject, to being the predecessor, object, or basis, and thus the predicate, of those mappings which are its successors and for which it has the role of a genetic or environmental domain or inheritance. (Bradley 2003a, 82)

Bradley's treatment of iterative mapping activity is analogous to how I, as "subject," presently experience objects in my environment in addition to the "object" of my immediate past self. A moment later, that "subject" switches roles and becomes the immediate past self (now as "object") of my immediate successor self as "subject." We will see later in this chapter, in *The Relational Reality Model*, how this process of succession is embodied in fundamental quantum process and includes all three elements of Bradley's generalized functional analysis (mapping activity, difference, and synthesis).

In addition to the Relational Reality model, discussed immediately below, this ontological generalization of the function as a mapping activity is another component of the *Logoi* framework, which is now seen as inclusive of both quantum process and fundamental mapping activity, augmented as well with both the modeling schema and anticipatory functionality of complex systems (see *Complex Systems* in chapter 4; also Robert Rosen, 2012).

PROBLEMS OF REDUCTION AND SCALE

The methodology of science is basically that of careful observation, experimentation, and model making, and the goal of the latter is to identify effective

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variables (hidden or not), correlations of such, and so on. In many cases, a common underlying metaphysical claim (often unstated) is that of determinism with its corollary assumption that the "real" is fully reducible to determinate actualities and unique trajectories (in the relevant phase spaces). In response to this claim, I ask why should we consider the "real" as needing to be so narrowly constructed?

Real consequences derive from a much broader set of real relations as argued above in *Elements of the Logoi Framework*. In particular, consider the many alternative choices that you did not make within the past few days, consider the innumerable alternative ways whereby you could have been hit by a passing car, or consider the alternative scenarios that you are constantly processing when driving, fully aware that just a small, careless change of steering (by you or the driver of an oncoming car) could lead to an accident or your own untimely death. Such alternative scenarios are major inputs to our actual choices and help us to drive safely. Such safe driver methods show how paths not taken can make a real difference. Paths not taken are effectively infinite; actualized paths are finite, unique and sequential. For those who insist that the real is reducible to nothing but the actual and introduce some actual "hidden variables" to satisfy the requirements of quantum measurements, how can we properly test such hidden variables that are entirely excluded from any direct measurement—are manipulations of theory alone sufficient to overcome these limitations? Such problems continue to haunt both physicists and philosophers.

The essence of my book and the *Logoi* framework is to challenge such actualist presuppositions and consider what consequences and solutions follow from that intellectual shift. I will now argue against the presupposition associated with the pattern noted above: namely the presupposition that the "real" is nothing but the "actual," or actualism.[32] Recent convergence in research (theory and experiment) in quantum measurement has yielded progress in both the standard Copenhagen interpretation and the decoherence interpretation.[33] Combining these results with new developments in mathematics (especially category theory, an algebra of relations), and in philosophical analysis enables an interpretive framework for quantum physics that provides viable interpretations for all known quantum experiments and does so without introducing new physics beyond basic, highly tested quantum physics.

This Relational Reality approach,[34] pioneered by Epperson (2009), and Epperson and Elias Zafiris (2013), a central component of the *Logoi* framework, in addition to independent research by Ruth Kastner (2013) and along with independent work by Hans Primas (2017), shows the need to make the distinction, as discussed above, within the conception of full ontological reality of *both* actualizations *and potentiae* (Kastner, Kauffman, and Epperson,

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2018). Actualizations have the essential characteristics of givenness and place; *potentiae* provide a needed basis for physical relationships through the application of optimization principles in possibility "spaces" (*potentiae*) (e.g., to minimize an action variable in physics when applying the principle of least action;[35] for details, see *"Law"—From Entailment to Constrained Processual Histories* section in chapter 4). In previous work, these researchers independently developed quantum interpretations that emphasized the importance of this distinction and, in that sense, their approaches are complementary. The Relational Reality model, in particular, requires this distinction between the logic of actualizations (standard Aristotelian or Boolean logic) and a non-Boolean logic for *potentiae*; real-world applications of these logics necessarily require as well (at least implicitly) three components (overall a triadic logic), covering input-output-context.

In summary, the Relational Reality approach accommodates the highly successful Copenhagen interpretation as applicable to the logic of actualizations, with epistemological emphasis, and adds a category-theory-enhanced realist treatment, building on the decoherence interpretation, capable of handling the logic of *potentiae* as well. In this way, we can avoid the presupposition of actualism, which has arguably been a major impediment to understanding the basis for indeterminacy in quantum physics.

The past century's flirtation with actualism is now being superseded by several new results in both philosophy and quantum physics. In addition to potentiality, as pointed out by Nathan Houser and Christian Kloesel, Peirce also extensively treated issues of context-bound reasoning and abduction, all relevant to these new developments (Houser and Kloesel, 1992). For quantum physics, as Epperson and colleagues state, "local Boolean measurement contextuality is not merely an epistemic coordination, but rather an ontologically significant, 'logical conditioning' of *potential* outcome states such that they can evolve, through coherent integration, into *probable* outcome states—a conditioning that *always* occurs in quantum mechanics" (Epperson et al. 2018). Several scholars have analogously argued for the physical reality of *potentia*. Early work on triadic logic, or the "included third," as Basarab Nicolescu documents, was carried out by Stéphane Lupasco (1900–1988), a philosopher of scientific formation (Nicolescu, 2015). Jeffrey Bub references various works in quantum logic from the late twentieth century that address the question of non-Boolean logics (Bub 1997). Extending early work by Yuri Orlov on the logical origins of quantum mechanics (Orlov 1994) and working with Clifford algebra, Elio Conte argues for a triadic logic basis for quantum physics, which he interprets as involving self-referential processes that enable "a transition from potentiality to actualization" (Conte 2011, 115). As stated by Epperson and colleagues, "Unlike the classical, *bipolar dualism* of physical objects and conceptual objects (e.g., Cartesian matter and mind),

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which are mutually exclusive categories of reality, actuality and potentiality are understood as a *dipolar duality* in quantum mechanics: they are mutually implicative categories of reality in that neither can be defined in abstraction from the other" (Epperson et al. 2018). This is because, ontologically, fundamental quantum process comprises both the logic of actualization (Boolean logic) and the logic of *potentiae* (non-Boolean logic), and separating these components always involves some form of abstraction, model making, or approximation, however precise may be the approximation (e.g., taking precise measurements, inevitably involving approximation, of quantum states at two distinct times for a quantum physics application).

CAUSAL ORDERS, FORM AND FACT, *POTENTIAE* AND THE ACTUAL

Constraints on the causal order will be further discussed in chapter 4. However, I here focus on principal concepts of the Relational Reality model, and recommend Epperson and Zafiris's pioneering work for its detailed exposition (Epperson and Zafiris 2013) augmented by concise summaries by each author, published later in an edited volume (Epperson 2016; Zafiris 2016). Essential for quantum physics are both the causal order, viz., the physical causal order, sometimes termed "efficient" cause, and the logical order, an order that is logically conditioned.[36] Quoting Epperson and Zafiris:

> The correlation of the asymmetrical relationship depicted by "cause-effect" statements with the asymmetrical relationship depicted by "if-then" statements has been an infamous philosophical problem since the time of Plato because while it is easily demonstrated, it cannot be proven by derivation or deduction from some more fundamental principle. Even classical mechanics provided philosophers of the early modern period with no readily discernible indication of why the physical order of causal relation correlated with the conceptual order of logical implication. As Hume famously argued, one cannot ever "directly observe" causal connection, any more than one can directly observe logical implication; rather, we infer causal connection only after directly observing system states in conjunctive relation—e.g., before and after a measurement interaction. (Epperson and Zafiris 2013, 58–59)

The mutual implication of the causal and logical orders discussed here interrelates the logical orders of actualizations and *potentiae* and further emphasizes the limitations of direct observation. For any scientific work, from successive measurements and theory, we "infer causal connections" that we inevitably cannot "directly observe." Decades of such inference,

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model making, theoretical work, and testing has led to the highly successful quantum physics that we now inherit and struggle to properly interpret. The Relational Reality model, building on the unparalleled practical success of quantum physics, utilizes this distinction of the causal order and logical order, including the associated logics of actualization (Boolean) and *potentiae* (non-Boolean), to provide a highly productive and intuitive interpretation.

Within this approach, any and all particular measurement outcomes, or data, may be direct observations of particular actualizations that we can represent in Boolean propositions. From such data, we can reasonably infer causal connections, logical implications, superposition, or entanglement effects that cannot be directly observed. Such inductive or abductive inference is a standard part of the scientific process. Epperson and Zafiris continue:

> Quantum mechanics . . . provides a strong indication that the asymmetry of the order of causal relation presupposes the asymmetry of the order of logical implication, yet cannot in any way be reduced to the latter; for its fundamentally indeterministic nature, both at the level of theory and empirical practice, utterly precludes any such sheer assimilation of contingency to necessity—e.g., in the spirit of Spinoza or Leibniz. Rather, quantum causality's necessary presupposition of the logical order entails simply that the causal and logical orders are properly understood as mutually implicative at the level of fundamental physics. Again, it is an essential presupposition of quantum mechanics that universally, every local measurement context is structurally Boolean—that is, every local context can be represented mathematically as a Boolean subalgebra, or alternatively as an equivalence class of Boolean subalgebras. It is by this presupposition that all local contexts are globally relatable coherently and consistently (as is presupposed by every physical theory whose laws are presumed to hold universally). (Epperson and Zafiris 2013, 59)

Here, Epperson and Zafiris emphasize the importance of distinguishing the orders of causal relation and the order of logical implication, in turn the Boolean order of contingent actualizations versus the non-Boolean order of *potentiae* and local to global coordination, a "logical causality." Here we witness local-global linkages (see below) as well as why the claim that any "assimilation of contingency to necessity" (as presumed in claims of absolute determinism) is fundamentally in error, both because of the indeterministic features of quantum physics, based on both theory and experiment, and because of the critical distinction of the causal and logical orders.

As an example of the Relational Reality model, and in the spirit of Whitehead's analysis of an actual entity but here updated to accommodate new developments in quantum physics, I here outline the workings of fundamental quantum process without reference to any particular scale. Consider

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then the process associated with an actual entity or "dynamic particular" (DP) (using Hartshorne's expression). First, there are the several inputs of the causal order: input particulars (i.e., past DPs, especially the immediate "past self" DP and input fields (various quantum fields, electromagnetic fields, etc.)), these being the focus of most mainstream physics accounts. Second, there are the constraints and considerations affecting both the causal order and the logical order (boundary conditions, initial conditions, structures of Boolean context), being a focus of George Ellis's book on *How Can Physics Underlie the Mind?* (Ellis 2016). Third, there are real effects of *potentiae* and non-Boolean context, which are emphasized in Epperson and Zafiris's monograph, that include all three of these modes affecting fundamental process. In the Relational Reality model, successions of DPs are sequences of fundamental process input-output functional pairings, always within an input-output-context triad. The output of one individuated, Boolean actualized DP is necessarily part of the input to the successive next DP (but never the sole input due to the triadic fundamental structure of such process). Specific space-time or DP outputs are part of actualized, Boolean characterizations of such process, but as such never enable a full account however much they may represent useful ways to portray dynamical system trajectories, quantum field interactions, and output measurables. Inevitably, the logical order and associated *potentiae* have real effect on DPs. Further, complexes of DPs may themselves individuate in multiple ways and multiple levels, and the innumerable possibilities for such complex relations enable complex systems emergence as described by complex systems theory (see *Complex Systems* in chapter 4). The *form* of things is constituted by constraints of context, *potentiae* and the logical order; *facts* arise from individuated, actualized dynamic particulars. Both form and facts are essential; any nominalistic facts-only account is necessarily incomplete (see *On the Failure of Actualism and Nominalism* in chapter 4). As another example of the Relational Reality model, and in application to describing electrons, Epperson and Zafiris state that,

> the electron, in other words, is always observed as actualized, in either one state or another, in satisfaction of PNC [Principle of Non-Contradiction], and never *observed as potentialized*—i.e., as a superposition of potential states in violation of PNC. In this way, superpositions are properly understood as relations of successive actual states, initial and final, via an appropriate measurement interaction.
>
> In quantum mechanics, this relation is fundamentally describable as an evolution of: [1] a pure state of *potential* outcome states (these are not mutually exclusive and can violate PNC), to [2] a mixed state of *probable* outcome states that are [a] mutually exclusive (satisfying PNC, i.e., "*at most* one outcome state will be actual upon measurement") and [b] exhaustive, in that the probability valuations,

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> element's "internal relational structure"—i.e., its internal relations to other elements and their relations. (Epperson and Zafiris 2013, 65)

Here we witness the introduction of the critical distinction of internal relations versus external relations in the application of quantum physics, in contrast to classical mechanics which is often characterized as only requiring external relations of isolatable substance and trajectories in classical phase spaces. If a complex system is characterized only by external relations, then one can conceivably support a substance-oriented, facts-only nominalist description. Indeed, Bertrand Russell rejected internal relations as inevitably leading to a problematic monism, and promoted a nominalistic logical atomism whereby the world consists exclusively of independently existing things in external relation. Instead of Russell's stark contrast of external vs. internal relations as pluralist versus monist extremes, McHenry highlights Whitehead's third approach. "Crucially, Whitehead's view of prehension does not treat the relations as abstractions, as entities in their own right, but rather as concrete functions of actual occasions. The relation is the present occasion's absorption of past actual occasions in its process of self-creation. In this manner, the unity of the universe grows from bottom-up. This marks the most radical departure from the position Russell advanced" (McHenry 2017, 325). Details on Whitehead's concept of prehension are given in chapter 4, sections *Unified Process Approach to Causation and Emergence* and *Generalizing the Function*.

