Perception and Entanglement in the Quantum World: A Phenomenological Exploration of the Physical, Social, and Philosophical Implications

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Note to Reader: This is a preprint of a work that adapts, integrates, and builds on three separate articles published in *The Journal of Mind and Behavior* (see Rosen, 2021, 2022, and 2023).

CONTENTS

ILLUSTRATIONS

PREFACE

What are the limits of human perception? Can the human eye reach down into the world of the very small and detect the activity of subatomic particles? Can the eye engage the mysterious core of the quantum world itself? Does perception have the capability of turning around on itself to view the source from which it arises? Are there circumstances under which the perceptions of separate quantum observers can become entangled with each other and their separate fields of observation coalesce? If human perception can be extended in these ways, what are the implications for society?

These are some of the central questions explored in this book. In addressing them, the scope of our inquiry clearly cannot be limited to the psychology of perception. We will need to delve into the foundations of physics and examine its underlying philosophical assumptions. And we will have to take into account historical and cultural factors if we are to fully appreciate the potential social impact of extending human perception in such an unprecedented way. All this speaks to the transdisciplinary nature of the present work, attesting to the fact that while human perception is certainly a primary focus, the book is about more than just that.

To sum up this work in a nutshell, it begins by introducing the startling possibility of human perception on a subatomic level. Then, after examining various interpretations of the quantum domain, the book shows how mainstream philosophical approaches fail to do justice to this enigmatic realm, while an interpretation grounded in phenomenological philosophy clarifies quantum reality. Aided by qualitative mathematics, the phenomenological approach is subsequently applied in new models of quantum perception and entanglement, accompanied by novel modes of observation and communication. In the end, the book contemplates the social implications of quantum entanglement and guides readers to imagine the emergence of a quantum society. Having given the bird's eye view of this book, let me now return to earth for a detailed preview of its chapters.

1. PREVIEW OF THE CHAPTERS

The first five chapters deal with quantum perception, its underlying theory, and the phenomenon of quantum entanglement. Then, in the two closing chapters, I call attention to the social implications of entanglement, especially in relation to the prospect of an emerging quantum internet.

Chapter 1 sets the stage for what is to come. Here I briefly introduce research that confirms the possibility that human beings are indeed capable of sensing single photons (see Tinsley et al., 2016; Holmes et al., 2018). I suggest, moreover, that human vision may be able to go further still, that it may be able to "to probe the very foundations of quantum mechanics" (Ananthaswamy, 2018a, para. 2). However, chapter 1 ends on a note of caution. An intimation is given that the visual observation of the microworld may be blocked from proceeding to deeper levels without adopting a whole new mode of observation.

The segue to chapter 2 comes with the realization that a full understanding of quantum perception requires that we examine quantum theory in sufficient depth. The

chapter begins with physicist Richard Feynman's famous 1964 declaration: "I think I can safely say that nobody understands quantum mechanics" (1967, p. 129). Among mainstream physicists, this statement appears to hold true, though there have been many attempts to interpret quantum mechanics. The most prominent of these is the Copenhagen interpretation, which, in a certain sense, can be viewed as a "non-interpretation." That is because the Copenhagen approach does not seek to uncover the deep meaning of quantum phenomena but limits itself to predicting the behavior of subatomic particles. What we see in chapter 2 is that the reluctance of Copenhagen physicists to search for meaning in the quantum world reflects at bottom their commitment to the philosophy of objective realism that is essentially at odds with the quantum phenomena themselves. After examining the limitations of several other theoretical and philosophical perspectives on quantum reality, I propose an approach based on the ontological phenomenology of Maurice Merleau-Ponty (1945/1962, 1964, 1968) and Martin Heidegger (1927/1962, 1964/1977). On my interpretation, the quantum dimension is seen to correspond to the dimension of Being, or what Merleau-Ponty called the "lifeworld," a concept he adopted from phenomenologist Edmund Husserl and later radicalized as the "flesh" of the world (Merleau-Ponty, 1968). In Merleau-Ponty's related concept of *depth* (1964), we discover a promising new way of comprehending the quantum realm by giving natural expression to primary features of the quantum that are anathema to the objectivist outlook, such as the fusion of observer and observed (or subject and object).

Chapter 3 begins by asking whether the philosophical notion of depth can be brought into sharper focus so as to make it more relevant to the book's key issue of perceiving the photon. A perceptual model of the quantum wave and quantum observation is then offered employing the Necker cube, a well-known figure from the psychology of perception. Upon noting a basic limitation of this model, we turn to the mathematical field of qualitative topology to make use of a higher-dimensional counterpart of the Necker cube, namely, the Klein bottle. Following an intensive investigation that departs from the Klein bottle's conventional treatment, we realize that this structure is not merely a mathematical "object." Instead, it signifies a self-reflexive process that flows back into the subject. Disclosed in this merging of subject and object is the dimension of depth that constitutes the dialectical lifeworld. The chapter ends by recognizing the relationship between Kleinian depth and the radiant energy of the photon, and this brings us back to the question of photon perception, and of how a new mode of observation is required if we are to observe the quantum reality that lies beneath the photon.

What would happen, asks chapter 4, if an observer hoping to directly view the underlying photonic wave were to maintain the objectifying stance of empirical tradition? In observing the Kleinian fusion of subject and object as if it were a mere object appearing before the observer's detached subjectivity, the wave would collapse, losing its coherence, and all that would be perceived would be the objectified particle. Therefore, in dealing with the depth-dimensional actuality of the photonic wave, the observer evidently would need to enter into it with her own subjectivity. Rather than remaining a disinterested bystander, she would have to relate to the wave in an intimate manner, immersing herself in its fleshly lifeworld, merging with it ontologically so as to become it.

In order to see what such a radical change in observational posture would entail, chapter 4 examines philosopher Evelyn Fox Keller's (1985) intimate science of "dynamic objectivity" and physicist David Bohm's (1994) notion of "proprioceptive thought," which

he viewed as a meditative act wherein "consciousness ... [becomes] aware of its own implicate activity, in which its content originates" (p. 232). What I propose in this chapter is that explorers of quantum reality will need to observe the photon in a proprioceptive way. In thus viewing the photon, the observer's attention is not limited to what appears out in front of him, as happens in the seldom-questioned conventional form of observation that drops the subject himself from awareness and leaves only the object to which he attends. Instead, operating proprioceptively, the subject consciously draws her attention back in upon herself as she observes the photon and by this act of self-inclusion brings subject and object together. Proprioceptive observation is therefore inseparable from observing oneself.

In chapter 5, I introduce the concept of quantum entanglement by tracing it back to Einstein, Podolsky, and Rosen's 1935 thought experiment that was motivated by Einstein's concerns about quantum mechanics. Einstein realized that if quantum theory were true, a pair of particles that are initially associated and then separated could behave as though still connected in an immediate way. He described the possibility of particles being entangled like this as "spooky action at a distance" and it was shocking to him for two reasons. For one thing, such entanglement would violate a basic principle of Einsteinian relativity that no signal can travel faster than the speed of light. But something more basic was involved. The relativistic structure of spacetime that limits the transmission rate of energy or information presupposes spacetime's *continuity* and, in such a continuum, information can only be transferred from one local point of space to another. Einstein was thus led to the conclusion that