Whitehead's third approach is supported by quantum physics for which, in the inevitable combination of local and global relations, along with "asymmetrical internal relations of relations," we now have requirements for both internal and external relations involving both form and fact. Further, the standard set theory, classical local-global mereology is displaced here with category theory mereotopological relations that are capable of handling the concept of "inducing the global" via contextual Boolean subalgebras, and structure-preserving relations between alternative contexts.

Several issues of local context, internal and external relations, and global system are brought together in quantum measurements, which always involve a certain level of self-actualization. Epperson and Zafiris express this as follows:

> The "choice" of any particular measurement context for any particular actual occasion in the global system cannot simply be derived in the classical sense of an experimenter choosing a particular device. The most one can say is that every quantum actual occasion has its own particular local context, which is constitutive of itself . . . This "self-determination" of an actual occasion's subjective standpoint/local context is a signature feature of Whiteheadian metaphysics. But it is also the case in both Whiteheadian metaphysics and quantum mechanics that the local

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measurement context of a novel actual occasion-in-process, though not externally determined, is nevertheless internally conditioned by virtue of its internal relatedness to its dative world. In quantum mechanics, this is evinced by the fact that the presupposed global logical structure is defined by a Boolean localization scheme, where compatible local Boolean contexts overlap, and the indexical local measurement context must be part of this overlap. (Epperson and Zafiris 2013, 164–165)

Here the result that "local measurement context must be part of this overlap" points to how any specific dynamic particular (DP), encompassing both fact and form, involves both internal and external relations at multiple levels, local and global, such that, directly and indirectly, any DP is imbedded in a multilevel web of relations. In practice, most such relations can be neglected in approximations and models for (methodological) reductive analysis but, ontologically, for any truly in-depth scientific *and* philosophical analysis, the world is incredibly interrelated.

The Relational Reality model provides explicit synergy between the extension of the local to the global, and restriction of the local by the global. Epperson and Zafiris provide details about such mutually implicative local-global relations as follows (setting aside category-theoretic and other mathematical details):

the fundamental dipolar process in which this framework is anchored—the essential process of quantum mechanics—is [1] the asymmetrical internal relation of a *global outcome state* to locally contextualized measurement outcomes (i.e., *extension of the local to the global*); [2] the asymmetrical internal relation of locally contextualized measurement outcomes to the *global initial state* (i.e., *restriction of the local by the global*). Again, it is a fundamental principle of quantum mechanics per the Kochen-Specker theorem that this dipolar process excludes the possibility of global Boolean contextualization, either synthetically via extension, or analytically via restriction. (Epperson and Zafiris 2013, 57)

This key passage reveals the fundamental reason why any and all God's eye view framings are incorrect, or at least misleading—it is because, by working only with two-valued Boolean algebra, unique global Boolean contextualization is prohibited. In other words, there is no unique specification of the global, and we must work with the coordination of multiple local Boolean frameworks. Epperson and Zafiris further emphasize this critical result as follows:

The constituent facts of this totality, in other words, are not determinate; they cannot *all* be assigned definite bivalent truth values (i.e., *either* true or false) such that PNC and PEM are satisfied among *all* possible relations of these facts. This totality, then, is not only epistemically indeterminate globally; it is ontologically

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> indeterminate locally—that is, as locally *constitutive* of the particular quantum measurement event internally related to it . . . it is via this dipolar process of asymmetrical internal relation that manifold local Boolean contextualized facts can be coherently and objectively integrated nonlocally—even if not comprehensively as a global Boolean totality—such that PNC and PEM condition causal relations not only *within* local Boolean contexts, but also *across* these contexts, even when measured systems are spatially well-separated. It is via asymmetrical internal relation, in other words, that a global totality of facts can be *coherently* internally constitutive of a local quantum process. (Epperson and Zafiris 2013, 57–58)

As we would expect for the diversity of *potentiae*, characterizing the global is inevitably not univocal, and such totality is "epistemically indeterminate." As well, due to the inevitable successiveness (input-output-context) of quantum process, including both dynamic particulars and *potentiae*, all quantum process is not causally closed but "ontologically indeterminate locally." Nevertheless, in spite of these indeterminacies, it is yet possible, by using asymmetrical internal relations, to properly characterize how a "global totality of facts" contributes to ongoing quantum process. Within the Relational Reality framework, this is the basis for the entanglement phenomenon of quantum physics.[39]

The importance of triads in fundamental process, and the inevitable triad of input-output-context or, as often expressed in application to quantum experiments, system-detector-environment, is emphasized by Epperson and Zafiris as follows:

> the inclusion of environmental relations in the quantum measurement formalism is not only justified; it is arguably prescriptive if quantum mechanics is to be considered a fundamental physical theory rather than merely a methodology. This is because "system," "detector," and "environment" are always formally entangled in quantum mechanics, such that their partitioning is purely arbitrary. (Epperson and Zafiris 2013, 69)

We have discussed above the importance of succession as part of fundamental process, and that such is more fundamental than space-time description. This succession has aspects of both logical order and causal order, and this distinction provides a useful introduction to the famed EPR argument in which Albert Einstein, Boris Podolsky, and Nathan Rosen (thus, EPR) claimed to have shown how quantum physics (without such distinction and assuming classical conditional probabilities) must be incomplete. Epperson and Zafiris frame it this way:

> It is crucial . . . to distinguish between "logical antecedence" and "temporal antecedence" here, for these are often casually assimilated. Temporal antecedence

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> refers to an asymmetrical *metrical* relation of events—that is, a "distance" relation of events as *objects* according to the parameter of time (or more accurately, space-time). Logical antecedence, by contrast, refers to an asymmetrical logical supersession of events which are *themselves* internal relational structures—that is, an internal relation of relations, such as that implied by the notion of conditional probability or more broadly, propositional logic, operative quantum mechanically. For example, in a classical conditional probability P(B|A), "the probability of B given A," there is no requirement that A's logical conditioning of B be understood as a supersession of events A-B since classical conditional probabilities are purely epistemic; that is, as classically conceived, conditional probabilities presuppose that all observables have precise values at all times, such that any logical dependency of B upon A is reflective only of one's knowledge of A and B as already extant facts. The historical significance of the EPR argument and its modern experimental incarnations is the definitive demonstration that this classical conception of conditional probabilities is entirely invalid in quantum mechanics, where measurement must be understood as generative of novel facts (measurement outcome events) and not merely revelatory of already extant facts. (Epperson and Zafiris 2013, 75–76)

Here we witness a direct failure of actualism, which requires that measurement is simply about the recording of already established facts and which claims that logical and temporal antecedence are distinguished only epistemically. Instead, Epperson and Zafiris highlight how,

> Thus in quantum mechanics, logical dependence depicted by a conditional probability like P(B|A) can only be understood as a Boolean logical conditioning of potential measurement outcomes at B by an actual measurement outcome A, such that P(B|A) depicts a supersession of ontological events and their asymmetrical logical relation.
>
> In this way, the traditional conflation of temporal and logical antecedence, and more generally, the causal and logical orders—a conflation that has dominated the philosophy of nature since the Enlightenment—has been definitively invalidated by quantum mechanics. (Epperson and Zafiris 2013, 76)

This failed conflation of temporal and logical antecedence correlates with the false duality of presuming that fundamental reality must be either discrete or continuous, which is overcome in the Relational Reality model by demonstrating requirements for both actual and potential relations, both causal/temporal and logical orders, both internal and external relations, and both discrete and continuous features. As articulated by Epperson and Zafiris,

> although the quantum actual occasions themselves are discrete, their *potential relations* are continuous and therefore metrically describable in terms of their

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> extensive features. Thus, in the same Aristotelian sense that potentia always presuppose actualities, the continuous metrical descriptions of extension deriving from these potential relations presuppose a discrete, mereotopological extensive order of actual facts. But at the same time, in the relational realist philosophical scheme it is also true that actualities always presuppose potentia, since potential relations are always generative of novel actualities—viz., the quantum mechanical evolution of potential fact to probable fact to novel actual fact. In this regard, the various attempts by the physical sciences to depict physical reality as either fundamentally discrete or fundamentally continuous (reflected, for example, by the tension between quantum mechanics and general relativity) neglect the fact that quantum actual occasions cannot be abstracted from, or even defined without reference to, their actual *and* potential relations, both logical/mereotopological and extensive/metrical. Potentiality and actuality are thus mutually implicative in the relational realist philosophy, whose fundamental objects are quantum mechanical units of logico-physical relation rather than simply units of physical relata. Objects are therefore always understood as relata, and likewise relations are always understood objectively. (Epperson and Zafiris 2013, 169)

Finally, as part of a concise summary that correlates these new concepts with Whitehead's framework, Epperson and Zafiris note that

> the relational realist scheme of internal relation among dipolar quantum actual occasions thus reflects a correlation of the order of logical implication and the order of causal relation—what Whitehead terms, respectively, the "genetic division" and the "coordinate division" of the predicative fact/actual occasion. (Epperson and Zafiris 2013, 173)

FUNDAMENTAL QUANTUM PROCESS

In summary, the Relational Reality model, whose focus is diachronic, articulates four stages of fundamental quantum process. For technical details, in addition to the primary volume by Epperson and Zafiris (2013), see also Epperson's more concise essay "Bridging Necessity and Contingency in Quantum Mechanics" (2016).

(1) actual initial state/global, uncontextualized *potentiae*;
(2) potential states/locally contextualized;
(3) probable states/probability valuation/conditionalization of *potentiae* / restriction of local by global/local relevance of global/decoherence;[40]
(4) actual outcome state/actualization of *potentia*/extension of local to global /global relevance of local.

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"particles" and pre-space *potentiae*, when coordinated through local-global correlations, then actively creates a particular, individuated new event actuality. Such fundamental, diachronic process is similar to Whitehead's concept of prehensive unification, including both actuality and *potentiae*, but without requiring his concept of eternal objects, at least not with a Platonic emphasis—see McHenry (2015).

In such fundamental process, we move from symmetry (applicable to pre-space *potentiae*) to broken symmetry; as well there is the ongoing emergence of temporality (physical time) and extension (space). In this way, the combination of multilevel (active) causation and general constraints on *potentiae* (physical relationships, or Peircean "generals" being a byproduct), in combination with local-global relations, enables multi-scale emergence (see *Unified Process Approach to Causation and Emergence* in chapter 4). The genuine newness, the novelty of emergence, then arises from pre-space *potentiae*, filtered through multiple levels of process, with both diachronic and synchronic (structural) aspects. Only actual states are fully particular in contrast to *potentiae*, which are not actualized particulars but are yet real (in denial of nominalism), and always to some degree "general."

LOCAL-GLOBAL RELATIONS

As described in detail by Epperson and Zafiris, "*locally*, every measurement context must be Boolean . . . this presupposition of local Boolean contextuality, yielding mutually exclusive outcome states . . . is a necessary prerequisite for the probability evaluation of these alternative outcome states (the Born rule), which is a categorical presupposition of quantum mechanics" (Epperson and Zafiris 2013, 60). If we limit ourselves to such local measurement context, then measurement procedure comports with the Boolean restrictions of classical physics as emphasized correctly by Niels Bohr in his Copenhagen interpretation.[46] However, Epperson and Zafiris point out that "*globally* (when local contexts are brought into nonlocal relation), intra-contextual Boolean material implication (that is, *within* individual local measurement contexts) must be relatable inter-contextually *across* these local contexts (i.e., 'globally'). In quantum mechanics, this is expressed as a tensor product relationship of potential outcome states" (ibid.).

A dramatic example of the importance of multilevel context is the phenomenon of quantum entanglement, which concerns how local processes get entangled with certain distant processes. Within quantum physics, this phenomenon is discussed in terms of quantum states. Several experimental confirmations of entanglement have now been completed (Krenn et al. 2014; Hensen et al. 2015). In the Relational Reality model, this confirmation of

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non-local effects in quantum physics is a signature of the combination of *potentiae* and local-global relations. This contrasts with how "Almost all correlations between independent observers known in science are local," as noted by Nicolas Gisin and Rob Thew (2007, 166). Such confirmation of entanglement, pointing to real non-local relations, thus both local and local-global relations, is an exceptionally important, yet recent result of quantum physics research. Gisin explains that entanglement goes beyond our normal application of space-time metrics, namely "that nonlocal correlations seem to emerge somehow from outside of space and time in the sense that no story taking place in space as time goes by can account for the way nature produces such correlations" (Gisin 2014, 105). So long as we stay within the confines of the logic of actualization, that is, the Boolean logic of space-time metrics, measurement outcomes, and their space-time correlations, we will remain unable to understand these non-local correlations. We need to evaluate approaches that incorporate the logic of *potentiae* (non-Boolean logic) arising from pre-space fundamental process. Concerning the latter, recent research in quantum field theory indicates both that there is a fundamental succession of quantum process and, Jesse Bettinger argues, based on theoretical work by Erik Verlinde, that such process is prior to the abstraction of space-time metrics (Bettinger, 2015).

Category theory, which is a general algebra of relations, has emerged in modern mathematics; and in application to quantum physics, Elias Zafiris has shown how category theory reveals the importance of both local field relations and local-global relations in explaining successions of quantum events (Zafiris, 2010). Combined with local-global connections, the handling of physical relations in the Relational Reality model exhibits non-local connectedness (entanglement) as inevitable and as logical constraints on *potentiae* (not as some "spooky action-at-a-distance"—an *aporia* arising from the presumption of actualism). The use of local-global here applies either to the inevitable reference to *potentiae* or, at least, to some expanded context, which generates the inevitable triad of input-output-context. Another effort toward a realist interpretation of quantum physics is shared by Dennis Dieks, who states "that from a realist viewpoint, quantum contextuality naturally leads to 'perspectivalism' [in which a] context—or perspective—is needed to define the value of a physical quantity, in accordance with the core of the Kochen and Specker results" (Dieks 2019, 629, 643).[47]

LOGOI FRAMEWORK IN A NUTSHELL

Let me sketch some ways that the *Logoi* framework opens up new avenues of thought, from basic physics to values, meaning and ultimate context. We

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have started with the fundamental notions of process, logic, and relations, and the three ways of knowing. The concept of relation is foundational for both basic science and humanities as illustrated in all scholarly fields. Semiotics is the study of relations and signs, indeed the study of anything that stands for something else (see chapter 5). However useful we find the approximation of symmetric dyadic relations, in the real world such relations are inevitably set within a triadic asymmetry, viz., input-output-context, the latter being either general (as within domains of *potentiae*) or particular (e.g., symmetry breaking upon a particular measurement outcome in quantum physics).

Augmenting these notions with the Relational Reality model leads to understanding fundamental process as woven, web-like with fundamental succession, including two basic types of logic, Boolean and non-Boolean, which correlate with a logic of actualizations (causal order) and a logic of *potentiae* (logical order), respectively. Then, instead of the usual dependence on God-given "law" and deductive entailment, the fundamental basis of physical relations is grounded in relations of relations in *potentiae* (*à la* potentiality "spaces" or pre-space), which can be determined in part by minimization principles such as the principle of least action. In this way, constraints on *potentiae* enable the generation of physical law with universal scope, or universality, and such process has both diachronic and synchronic aspects, exhibited, respectively, by fundamental quantum process (viz., causation) and multilevel emergence of systems with increasing complexity.[48] Multilevel process (coextensive with Peircean triads of input-output-context and Auxier's quanta of explanation) combined with local-global relations and *potentiae* enable multiscale emergence.

If one holds on to actualism or nominalism, then one abandons any fundamental basis for *potentiae*, quantum fields and other higher-level concepts essential to human understanding; likewise abandoned is any basis for human free will or meaning (see *On the Failure of Actualism and Nominalism* in chapter 4). In contrast, without arbitrarily invoking miracles or some abstract belief system (whether atheistic or theistic), the *Logoi* framework provides a systematic framework from which emerges a viable basis for mind and consciousness. To see how this is possible, building on elements of the *Logoi* framework, I propose that mental processing is distinct from brain actualizations, and has the capability to reflexively contrast "that which is" with "that which could be" and to make decisions among alternative possibilities. Here note that conventional "brain states" are outputs captured by the logic of actualization alone, whereas I hypothesize that mental processing and the inference of "mind" involves both the logic of actualization and the logic of *potentiae*. Such an expanded concept of mind and consciousness is developed in *On the Emergence of Consciousness and Mind* within chapter 7.

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Combining such local-global connectedness with biosemiotics (accounting for enhanced information and dynamical depth, see Koutroufinis 2014) enables multilevel frameworks of increasing semiotic complexity with values and meaning (arising from multiple levels of context), and ultimately consciousness, language, and spiritual awareness (enabling enhanced access to *potentiae* and anticipatory capabilities) (see chapter 8, and *Biosemiotics and Anticipatory Systems* within chapter 5). As James Bradley expresses it, this only becomes fully intelligible and self-explanatory with full inclusion of the "self-actualizing activity of recursive subjects" and communities of such (Bradley 2003b, 150). Such high-level functionality only appears in self-aware beings imbedded in multiscale physical and biological systems.

Eventually, with the emergence of consciousness, such self-aware beings evolve to become aware of their ultimate context, not just of multiscale contingencies (worlds-upon-worlds) but also aware of the noncontingent ground of contingency, which may be (or is sometimes characterized as) the spiritual dimension (see chapter 8). At the level of ontology alone, such beings can only be confident of the way of numbers (science) and, to varying degrees, the way of context, or the way of signs (humanities, and semiotics). Going beyond these two ways through the recognition of ultimacies and unrestricted domains of discourse would logically lead to an ultimate basis for closure and meaning, transcending the anthropomorphic, and this in turn leads to the way of spirit (spirituality; the religious dimension). This progression completes the three fundamental ways of awareness for finite beings (the way of numbers, of context/signs, of spirit). These three ways of awareness are also interwoven with two basic modes of knowing, as explained by Primas, the sequential and the non-sequential (Primas 2017, 68), which have corollaries with complementarity[49] in quantum physics, grounded in the distinction of Boolean and non-Boolean logics as argued by Primas (2017, 69), in linear versus correlative thought in Chinese culture (Hall and Ames 1998), and in partial hemispheric specialization of the human brain (left hemisphere tending to emphasize temporally sequential and analytic knowledge; right hemisphere tending to emphasize temporally nonsequential holistic knowledge—see Levy-Agresti and Sperry (1968).

ON *POTENTIAE* VERSUS SOME ALTERNATIVES

The Relational Reality model affirms the ontological reality of *potentiae*. This important distinction of actuality and *potentiae* as both aspects of the "real," understood inclusively, has a long history going back to Aristotle. "In 1890 *The Century Dictionary of the English Language* devoted two columns to definitions of potential and potentiality—many of them written by Charles

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Peirce" (Edward Moore 2012, 179). Shortly after Peirce's work, a classic treatise that emphasizes this distinction is that of Whitehead's *Process and Reality* (Whitehead 1929, 1978). Recently, Stuart Kauffman and Arran Gare also emphasized this distinction (Gare 2015). Along with a concise argument for objective chance, Mario Bunge points out that

> Spinoza drew a sharp distinction between *natura naturans* (nature in the making or creating) and *natura naturata* (nature made or created). The pairs possibility/actuality, past/future, input/output, and probability/frequency belong in the study of the *naturans/naturata* duality, whereas the notion of present or now is not only an egocentric particular, as Bertrand Russell pointed out, but also a hinge between *naturans* and *naturata*. (Bunge 2018, 243)

Despite such exceptions, the notion of potentiality no longer receives the attention it once did. As Edward Moore noted, "Twentieth century philosophy has been a philosophy of the actual" (Moore 2012, 179). Ironically, some leading philosophers, desiring to avoid Bunge's objective chance and inspired by both nominalism and the analytic tradition, dominant in twentieth-century philosophy, are trying to be ever more metaphysically parsimonious through reductionist, deflationary ontologies (see Amie Thomasson's *Ontology Made Easy* (2014)).[50] In parallel to such deflation, some leading scientists and philosophers, committed to reductionism and actualism, have invoked multiple worlds and universes (multiverses) to explain recent experiments in quantum physics—thus proposing new forms of inflationary ontology; indeed, highly inflationary "deflations!"[51] These scientific speculations appear to continue unabated even when, as noted by Peter Woit, they go beyond any possibility of falsification (Woit 2007). Another theory-centric strategy is to reduce everything to mathematics, a modern Platonism, one argued by Max Tegmark (2014), which is a strategy that Raymond Tallis thoroughly debunks (Tallis 2017, 187–188). Yet another effort to grapple with interpretive problems of modern physics is Gerard 't Hooft's effort, admitted by the author as rather incomplete, to retain ontological determinism through a cellular automata theory of quantum physics ('t Hooft 2016). (Note: Both Tegmark and 't Hooft are excellent mathematical physicists, but here we are focused on philosophical issues for which physicists in general are not well versed.). Essentially all such alternatives presume a form of reductive substance philosophy combined with actualism and the givenness of certain deductive laws of physics, which itself remains a mystery because we now lack (for generally accepted philosophic procedure) the law-giver available to eighteenth-century deists.

Here I strive to avoid such extremes in reduction, deflation, or inflation, and work to identify a set of basic notions, principles, and ontology that can

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but added to that are some common presuppositions based on an overlay of mechanistic-materialist metaphysics. These added elements of presuppositions and ontology commonly associated with classical mechanics are presented in the two right-hand columns of table 2.1, which provides a concise summary of the Relational Reality model by contrasting its framing of quantum physics with key characteristics of the earlier, yet highly successful classical mechanics model. I recognize the limitations of this table or any simplistic comparison of classical and quantum physics. Comparisons of technical, scientific details are reasonably straightforward, which is reflected in the columns pertaining to prime focus and epistemology. However, inferences about presuppositions and ontology are less established; my table here is simply intended to point to common assumptions and trends, not final characterizations. One can point to examples where classical physics is used to study asymmetries or irreversible systems (as with thermodynamics), and yet it is most commonly presumed that such analysis involves underlying symmetries and reversibility. Similarly, quantum physics is often used to evaluate conditions of symmetry and possible hidden variables, yet more fundamentally, as we have seen, context and asymmetry are yet more fundamental, and hidden variable claims most often arise when researchers remain limited to actualism and determinism.

Notwithstanding some limitations in the relatively simple characterizations utilized in table 2.1, in many cases, when shifting from CM to QP, it represents an augmentation from a feature X to a more complex framework involving both X *and* Y. Thus, we transition from dyads, input-output, external relations, symmetry, reversibility, continuity, and Boolean logic for CM, to dyads *and* triads, input-output *and* context, external *and* internal relations, symmetry *and* asymmetry, reversibility *and* irreversibility, continuity *and* discontinuity, and Boolean *and* non-Boolean logic for QP. In many cases, the great practical success of classical physics has lured us into accepting the presuppositions and ontology of CM that go beyond classical physics, which shares with CM only its prime focus and epistemology (see columns 2 and 3 of the table). Unfortunately, as I have discussed in an earlier work, such classical metaphysics when applied to interpretations of QP can result in many quantum puzzles (Eastman, 2008). The resolution of these puzzles depends on identifying and removing classical metaphysics assumptions (presuppositions and ontology for CM) and then deploying the more inclusive interpretive framework enabled by QP (presuppositions and ontology for QP, see table lower right). My candidate for this purpose overall is the *Logoi* framework, which includes the Relational Reality model described above.

A fundamental CM claim is that preexistent imposed law results in strict entailments from causes to effects such that effects are, for all practical purposes, contained in their causes and there is strict deterministic entailment. However, this constitutes a speculative claim that has both scientific

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Table 2.1 A Comparison of Classical Mechanics and Quantum physics

Physics Model	*Prime focus*	*Epistemology*	*Presuppositions*	*Ontology*
Classical Mechanics (CM)	measurements and data imposed "law"	dyads input-output measurement as revealing extant "facts" facts (empiricism)	context "hidden" external relations (without history) symmetry reversibility continuity	preexistent law logic of actualizations (Boolean only) effects *in* cause (determinism) input to output entailments
Quantum Physics (QP)	measurements, data, *and* environments filtering of *potentiae* emergent relations of relations	dyads *and* triads input-output *and* context process as generative of novel facts both fact *and* form	context affirmed external *and* internal relations (with history) symmetry *and* asymmetry reversibility, yet fundamental process as irreversible continuity *and* discontinuity	emergent 'law' logics of *both* actuals (Boolean logic) *and potentiae* (non-Boolean logic) effects *in* cause, *and* cause *in* effect; cause-effect as mutually implicative phases of fundamental quantum process

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and metaphysical dimensions; namely, that the fundamental ontology of the world can be ordered fully by a Boolean-only logic of actualizations, and that the real is nothing but the actual. The latter is a metaphysical claim most often simply presupposed yet, occasionally, such actualism is made explicit, such as with Samuel Kimpton-Nye's thesis in analytic metaphysics. Along with a complex argument about supporting the reality of possibilities and potencies in a metaphysics of modality, he states that,

> concrete objects and their properties are plausibly the sorts of things that science can tell us about and since the claim is that it is those very objects that ground facts about metaphysical modality, hardcore actualism places *scientific* methods at the centre of the epistemology and methodology of modal metaphysics. Modal metaphysics is no longer primarily concerned with abstracta or possibilia, which, by definition, are *not* accessible via empirical scientific methods. Hardcore actualism thus constitutes a significant step towards achieving continuity between natural science and metaphysics. (Kimpton-Nye 2018, 32)

In contrast to how the application of such "hardcore actualism" in analytic circles tends to presuppose just Boolean-only thinking (with epistemic potencies but not ontic *potentiae*),[53] our results show how quantum physics itself points to an ontic duality of fundamental context because of its need for both Boolean and non-Boolean logics. In this way, modal metaphysics (past-present-future analysis) can fully partner with forefront scientific and philosophical analysis; ironically, physics results themselves undermine the metaphysical claim that the real is merely the actual (actualism).

As shown above, recent research in quantum physics and philosophy has led several research groups to recognize that the real is *both* the actual *and* potential relations or *potentiae*; in turn, there is *both* a (Boolean) logic of actualization *and* a (non-Boolean) logic of *potentiae*. In contrast with narrow, Boolean-only treatments in contemporary analytic metaphysics, this more complex logical space is both more consistent with the science and with basic human experience. As expressed by Epperson and Zafiris, causes and effects are mutually implicative.

A standard CM claim is that measurement merely reveals already extant facts (sometimes suggesting a God's eye view that transcends modal distinctions), and that proper theory must always remain grounded in such empirical facts, such being the logic of actualization (arguably this was the core of nineteenth–twentieth-century empiricism). In contrast, although limited (epistemologically) to measurements of input-output, the theoretical framework of QP, along with careful philosophical analysis and theory of measurement, enables inference and application of both the logic of actualization and the logic of *potentiae*. This provides a robust alternative basis for understanding

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potential relations and abstractions in ways that go beyond simple reference to properties, dispositions, and potencies within a nominalistic framework.

For CM, the methodological goal of context independence was often converted into an ontological claim of context independence and full isolation of the input-output dyadic. In contrast, for QP, its theory of measurement always includes reference to the measurement process (input-output), measurement outcomes (data), and the measurement environment (laboratory, systems, context); thus, the input-output-context triad (see chapters 4, 5, and 7). Going beyond the context-free external relations presumed by CM, the applications of QP involve multilevels of such process enabling emergent relations of relations (both external and internal, see chapter 4).

Although some QP formalisms exhibit time-reversible structure (e.g., the Schrödinger equation), fundamental quantum process is irreversible due to symmetry breaking as arises during its phases of succession (discussed in the section *Fundamental Quantum Process* above); thus, both symmetry and asymmetry are integral aspects of QP. Finally, users of CM most often presume that law is simply a given—preexistent, whereas the status of law itself is an open question with QP. One way to understand quantitative physical relations (law) is in terms of constraints on *potentiae*—this approach is detailed in the section *"Law"-From Entailment to Constrained Processual Histories* in chapter 4.

SUMMARY OF KEY *LOGOI* FRAMEWORK TERMS AND CONCEPTS

The *Logoi* framework incorporates the Relational Reality model and yet goes beyond it, in the spirit of systematic philosophy, to add some fundamental notions that are either presupposed or function as grounding elements of that model. A few common concepts are conspicuously absent in the *Logoi* framework's core metaphysics because they are here suggested to be derivative notions, and not truly fundamental, however much they may be essential to measurement and scientific applications. Among others, these derivative notions are physical law (vs. constraints on *potentiae*), causality (as having an epistemic focus vs. ontic causation), time (vs. temporality), space (vs. fundamental extension), and space-time metric (vs. quantum field theory constraints on fundamental extension).[54]

A concise summary of the hypothesized fundamental notions of the *Logoi* framework, and their place in a theory of actualization, is as follows:

Process/succession: input-output succession within context (constraints/*potentiae*); continuous-discrete;

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Logic: logic of actualizations (two-valued Boolean logic) and a logic of potential relations, or *potentiae* (multivalued logic, non-Boolean);
Relations: constitutive of process (part-whole; local-global; internal-external), including relations of relations/semiotics, as well, extension;[55]
Potentiae: potential relations within a non-spatialized fundamental level of reality (pre-space), ordered by a multivalued non-Boolean logic; input to every fundamental quantum event;
Local-global relations: relations affecting every fundamental quantum event, which can be discussed as either the broader context of the input-output-context triadic, or linkages with the order of *potentiae* that enable entanglement phenomena;
Structure of relations: real-world interactions always involve sequences of triads (input-output-context); dyads of simple input-output are always approximations;
Fundamental ontology: dimensions of both contingent and non-contingent being/becoming;
Ways of knowing: way of numbers (science), way of context/semiotics (arts/humanities), way of spirit (religious dimension);
Basic modes of knowing: sequential and non-sequential (linear vs. correlative thought, as in Chinese culture), such duality correlated with complementarity in quantum physics, which is grounded in the distinction of two fundamental logics, the logic of actualization and the logic of *potentiae*.

From the above fundamental notions of the *Logoi* framework, we now lay out in chapter 3 a Gordian knot of classic philosophical problems for which the above conceptual toolkit can be productively applied.

NOTES

1. Such direct awareness and immediacy of experience could be thought of as a kind of "*a priori* empiricism" after Friedrich Schelling (John Laughland 2016); more fully, as an exemplar of Whitehead's radical empiricism (Auxier and Herstein 2017). Indeed, Michael Grant points out that "Tallis believes that human discourse—in contrast with animal responses to present actualities—is predominantly about *possibility:* possible states of affairs which may or may not be realised. It is this, he argues, that makes language the supreme means by which explicitness may be elaborated and new meanings created" (Michael Grant 2000, 110). Unfortunately, a focus on language can undermine proper metaphysical analysis because, as Michel Weber expresses it, "Language, like sight, prefers clear-cut distinctions, independent entities, external relationships" (Weber 2013, 109).

2. The reliability of immediate, direct feeling, and even the concept of "feeling," has a long history of controversy in philosophy. This is a worthy philosophical debate,

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27. An iterative map is one that is applied repeatedly to an object or sequence of such. Iteration or recurrence are standard mathematical and simulation tools. Generally, for mathematics, mapping is a synonym for a function or morphism; see Eric Weisstein (2020).

28. Such ontological reduction commits one to an "analytical illusion" as described by Teilhard de Chardin (2017, 139).

29. Individuation concerns the problem of how to uniquely distinguish one entity from everything else. As shown by Doyle (2019), problems of individuation have a long history in philosophy.

30. The Copenhagen interpretation focuses on Niels Bohr's correspondence principle and Max Born's statistical interpretation of the wave function; see Jan Faye (2019).

31. Details about Bohmian mechanics are documented by Sheldon Goldstein (2017).

32. The problematic philosophical claim of "actualism" is that the domain of the real and the actual are one and the same, thus excluding *potentiae* from the domain of the real.

33. The decoherence interpretation of quantum physics focuses on the loss of a system's information into its environment; without such loss, a quantum state could maintain coherence.

34. Hereafter, in this volume, reference to the Relational Reality model is intended to acknowledge reference to Michael Epperson's initial introduction of the "Relational Realist Interpretation" of quantum physics (Epperson 2009), and to the in-depth monograph *Foundations of Relational Realism* (Epperson and Zafiris 2013) coauthored with mathematical physicist and category theory expert, Elias Zafiris. Going beyond standard epistemic or actualist approaches, as stated by Epperson, "the relational realist interpretation of quantum mechanics is a *praxiological* interpretation; that is, these physical and logical relations are *ontologically active relations*, contributing not just to the epistemic coordination of quantum actualizations, but to the process of actualization itself" (Epperson 2009, 355).

35. The Principle of Least Action is a basic variational principle that uses an optimization method to obtain a system's dynamical trajectory "by imagining all possible trajectories that the system could conceivably take, computing the action (a functional of the trajectory) for each of these trajectories, and selecting one that makes the action locally stationary (traditionally called 'least'). True trajectories are those that have least action." An equivalent concept is Hamilton's principle, which is set up to "emphasize a particular constraint on the varied trajectories" (Chris Gray 2009).

36. Epperson and Zafiris' deployment of logical causality and a distinct logical order emerged from their work in interpreting quantum physics. Their concept of logical causality may be considered as a type of logic in reality as argued by Joseph Brenner in his work *Logic in Reality* (2008).

37. "In mathematics, topology is concerned with the properties of a geometric object "in which two objects are considered equivalent if they can be continuously deformed into one another" such as by stretching, twisting, crumpling and bending, but not gluing or tearing apart (Stephan Carlson 2017). As Vesselin Petrov states,

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"Whitehead . . . can rightly be considered as one of the leading topologists of his time, as one of the originators of contemporary topology" (Petrov 2017, 163).

38. An internal relation is "a relation that is involved in or essential to the nature of the thing related" whereas an external relation is "one that does not affect its relata or is not a part of its relata" (Merriam-webster.com, 2020).

39. Quantum entanglement, experimentally demonstrated in multiple ways, is a phenomenon of quantum physics that "*implies the existence of global states of composite systems which cannot be written as a product of the states of individual subsystems*." As a consequence, pairs or groups of particles can potentially interact even when separated by a large distance (Horodecki et al. 2009, 865).

40. In physics, classical systems have unique, univocal states at a given time whereas quantum systems retain superpositions of states. A decoherence process brings a quantum system approximately into an apparently classical state by shifting the treatment of basic interactions to systems larger than what can be directly observed in standard quantum experiments.

41. Kastner, Kauffman and Epperson point out that a tacit assumption behind PEM is "that of actualism: the doctrine that only actual things exist," whereas in quantum physics, PNC and PEM "together evince the ontological significance of both actuality and potentiality" (Kastner et al. 2018, 161).

42. Here I am using "classical physics" to designate the proper classical approximation that it represents, relative to quantum physics; in turn "classical mechanics" here denotes the same physics but added to that are some common presuppositions based on an overlay of mechanistic-materialist metaphysics (see Čapek 1961; later in this chapter, see *Summary of the Relational Reality Model*).

43. An excellent introduction to quantum physics, including explicit examples of both the matrix and wave approaches, is provided by Steven Holzner (2012).

44. "One reason the global can never be deduced from the local quantum mechanically, but only induced, is that observables contextualized by multiple local measurement contexts do not commute; and as Kochen and Specker have shown, it is impossible even in principle to imbed local contextual Boolean subalgebras into a 'global' Boolean algebra . . . the ontological significance of the Kochen-Specker theorem with respect to relating local and global states is intimately related to the logical problem of predicating totalities" (Epperson and Zafiris 2013, 64-65).

45. An analogous suggestion has been made by Poli "to introduce propensities instead of forces, where the former should be regarded, not as simple possibilities, but as physical realities, as real as forces or fields . . . Forces and causes are the isolated, individualized versions of propensities. The latter apply to complex situations taken as wholes" (Poli 2010, 773).

46. Within Bohr's Copenhagen Interpretation, two sets of quantum system description are taken to be complementary. Initially, this was framed in terms of particle and wave properties, but later refined to focus on space-time descriptions (kinematic properties) or claims of causality (dynamic properties). As stated by Faye, "In general, Bohr considered the demands of complementarity in quantum mechanics to be logically on a par with the requirements of relativity in the theory of relativity. He believed that both theories were a result of novel aspects of the observation problem, namely the fact that observation in physics is context-dependent" (Faye 2019).

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47. See Carsten Held's essay "The Kochen-Specker Theorem" in the *Stanford Encyclopedia of Philosophy* (Held 2018).

48. In the study of complex systems, one studies how parts of a system lead to collective behaviors of the system, and how the system interacts with its environment. Complex systems are discussed in chapter 4.

49. Complementarity is both an experimental and theoretical result of quantum physics, which holds that objects have certain pairs of complementary properties (particle-wave, position-momentum, etc.) that cannot be observed simultaneously. The concept of complementarity is central to the highly influential Copenhagen interpretation of quantum physics introduced by Neils Bohr. In general, its application is focused on epistemological considerations, and its apparent ontic consequences remain controversial; see discussion by Adam Becker (2018). However, Becker's book takes no account of the Boolean-non-Boolean logical distinction utilized by the *Logoi* framework, which readily explains complementarity from a more fundamental standpoint.

50. A detailed critique of analytic philosophy is provided by Robert Hanna in works featuring the importance of Kant's theories of the epistemological, metaphysical, and practical foundations of the sciences (Robert Hanna 2006; 2020).

51. In contrast to standard multiverse arguments, compatible with the modal realism of David Lewis in which all possible worlds are real, Whitehead's cosmic epochs are different stages of what is ultimately one unified reality similar to what is hypothesized by Roberto Unger and Lee Smolin in their work *The Singular Universe and the Reality of Time* (2015); see also McHenry's essay on the multiverse conjecture (McHenry 2011).

52. The Russell-Einstein Manifest of July 9, 1955, is available through the *Atomic Heritage Foundation* (atomicheritage.org, accessed June 30, 2020).

53. Details of contemporary debates within analytic metaphysics are beyond my current scope, which emphasizes fundamental ontology. In general, such debates focus on epistemology and constraints of linguistic reference. These debates most often emphasize the importance of properties, issues of individuation, and possible attributions of causal powers, among other features; for example, see Lorenzo Azzano (2014). A detailed critique of analytic epistemologies is provided by Phillip Stambovsky (2009).

54. Arguments for such derivative status and various aspects of these contrasts are presented in chapters 2–4.

55. Inspired by Whitehead's work, Auxier and Herstein state that, "in the *idea* of extension, *undivided divisibility*, we have a whole to which all the possibilities, including unrealized possibilities, belong, under the condition that we not speak of cosmic epochs beyond our own, except conjecturally" (Auxier and Herstein 2017, 150).

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Chapter 3

Gordian Knot to *Logoi* Framework

Many challenging philosophical problems have arisen out of science including, among others, causality, emergence, continuity, temporality, and potentiality. These fundamental issues impact numerous ongoing debates. For example, the free will debate is dependent on presuppositions related to causality, emergence, and potentiality; and the determinism debate is dependent on these same presuppositions and more. The results of addressing this class of interrelated problems one by one have thus far been unsatisfactory because the issues are interconnected and mutually implicative. An integrated, systematic philosophical framework is required, whether the *Logoi* framework here proposed or some other analogous framework (see *Integrative Frameworks and Methodology*, chapter 8). In addressing these problems via some version of strong reductionism, many thinkers often make unrecognized, generally implicit, philosophical claims that a part can appropriately represent the whole, and that such part-whole mereology obeys simple mappings and a single logic. A more productive way of interpreting the insights of contemporary physics would approach these challenges from a more empirical systems approach, which at its core posits that a local event is not only embedded in a more global context but is in part constituted by its history and processual context and so cannot be removed from such context without error or distortion. Focusing on isolated parts is a powerful methodological tool for science, but it can only result in ontological approximations, however practical and operationally effective. Complementing the scientific process, integrative, systematic philosophical frameworks are needed to clarify fundamental presuppositions in addition to interpretive and contextual relations.

My *Logoi* framework offers a comprehensive vision for addressing a Gordian knot of problems arising out of both the discoveries of modern science and more than two millennia of philosophical debate. Although I do

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along with a logic of actualizations, and a theory of relations, including relations of relations (the meta-level). Details of how this is carried out within the *Logoi* framework are provided throughout this work. An alternative tripartite schema, somewhat analogous to Bradley's, is that of form, dynamics, and unification which, John Berthrong argues, can provide a bridge between philosophical frameworks, West and East, from Whitehead and Robert Neville to the neo-Confucian Chu Hsi (Berthrong, 1998).

THE *LOGOI* FRAMEWORK

Based on a confluence of recent scientific research results, philosophical analysis, and human experience, my proposed *Logoi* framework incorporates the Relational Reality model for quantum process, which is concisely summarized below. Along with this summary, I also highlight some implications of this *Logoi* framework, which are explained in greater detail in subsequent chapters. The *Logoi* framework is a systematic philosophical framework based on a complex synthesis that leverages advances in multiple disciplines, especially quantum physics and philosophy, information and semiotics, and complex systems theory. My efforts in multi-pronged analysis, multilevel synthesis, and the development of integral wholes is consonant with Roberto Poli's study of both part-whole and whole-whole connections within which he demonstrates how reductive methods alone inevitably lose relevant information (Poli 2009).

The most fundamental notions are process, logic, and relations as explained in chapter 2. Closely associated with these are the fundamental notions of succession (*à la* process), *potentiae* (domains of non-Boolean logic), and local-global relations, and relations of relations or meta-levels. These notions all reflect basic human experience and correlate very well with concepts inferred from quantum process and results of both modern science and humanistic scholarship. Based on experimental results and analysis in quantum physics, and from phenomenological analysis, I hypothesize that all reality, taken inclusively and at all levels, consistent with the "quanta of explanation" per Auxier and Herstein (2017), includes *res extensa*, *res qualia*, and *potentiae* (latin, respectively, for "real extension," "real qualitative relations," and "potential relations"). Fundamental process arises from never-ending successions of events, each of which is constituted by a combination of its immediate fields and "particle" inputs and *potentiae* for their actualization. Temporality and spatiality are co-extensive with such process; that is, they arise as part of the process itself (i.e., they are not pre-existing space-time structures functioning as containers for process). While the pre-space

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relations of the logic of *potentiae* exhibit full symmetries of physical theory, various broken symmetries arise upon the actualization process, especially the asymmetry of time that emerges from the inevitable successiveness of such process.

Many antinomies in understanding the concept of time, as detailed, for example, by Tallis (2017), can be readily resolved within the *Logoi* framework. Alternative paths in possibility pre-space can be modeled as sums of certain physical parameters over *potentiae* (e.g., Feynman sums over histories). Using minimization techniques, including symmetry principles, many central laws of physics can be derived (see discussion about physical relations in chapter 4). Relation is a fundamental notion[2] and, in addition to modern field physics, relations of relations in *potentiae* pre-space give rise to non-local (local-global) connectedness [topology, category theory (an algebra of relations)]. Such local-global linkages provide context for any complex system and enable multiscale emergence, in turn giving rise to multilevel frameworks of increasing complexity.

THE RELATIONAL REALITY MODEL

The Relational Reality model, introduced in chapter 2, is a central component of the *Logoi* framework. Within the conception of full ontological reality for both the logic of actualizations and the logic of *potentiae*, this model makes a critical distinction in associating the former with standard Aristotelian or Boolean logic, and linking the latter with a non-Boolean logic.

The scientific basis for this distinction of logics arises from a recent convergence in three quantum physics research programs that have yielded a breakthrough in the understanding of fundamental quantum process. In particular, in their paper “Taking Heisenberg’s Potentia Seriously,” Ruth Kastner, Stuart Kauffman, and Michael Epperson combine their three approaches, each comprising a decade or more of substantial research and publication, to show why quantum *potentiae* should be considered as having ontological reality, and why that concept is uniquely capable of solving a complex set of quantum problems (Kastner et al. 2018). Further, both Kastner (2013) and Epperson and Zafiris (2013) have independently proposed specific solutions for the problem of quantum measurement transition that is “grounded in the ontological interpretation of quantum potentiae” (Kastner et al. 2018, 162). Independently of the Kastner et al. collaboration, Christian de Ronde has argued as well for the distinct reality of quantum possibility in a modal interpretation that emphasizes modality and contextuality (de Ronde 2007) with more details provided in a later PhD dissertation and paper, although this insightful philosophical work does not directly address non-Boolean

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logic and category theory as carried out by Epperson and Zafiris (see de Ronde 2011, 2015). Gregg Jaeger has further clarified uses of *potentia* by Aristotle and Werner Heisenberg (Jaeger, 2017). Elio Conte also argues for a triadic logic basis for quantum physics, which he interprets as involving self-referential processes enabling "such transition from potentiality to actualization" (Conte 2011, 234). These approaches, emphasizing *potentiae,* contrast with conventional approaches, most often invoking the metaphysical claim of actualism (almost always as an unstated presupposition; see extended critique of actualism by Kastner et al. (2018, 161–163)), which either adds some new, untested physics to enable resolution, or hypothesizes vast realms of actualized possible worlds (as with the many-worlds interpretation, or multiverses), leaving Ockham's razor not just dulled, but surely crushed.[3]

It is especially significant that the combined efforts of Epperson and Zafiris, Kauffman, and Kastner, keeping in mind complementary philosophical work by de Ronde and others, achieve this advance by adding interpretive nuance but without introducing any new physics, which enables their complementary approaches to fully leverage the century-long success of the standard formulation of basic quantum physics. For the purpose of the *Logoi* framework, I focus on the Relational Reality model of Epperson and Zafiris (2013), which is part of the Kastner et al. integration, because their model handles both the issue of distinct logics for the realms of actualization and *potentiae*, and also local-global features. Their approach is unique in its focus on category theory analyses for quantum physics issues. Their work demonstrates the necessity of making the philosophical distinction, within full reality, of both actualizations *and potentiae*, the former as essential to givenness and place, the latter potential relationships as providing a needed basis for fundamental indeterminacy and for physical relationships (see *"Law"–From Entailment to Constrained Processual Histories* in chapter 4). As Auxier and Herstein state, "Epperson's and Zafiris' insistence that relations should be treated as having a genuine standing of their own, and not as merely parasitic upon their relata, makes their work one of the most important contributions in the philosophy of physics in recent years." (Auxier and Herstein 2017, 21) Let me rephrase the key point above for emphasis: the Relational Reality model requires a distinction between the logic of actualizations (standard Aristotelian or Boolean logic) and a non-Boolean logic for *potentiae*; real-world application of these logics necessarily requires three components; these are input-output-context with context most often designated as "environment" in quantum physics applications.

Quantum theorist Hans Primas affirms this position. He states that "modern physics proves that the description of matter requires a theory with a non-Boolean logical structure, with the consequence that any description of a universe of discourse including the material world needs to be non-Boolean . . .

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A partial Boolean algebra is a family of Boolean algebras whose operations coincide on overlaps so that it is *locally Boolean, yet globally non-Boolean*" (Primas 2017, 3). Several key issues, central to the *Logoi* framework, such as the fundamental logical orders, domains of discourse, and context, are reflected in Primas's detailed exposition.

> The family of Boolean contexts plays a privileged role since a sound theory should be able to describe intersubjectively communicable empirical propositions. Therefore the overall non-Boolean framework must have a locally Boolean logical structure. This guarantees that aspects of reality can be perceived by projections onto empirically accessible Boolean reference frames.
>
> The requirement that empirical propositions have to be truth-definite can only be achieved by deliberately suppressing irrelevant features . . . *Objectivity* in the modern sense is enforced by the requirement that an empirically meaningful statement has to belong to a Boolean domain of discourse.
>
> In order to describe aspects of an overall non-Boolean reality we have to ignore particular global features such that the remainder separates into facts. Inevitably, such a description is valid only within the adopted partition of the world, that is, within the *chosen context*. Every locally Boolean description suppresses correlations between Boolean domains. (Primas 2017, 4)

In this framework, the overall non-Boolean reality also includes the pre-space realm of potential relations (*potentiae*), in addition to measurement outcomes (facts), which by themselves are necessarily limited to an adopted partition of the world, that is, a chosen context. In this way, measurement outcomes are restricted to an objectivity and, within such constraints, limited to particular Boolean domains of discourse (i.e., sets of actualizations).

By applying recent developments in mathematical category theory to quantum physics, in ways complementary to Primas's focus on algebraic quantum theory, the Relational Reality model shows how to correlate these two logical orders, Boolean and non-Boolean or, equivalently, the logic of actualizations and the logic of *potentiae*. A key starting point is the recently achieved recognition that quantum physics exemplifies the fact that physical extensiveness (viz., the grounding for standard space-time description) is fundamentally topological rather than metrical, with its proper logico-mathematical framework being category-theoretic rather than set-theoretic. By this thesis, as Epperson and Zafiris argue (2013, 64–65), extensiveness fundamentally entails not only relations of objects, but also relations of relations; thus fundamental quanta are properly defined as "units of logico-physical relation" rather than merely "units of physical relata," the latter being presumed as exclusive by both materialism and the broader presupposition of actualism. Objects are, in this way, always understood as relata, and likewise relations

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are always understood objectively. Objects and relations, in other words, are coherently defined as mutually implicative. This approach coheres well with contemporary research in semiotics (see chapter 5), and with John Deely's treatment of "things" and real processes (not mind dependent) in addition to objects (as mind-dependent entities) (Deely 2009).

In their seminal work, Epperson and Zafiris demonstrate that a revised decoherent histories interpretation of quantum mechanics, involving both local and global system histories, structured within a category-theoretic topological formalism, provides a coherent and consistent conceptual framework by which local quantum events can be globally and internally related, both causally and logically (Epperson and Zafiris 2013, 25). Further, this Relational Reality model enables a quantum physical description of spatiotemporal extension that is highly compatible philosophically with the model proposed by Whitehead, considered through the non-reductive lens of Auxier and Herstein (2017) and Campbell (2015), refining and enhancing Whitehead's model by elevating it from a set-theoretic basis to a category-theoretic one; that is, from simply sets of things, however complex, to relations of relations, an algebra of relations. Albeit a speculative ontological project, the conceptual framework of the Relational Reality model incorporates a rigorous mathematical formalism yielding uniquely powerful solutions to several critical problems of quantum physics, and does this by integrating their solutions within a coherent and intuitive ontological scheme.

The central thesis of the Relational Reality model is that the classical, conventional conception of the relationship between physical objects and their presumed direct mapping to discrete facts must be reconceived such that physical things are understood as the outcome of real histories of quantum events. This requires a reconceptualization of ontological and contextual properties as mutually implicative features of every quantum event (thus, inevitably, the triad of input-output-context). In this Relational Realist framework, quantum events are identified as measurement outcomes that refer to corresponding physical observables. The theory then provides the means of relating these events. In this respect, the conceptual complexity of any ontological interpretation of quantum theory stems from two factors:

(1) The actualization of a measurement outcome event representing the state of a quantum system, though always globally objective, can only be predicted probabilistically and contextually—that is, relative to a particular local Boolean measurement context of a selected observable (i.e., a context wherein measurement outcomes can be expressed as mutually exclusive and exhaustive true/false propositions). It is always via such local Boolean contextuality that the universe is decomposed into the triad of system, measuring apparatus, and environment with their respective

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complementary integration of this and related models, systematically breaks the Gordian knot problem set by denying key presuppositions, or by resolving impediments that generate these problems. In particular, my tentative (admittedly incomplete) responses[9] for each problem within the Gordian knot are briefly explained below; subsequent chapters offer more full explanation. This latest effort at untying the Gordian knot leverages the work of numerous scholars who have advanced the relevant research. The unique power of the *Logoi* framework lies in reconceptualizing both problems and potential solutions and in leveraging and synthesizing such prior work to augment the framework. For most knots, further discussion is provided in chapter 4, with the exception of knots 8 (information and knowledge) and 11 (matter-symbol problem) (see chapter 5), and knot 13 (problem of meaning) (see chapter 8).

1. *Measurement*—Quantum systems can have many values at once for an observable, but upon measurement, such systems "collapse" to only one value. When and how does this happen? What is the meaning of wave function collapse in quantum physics, and what is the role of measurement contextuality in determining objective outcomes?

   Response: The Relational Reality model leverages new developments in category theory, decoherence theory in quantum physics, and philosophy to resolve this quantum theory of measurement problem, utilizing as well the concept of partial Boolean algebras. The introduction of *potentiae* as part of full reality is a key to solving problems of interpreting quantum physics, illustrating as well the fundamental distinction between the orders of actualizations (Boolean logic) and *potentiae* (non-Boolean logic); wave function collapse is a transition between these orders. Objective outcomes pertain to the order of actualization whereas the ontological ground of context and possibility in the world arises from the creativity of pre-space *potentiae*.
2. *Potentiality*—Are possible relations (*potentiae*) part of the real (having some ontic status), or do they merely have some pragmatic or epistemic status?

   Response: Both actualizations and *potentiae* are part of the real, built on affirming the reality of both non-Boolean (possibility) logic and standard Boolean (actualization) logic as essential to contemporary quantum physics. Thus, the *Logoi* framework treats *potentiae* as genuinely real (ontic, not just epistemic). Indeed, such a reality is arguably presupposed in practice via human choice and action, thus the importance of recognizing a distinct order of *potentiae*.[10]
3. *Continuity*—How are the discrete and continuous aspects of the world to be reconciled? In particular, how can one reconcile quantum physics (whose fundamental structure consists in discrete topological and logical

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relations) with theories of relativity (whose fundamental structure consists in continuous metrical relations)?

Response: Both discreteness (quantization as fundamental in quantum actualizations) and continuity (real and continuous wave functions in non-Boolean possibility space; that is, pre-space *potentiae*) are essential to the fullness of reality. For example, the Relational Reality model reconciles quantum physics (with its quantization of observable outcomes via *discrete* topological and logical relations) with relativity theories, which involve only continuous variables, and whose fundamental structure consists in *continuous* metrical relations. Further, such metrical relations, instead of being simply assumed as in standard theory, are here hypothesized to be derivative and emergent from continuous pre-space structures and fundamental quantum process.

4. *Temporality*—Is the experience of time (and of temporality) an illusion or does it have some ontic basis in the real world?

   Response: Temporal passage and temporality are real emergents from fundamental quantum process as each and every quantum event involves passage from alternative possible outcomes, given particular input of fields and "particles," to particular and discrete actualizations; asymmetric temporal passage is coextensive with such quantum process. Symmetry in variables pertains to non-Boolean possibility space constraints (of pre-space *possibiliae*) and not to particular, discrete actualizations, which always exhibit symmetry breaking and have the asymmetry of input-output-context, however effective the local approximation of (context independent) symmetry may be. For the Relational Reality model, topological relations of inclusion yield an asymmetrical logical order (*à la* the arrow in category theory)—the logical asymmetry of this process is reflected temporally as the one-way arrow of time. Temporal order is a derivative and emergent metrical-extensive relational feature of fundamental quantum process. In short, certain abstract models may suppose (incorrectly) that time is mere illusion, but fundamental succession and temporal passage are real emergents. This resolves the apparent conflict exhibited by *Bergson, Einstein, and Their Famous Debates of 1922* (see chapter 2).

5. *Causal relations*—Is our inference of causal relations only based on epistemic or pragmatic considerations (as with Hume's habits of association), or is there a more fundamental ontic basis for causation?

   Response: Causal relations represent real relations within pre-space *potentiae*, and correlations in the passage from potentiality to actuality for each and every quantum event; physical relations represent general constraints on such process imbedded in highly correlated non-Boolean *possibiliae*. Within the Relational Reality model, global information

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conditions the generation of individual local potential facts and such local facts incorporate aspects of the global totality as input, and, in turn, become part of a new totality. Regarding the common presupposition in physics of causal closure (i.e., physical causal completeness within finite systems), Relational Reality's approach to the local/global framework and part/whole relations, which includes both physical causality and logical causality, is free from the paradoxes of self-reference[11] and the imposition of a classically conceived spatiotemporal continuum. Thus, no ultimate closure is available for finite systems and, even for the universe as a whole, because ever new facts break such closure (thus, a corollary for finite physical systems to Kurt Gödel's proof in logic). Further, the fundamental distinction of the Boolean and non-Boolean logical orders (i.e., the order of actualizations and *potentiae*, respectively) denies simple causal closure of the physical.[12]

6. *Physical Relationship*—What is the ultimate basis for physical relationships? What enables the uniformity of physical relationships across the universe (i.e., universality)?

   Response: Fundamental process arises from never-ending successions of events, each of which are constituted by a combination of their immediate fields and "particle" inputs and *potentiae* for their realization. Temporality and spatiality are co-extensive with such process, and the asymmetry of time emerges from the inevitable successiveness of such process ("one darn thing after another"). Alternative paths in pre-space *potentiae* can be modeled as sums of certain physical parameters ("action") over *potentiae* (Feynman "sums over histories"). Most laws of physics can be derived using this technique (utilizing the Principle of Least Action (PLA), including symmetry principles); in particular, electromagnetism, quantum physics, and quantum field theory with time-space metric and gravity as emergent (see *"Law"–From Entailment to Constrained Processual Histories* in chapter 4). Relation is a fundamental notion and, in addition to PLA and modern field physics, relations of relations in pre-space *potentiae* give rise to quantum entanglement deriving from non-local (local-global) connectedness [topology, category theory (an algebra of relations)]. Pre-space *potentiae* are properly characterized by symmetry conditions due to the inclusiveness of potential relations, which enable approximate context independence, whereas asymmetry arises from actualizations of quantum process, which impose context dependence (viz., input-output-context). Finally, non-local connectedness (via local-global constraints enabled by global topological phase, etc.—the entanglement phenomena of quantum physics) enables uniformity of physical relationships across the universe, which constitutes the principle of universality.

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7. *Emergence*—What is emergence? Is it epistemic only, via supervenience, or does it arise by means of some ontic, multilevel creation of genuinely new processes or entities?

   Response: potentiae + process + local-global; fundamental quantum process always involves a transition from potential relations (*potentiae*) to actuality, with an associated range of possible outcomes; full reducibility to constraints of pre-given actualities is a limiting condition upon highly restricted initial conditions, boundary conditions, and constraints. Determinism and entailment are logical and physical limits, most often imbedded in complex networks of constraints, often not known or visible—not fixed and inevitable God-given law as presumed in classical metaphysics. The Relational Reality model incorporates the creativity of ontic possibility (*potentiae*), which enables genuine, ontic emergence in context of local and global histories of logically conditioned events; further, this model makes possible the emergence of a metrical continuum (space-time) from more fundamental quantum, topological-logical structure via pre-space (equivalently, Whitehead's extensive continuum). Complementary to diachronic quantum process, such multiscale emergence is synchronic, and the associated "actual entities" can, in principle, be of any scale.
8. *Information and knowledge*—How is knowledge grounded if not solely in information?

   Response: Knowledge (based on information—a sequence of symbols that can be interpreted as a message) cannot be framed with symbols alone—the "symbol grounding problem." For the *Logoi* framework, information is fundamentally a logical notion, which is locally formulated by the Relational Reality model in terms of Boolean algebraic logic (i.e., a logic of measurement outcomes/actualizations). Symbol references, context, and thereby knowledge are grounded in relational information exchange (having both epistemic and ontic components). In addition, such context-boosted information is coextensive with input-output-context triadicities of an inclusive semiotics, which go beyond the local, Boolean limitations of information; this correlates with the distinction highlighted by Robert Logan between syntactics (Shannon information) and full semantics (see chapter 5) (Logan, 2014).
9. *Induction*—How can we justify inductive inference from the observed to the unobserved? Are there objective regularities enabling an effective and intuitive solution?

   Response: The inevitable encoding and decoding framework of complex physical systems points to an ontological (not just epistemological) basis for induction. Further, local-global interrelations formulated

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in the Relational Reality model point to a physical grounding for both emergence and inductive processes; such interrelations are reinforced by recent research, as summarized by Ellis, supporting top-down causal relations and constraints (Ellis, 2016). Such complex systems and local-global features provide a uniform basis for objective regularities and consistent mappings from the observed to the unobserved.

10. *Access* of mathematical entities—Are the abstract realms of logic and mathematics distinct yet inaccessible (as with Plato's allegory of the cave), or are such features a deeply imbedded aspect of reality?

    Response: The Relational Reality model clarifies, via its handling of *potentiae* and local-global relations, the fundamental basis for the causal efficacy of certain mathematical entities; that is, as symbols for relations of relations in pre-space, the order of *potentiae*. Unlike the asymmetry of actualizations (or measurement outcomes) via quantum process, such real "relations of relations in pre-space" are symmetric, which explains the importance of symmetry in physical relations even though the fundamental quantum process itself and the emergent lived world incorporate fundamental asymmetry. In the real world, the context independence required for full symmetry is, at best, an approximation because of the unavoidable role of context (i.e., the inevitable input-output-context triadic).
11. *Matter-symbol problem*—What is the fundamental relationship of knower and known?

    Response: As Howard Pattee states, "Epistemology by its very meaning presupposes a separation of the world into the knower and the known . . . the knowledge vehicle cannot be in the same category as what it is about . . . the epistemic cut." (Pattee 2010, 525) The knower-known relation always maps to some form of input-output, and this in turn always involves both an input-output-context triadic and fundamental quantum process, which bridges the logic of *potentiae* and the logic of actualization. The epistemic cut and matter-symbol problem emerge from the distinction of standard input-output logics, and they are overcome through the interplay of triadic forms and these fundamental processes. In this way, the knower-known distinction, the epistemic cut, and the matter-symbol issue have interrelated epistemic and ontological components.
12. *Problem of consciousness*—How does the physical brain alone enable consciousness?

    Response: The hundreds of attempts to solve the mind-body problem, what Arthur Schopenhauer called the "world-knot," have all failed. The *Logoi* framework provides a new way to potentially transform the formulation of this complex problem. Consciousness is an emergent capability of the mind, distinct from brain actualizations (Boolean outputs), with the

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With continued failure to resolve the quantum measurement problem and conceptual incompatibilities between quantum and relativity theory, various approaches have arisen over the past several decades that appear to celebrate high abstraction and theory. With the exception of Croca's non-linear theory, most of these proposals appear incompatible with basic human experience or intuition. Examples of such scientific exotica are "many worlds" (of the many-worlds interpretation for quantum measurement), and multiple universes (or multiverses). A few of these theory-oriented concepts are listed below along with their primary problematic features:

1. multiverse/many worlds—denies any distinction between actuality and possibility; every wave function collapse actualizes a new world, thus yielding severe ontological overflow;
2. fully time-symmetric solutions for the measurement problem solve some formal problems but, in early formulations, hold on to actualism and deny temporality. However, the Possibilist Transactional Interpretation (PTI), in Ruth Kastner's interpretive extension of John Cramer's earlier work (Kastner 2013), provides a promising alternative that avoids these limitations and affirms *potentiae*, although its current formulation does not focus on topological and phase effects. Nevertheless, PTI comprises both unitary and non-unitary evolution, the latter being the onset of a transaction, and thereby addresses both phase and topological effects. Evaluating details of the relationship of PTI and Relational Realism is a topic for future research (Ruth Kastner, private communication, 2020);
3. block universe model—denies potentiality and claims absolute determinism; inconsistent with hard-core common sense; presumes a direct entailment model for physical relationships; based exclusively on a Boolean logical model, which neglects the non-Boolean component of quantum process and the inevitable context for real physical process. An extensive critique of block universe notions is provided by Tallis (2017). Further, Kastner et al. point out that the "static block world comprising no more than a set of actual events cannot really be a dynamical ontology" (Kastner et al. 2018, 163).
4. epistemic-focused models—Bohr's Copenhagen interpretation focuses on measurement outcomes, or facts, and their correlation; within its epistemic limitations this standard model is basically correct. However, efforts to ontologize this interpretation encounter serious problems, and these problems, first highlighted by the Bohr-Einstein debates, motivate the investigation of alternatives for a realist interpretation. Another epistemic-focused approach is that of quantum Bayesian models, which take a subjectivist view of quantum probability as a measure of an individual's degree of belief. As Bunge states as part of his detailed critique,

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"An alternative to the realist view of chance and probability is the subjectivist doctrine. This is also known as Bayesianism because of its heavy reliance on a certain interpretation of Bayes' theorem. Bayesianism is the opinion that probabilities are just opinions: that every probability value is a measure of the strength of the belief of a person in a fact or in a statement" (Bunge 2015, 106).

5. David Bohm's nonlocal model—uses extra dynamical variables to recover, as Virendra Singh states, "some of the desirable features of classical physics . . . The first such successful attempt was that of Bohm, who in 1952, showed that a realistic interpretation of quantum mechanics can be constructed which maintains a causal description and avoids treating systems and measuring apparatus differently" (Singh 2008). Work continues on this Bohmian interpretation, especially by a community of scholars led by Bohm's colleague Basil Hiley (Bohm and Hiley 1993), but the theory does not make the Boolean/non-Boolean logical distinction that Primas considers as essential. The Bohm theory is also highly nonlocal in its core variables; the "hiddenness" of these variables greatly complicates testing as well; however, at least it is, in principle, testable unlike the many-worlds interpretation. Jan Walleczek and colleagues have edited an excellent survey of contemporary work on the Bohmian approach (Walleczek et al. 2019).
6. nonlinear model—J. R. Croca and his Portuguese group have developed a non-linear theory, which attempts to unify classical physics, relativity, and quantum physics in a causal description that "contains the linear domains of physics as a particular case" (Croca 2015, 17). This nonlinear model avoids the ontological overflow of multiverse models; however, it also presumes actualism and its nonlinear theory would be very difficult to apply in practice.

Another approach, developed by Marina Cortês and Lee Smolin, less developed than any of the above, introduces energetic causal sets based on quantum information processing systems whereby only causality (and not space-time) exists at the fundamental level. The theory focuses on "real ensembles" in which, as stated by Smolin, the "brazenly non-local interactions between simple, causally related objects widely distributed in space explain all the probabilities, uncertainties and spooky interactions of quantum physics" (Smolin 2019, 37); and further, this model "explains things not in terms of objects situated in a pre-existing space, as we do now, but in terms of events and the relationships between them" (Smolin 2019, 36). This approach has some promising features such as an objective "flow" of time; however, it introduces untested new concepts and physics. In contrast, the Relational Reality model builds directly on the core quantum physics that

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has been multiply tested over many decades, and augments this with a robust interpretation that enables an understanding of all available experiments as discussed in chapter 2.

Although the Relational Reality model denies naive realism, it affirms a critical realism[14] that is intuitive, and maintains hard-core common sense (i.e., assumptions that we presume in our practice universally or nearly universally). For example, although there are very high levels of coherence and predictability of events (thankfully so for the safety of auto and air travel, etc.), there remains an ontologically genuine remainder of real possibility which, for human affairs, includes some amount of genuine human choice. This remainder of real possibility enables a consistent basis for ethics and supports our normal human intuition of selecting, at least at times, between real choices.

LEVERAGING WELL-ESTABLISHED SCIENTIFIC RESULTS

It has been claimed that quantum physics provides its own interpretation and that a unique and "simple" solution to the quantum measurement problem is the many-worlds interpretation. This is incorrect: none of the proposed solutions for the quantum measurement problem arise without philosophical assumptions derived from beyond quantum physics. In particular, the many-worlds interpretation depends on the presupposed (unstated) and questionable philosophical claim of actualism, which is that the domain of the real and the actual are one and the same, thus excluding potentiality (*potentiae*) from the domain of the real.[15] Based on both an analysis of quantum physics using partial Boolean algebras (Atmanspacher and Primas 2003; Primas 2017), and via a category theory analysis of the quantum measurement problem (Epperson and Zafiris 2013), Atmanspacher, Primas, and Epperson and Zafiris, have shown that the hypothesis of actualism is not necessary, and indeed false. By conflating all non-Boolean possible systems to one Boolean system of actualizations (thus throwing all non-Boolean solutions into an inaccessible multiverse ether), such many-worlds or multiverse theories yield unimaginable ontological overflow, and neglect the powerful distinction of local Boolean systems of actualizations and global non-Boolean frameworks of *potentiae*.

The Relational Reality model leverages well-established scientific results, especially the past century of experiments and theory that form the core of modern quantum physics, a theory that is arguably the most highly developed and tested of all physical theories. The Relational Reality model enables coherent and multidisciplinary solutions for the Gordian knot of problems above and yet avoids speculative extensions beyond well-tested physics.

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The power of the Relational Reality model derives from both scientific and philosophical considerations. It enables us to reframe fundamental quantum process as an exemplar of what Bradley describes as a strong theory of active existence whereby "active existence is to be analyzed independently of any notions of production or of a pregiven real. Speculative event-theory [see indented quote below] . . . refuses to refer things away from themselves to something else as their principle of actualization. Acts of existence are now to be understood as finite, groundless self-actualizations" (Bradley 1996, 235).

This feature of self-actualization arises explicitly in the Relational Reality model, as argued by Epperson and Zafiris (see chapter 2): "It is also the case in both Whiteheadian metaphysics and quantum mechanics that the local measurement context of a novel actual occasion-in-process, though not externally determined, is nevertheless internally conditioned by virtue of its internal relatedness to its dative world. In quantum mechanics, this is evinced by the fact that the presupposed global logical structure is defined by a Boolean localization scheme, where compatible local Boolean contexts overlap, and the indexical local measurement context must be part of this overlap" (Epperson and Zafiris 2013, 164–165). In this way, the self-actualization of quantum events arises from the inevitable contribution of internal relations for asymmetric, diachronic quantum process, which augments the external relations that were the focus of classical physics.

Bradley further notes a basic shift of thought in the late nineteenth century such that

> prior to the late nineteenth century, speculative metaphysics characteristically defines the active existence of things—the concept of the actualization of things—by reference to the causal or productive activity of a pregiven, grounding reality, which is understood as in some sense complete and is variously conceived as the realm of form, or as the emanation of an incomprehensible One, or as the transcendent activity of the Creator God, or as the immanent activity of the Whole or Absolute. By contrast, one central theme that characterizes the development of speculative metaphysics from the late nineteenth century onward is to be found in the work of the later Nietzsche, the later Heidegger, Bergson, and Whitehead. Here, the active existence of things can generally be said to be conceived strictly as a matter of finite, singular "acts of duration" or "events" of self-actualization. (Bradley 1996, 235)

The alternative weak theory of existence since Frege, commonly applied as a nominalist strategy and fashionable in analytic philosophy circles for the past century, as pointed out by Bradley, "is best described as treating existence in such a way that it has no independent features of its own, but is exhaustively definable as the satisfaction or exemplification of the variables

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of the propositional function.[16] Against such a view, speculative [systematic] metaphysics holds that existence is much more than a silent, featureless pendant of the propositional function" (Bradley 1996, 233). In contrast to this weak theory, which often resorts to a "Wittgensteinian strategy of dissolving philosophical problems" (Bradley 1996, 244), the active existence approach, applying a series-relative strategy, is capable of solving many such problems. For example, Bradley continues,

> consider that cluster of distinctions related to the contrast of "mind" and "world." In a serial analysis, mind and world, subject and object, ideal and real, are no longer treated as self-contained elements that stand in some kind of fixed contrast or opposition to one another. Instead, they are defined as distinctions of serial order, as states or stages of serial construction. Thus, the concepts of world, reality, and object refer to antecedent events or phases of events, and the concepts of mind, subjectivity,[17] and ideality refer to successor events or phases of events as they construct themselves out of their antecedents. (Bradley 1996, 234)

This series-relative strategy is part of how we have addressed many of the Gordian knot problems and builds on the fundamental succession reflected in quantum process. Recognizing the limits of his philosophical analysis, Bradley asks "How are the structures that govern the genetic-serial relations of predecessor and successor events to be elaborated?" (Bradley 1996, 243). The complexities of such elaboration are outlined by Whitehead in his seminal work *Process and Reality* (Whitehead 1929, 1978), and now a contemporary scientific and philosophical elaboration is provided by the *Logoi* framework, including its Relational Reality model, which may be helpfully augmented, at multilevel, with the quantum of explanation concept as sketched by Auxier and Herstein (2017).

NOTES

1. In contrast to nominalist "standard empiricism," Nicholas Maxwell argues persuasively for metaphysical, anti-nominalist considerations within his "aim-oriented empiricism," which is closely related to Whitehead's approach. Maxwell demonstrates the importance of metaphysical blueprints (effectively the coherence criteria), theoretical unity (viz., the rational criteria of being logical and coherent), and empirical success (effectively Whitehead's empirical criteria) (Maxwell 2017).

2. Phillip Stambovsky emphasizes the centrality of relation for the great nineteenth-century logician, Rudolph Hermann Lotze, stating "the cardinal ontological moment of *relation*–Lotze's historically influential core metaphysical principle" (Stambovsky 2009, 159).

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Chapter 4

Causation, Emergence, and Complex Systems

Causation is an efficacy by which a given initial process or state (the cause) effectively guarantees the occurrence of another state or process (the effect). Substantial effort is expended in scientific experiments to minimize environmental effects and to isolate causes and effects. Such efforts are always an approximation to enable the modeling of real complex systems that involve interactions between their components and environments. Complex systems exhibit emergence wherein an entity is observed to have properties that its parts do not have on their own. The cause-effect relations of complex and emergent part-whole systems are often difficult to sort out. Here I explore the interrelationships of causation, emergence, and complex systems, and will argue that causation and emergence are interdependent processes focused, respectively, on diachronic and synchronic aspects of fundamental process.

In the history of thought, several stumbling blocks or impediments have tended to undermine a deeper understanding of causality, emergence, and complex systems. In the first six sections below, I highlight these impediments which are, in turn, substantialism, actualism, nominalism, deductivism, mechanism, determinism, and physicalism. After this analysis of stumbling blocks, I examine the implications of fundamental relations and quantum process as key pathways for an understanding of causation, emergence, functions, symmetry, and levels and thresholds of emergence. Finally, I address the emergence of physical relations (i.e., law), landscapes of *potentia*, and higher levels of emergence including consciousness.

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SUBSTANTIALISM—FROM SUBSTANCE TO PROCESS

The appearance of relative permanence is encouraged by vision-dominated encounters with the world, which led the Greco-Roman world to emphasize a worldview of perceptual objects. In contrast to such substantialism, the ubiquity of change highlights the importance of process. Long time-scale processes, of course, often allow a more static interpretation (e.g., the life cycle of mountains, continents, and planets) whereas flow and dynamics is most evident with short time-scale processes. In the limit of micro-scale interactions, as Rodney Brooks concisely explains, dynamics and process are dominant as exemplified by both direct experiments and quantum field theory (Brooks 2015). Only a commitment to a problematic substance metaphysics enables the exclusive use of the adjective "particle" for quantum-level entities, which are widely recognized as being grounded in quantum fields. The importance of both continuity and change in our experience is well expressed by Elizabeth Kraus: "Being and becoming, permanence and change must claim coequal footing in any metaphysical interpretation of the real, because both are equally insistent aspects of experience" (Kraus 1998, 1). A diverse array of thinkers have added to the critique of substance thinking including, as pointed out by Timothy Mooney, the noted philosopher of de-construction, Jacques Derrida (Mooney 2002).

The substance metaphysics that so pervades Western philosophy should not be regarded as, in any way, a universal concept. Indeed, entire civilizations have instead emphasized becoming and process. In particular, as Hall and Ames have argued, an emphasis on flow and dynamics tends to dominate Chinese philosophy: "The process or field of existence viewed *in toto* and as integrated from a particular *te* [virtue] perspective is called *tao* [way]. When viewed in terms of the integrity of individual entities, however, this field is a collocation of particular foci, or *te*" (Ames 1987, 239).[1]

My own worldview includes both aspects, being and becoming, permanence and change, grounded in the organic, processual feel of my early farm experience yet adding in the usual elements of linguistic abstraction combined with formal education in physics and philosophy. During my space physics career, I was frequently reminded through practical examples that classical physics is simply an approximation to modern physics (especially quantum physics). In one project, I worked with low-light-level photoelectronic imaging systems as part of experiments in ionospheric physics; such systems were later enhanced for night vision applications. The photons of available light are converted into electrons and then multiplied using photomultipliers, and then converted back to photons for the final sensing element. The conversion of photons into electrons depends on the quantum photoelectric effect for which Albert Einstein obtained the Nobel Prize in 1921. These experiences

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helped me to understand, better than the abstractions of classroom study, how the default substance-oriented ontology of classical mechanics is not just misleading, but simply wrong given current understandings of field theory, and especially quantum physics and quantum field theory.[2] Quantum physics is applicable to essentially everything in the world about us even though classical physics is an excellent approximation for many real-world applications, and is often the best tool for most applications due to its relative simplicity.

We should keep in mind that the dictionary definition of *causation* ("the relationship of cause and effect") in no way requires default to the presumed ontology of classical mechanics.[3] This trend for going beyond substance-oriented ontology in science is reflected as well in the fundamentals and history of mathematics. Desmet reports that "According to Whitehead, the history of mathematics is a history of increasing 'emphasis on pattern, as distinct from the special entities involved in the pattern,' and it coincides with a transformation of mathematics into 'the intellectual analysis of types of pattern'" [imbedded quotes are Whitehead's own in *Essays in Science and Philosophy* (Whitehead 1948, 83)]. Desmet further notes that most mathematicians now agree that mathematics is the science of pattern (Desmet 2010b, 227).

ON THE FAILURE OF ACTUALISM AND NOMINALISM

Both actualizations and potential relations (*potentiae*) are genuinely part of the real, a result based on recent research outcomes in quantum physics, in addition to phenomenological and philosophical analyses of human experience along with the Relational Realism model summarized in chapter 3. This important result profoundly impacts some classic debates about "What is the real?" Proper scientific propositions about measurement results (data), and theoretical modeling of such, have sometimes been extended to buttress the metaphysical claim of actualism whereby the domain of the real is claimed to be nothing but the actual. The claim of actualism cannot be confirmed based on scientific propositions alone, however much extended; nonetheless, as we shall see, it can be readily refuted based on philosophical analysis and ordinary human experience.

Closely related to the claim of actualism is the concept of nominalism and a unifying problem that links together causation, emergence, and complex systems, namely the problem of particulars versus universals, which Ganzalo Rodriguez-Pereyra summarizes this way:

> Philosophers have often found it necessary to postulate either abstract objects or universals. And so Nominalism [being the denial of such abstractions] in one form or another has played a significant role in the metaphysical debate since

> at least the Middle Ages . . . "Nominalism" carries an implication that the corresponding doctrine asserts that everything is particular or concrete . . . one kind of Nominalism asserts that there are particular objects and that everything is particular, and the other asserts that there are concrete objects and that everything is concrete. (Rodriguez-Pereyra 2016, 1)

In spite of the difficulties and refinements of this metaphysical debate over the centuries, Mary MacLeod and Eric Rubenstein conclude that "a consensus does seem to be emerging though . . . that two genuine contenders are left: Strong Realism and Trope Nominalism" (MacLeod and Rubenstein 2019, 16).[4] As will be shown below, all forms of nominalism are inadequate; thus, we appear to be left with realism. However, such realism is most often taken to designate Platonism, but that representation is overly restrictive as we shall see. In addition, the particular type of realism referenced by MacLeod and Rubenstein only makes reference to individual, quality dyads and makes no reference to a more sophisticated theory of relations and universals as applied in the *Logoi* framework and articulated further in this chapter and chapter 8.

Defining "metaphysics" is not simple; indeed, Ilana Moss provides thirty definitions (Moss 2018). What appears to be an essential element of all such definitions is that a metaphysical proposition points to some reality or understanding that permeates all reality and is yet not immediately evident in particular observations.[5] By this criterion, both *nominalism* (in either sense above) and *realism* (the affirmation of abstract objects or universals) are, by definition, metaphysical claims. Since we cannot resolve this debate by only demonstrating the presumed scientific merits of either position, is it yet possible to make progress on this question? Indeed, we can.

A key discovery inspiring the *Logoi* framework, as seen above, is how the real is both the actual and potential relations, or *potentiae*,[6] a result suggested by (yet not entailed by) both human experience and the quantum physics requirement of two fundamental kinds of logic, the Boolean logic of actualization and the non-Boolean logic of *potentiae*. Because nominalism is basically the affirmation of actualism, which depends on the claim that the realm of Boolean logic is all inclusive, it is now apparent why nominalism is necessarily wrong; or, to put it more tactfully, necessarily incomplete.[7] Paul Teel has argued that Charles Sanders Peirce, who himself had transitioned from a nominalist to a realist position, was especially articulate in his critique of nominalism. "Peirce's debate with the nominalists is often . . . centred around the word 'mere.' Peirce has a problem not with the statement that there are facts, but with the statement that there are merely facts. Or again, Peirce's problem is not with the statement that generals are thoughts, but with the statement that they are merely thoughts" (Teel 2011, 205). Complementing Peirce's critique of the notion of mere

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facts, Hartshorne's definition of *metaphysical propositions* emphasizes their generality (not their transcendence) by how any particular observation or possible observation could potentially falsify a metaphysical proposition because they must be universally exemplified. As stated by Viney and Shields, "Central to all of Hartshorne's definitions [of metaphysics] is that genuinely metaphysical propositions are unconditionally necessary and non-restrictive of existential possibilities. If metaphysical propositions are true at all, they hold true of all possible world-states or state-descriptions" (Viney and Shields 2020, 51).

Another way to put the claim of nominalism into a broader context is to outline the full range of concepts of the universal. In one formulation, Desmond itemizes five basic types of universals: Platonic (transcendent to the instances of becoming), Aristotelian (immanent in the process of becoming), nominalist (no ontological dimension), idealist (concretized in immanent becoming), and intimate universal (emphasizing, as interrelated, both immanence and transcendence) (Desmond 2016, 3–4). The nominalist form here, of course, is paradoxical because it is typically part of a metaphysical claim that no universal whatsoever has any reality! As a nominalist would claim, there is, Desmond points out, "nothing ontologically beyond, and nothing ontologically immanent, but merely a sound of the voice, a *flatus vocis*, affixed to a particular idea that tries to insinuate a more general range of reference" (Desmond 2016, 4).

As we have seen above in the analysis of fundamental quantum process, specific potential relations (*potentiae*) are an essential ingredient in such process, and no mere trope or other pseudo-concrete object can plausibly play that key explanatory role. Once again, Gonzalo Rodriguez-Pereyra notes that "according to widespread usage a universal is something that can be instantiated by different entities and an abstract object is something that is neither spatial nor temporal" (Rodriguez-Pereyra 2016). Nominalism then denies these non-particular entities. However, we have found that both the order of *potentiae* and the order of actualizations have a critical role to play in fundamental process, but neither has a specific space-time place. Recall that space-time is not pre-given; instead temporality and space-time metrics emerge from such process.[8] Fundamental quantum process, as we have seen, necessarily incorporates local-global interrelations, which are confirmed in multiple quantum experiments that test Bell's theorem and entanglement. Again, concrete objects alone cannot play the role of such local-global relations, or of specific input *potentia* from within a landscape of *potentiae*, whose ultimate relata[9] cannot be merely specific concrete objects.

Thus, fundamental quantum process and the inferred fundamental orders (of actualism; of *potentiae*), as described here, violate key claims of philosophical nominalism. Ockham's razor is a worthy principle and discourages

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> productive aspect; "actuality" is the same in its backward or preservative aspect. Logical modalities express the ways in which creatures may understand their situations as heirs of a definite past and as contributors to future creatures which are definite in advance only with respect to the contributions that will be at their disposal. (Hartshorne 1963, 605)

The famed co-founder of quantum physics, Werner Heisenberg, explicitly argued for the importance of *potentia* (Heisenberg 1958), yet this had only minor influence in the theoretical physics community, which tended to favor actualism and determinism. However, beginning with a series of experiments enabling quantitative tests of the famed EPR argument of the 1930s, the subfield of quantum theory of measurement has witnessed a renaissance, which has led to many robust and productive debates (e.g., see the *Foundations of Physics* journal, published since 1970). The outcome of these debates remains open, but significant constraints for some form of realism have become more clearly established. In response, some realist-minded physicists have adopted variations on the many-worlds interpretation (MWI), which maintains actualism and refuses the actuality-*potentia* distinction but at a very high cost in plausibility due to its highly inflated ontology. Other options for a realist approach require the introduction of untested new physics; for example, those like Ghirardi-Rimini-Weber (GRW) building on the Lindblad equations, as noted by Steven Weinberg (2017). Epperson provides a substantive critique of the GRW strategy (Epperson 2009).

Without introducing any new physics, there is one approach that has arguably enabled a critical realist approach without highly inflated ontologies (as with multiverses) or any new untested additions to the physics. This realist approach builds on the highly successful, and widely supported decoherence interpretation of quantum mechanics as developed, for example, by Wojciech Zurek (2006), and simply adds to this the philosophical distinction of actuality and *potentiae* as both part of the real (thus, a denial of actualism and simple entailment), utilizing as well recent developments in mathematical category theory, which are relatively uncontroversial and appropriate for this important application. As outlined in chapter 2, the first full articulation of this new Relational Realist interpretation of quantum mechanics appears in the work of philosopher Michael Epperson and mathematical-physicist Elias Zafiris (Epperson and Zafiris 2013; Epperson 2016; Elias Zafiris 2016). Independently, Ruth Kastner succeeded in a new realist interpretation, also incorporating *potentia*, by adapting and enhancing John Cramer's Transactional Interpretation; as well, this approach simply uses the well-tested core of quantum physics (Kastner 2013). Of these two recent advances, the work of Epperson and Zafiris provides a focus on logic issues and yet maintains a simple ontology, but this in turn leads to updating our understanding

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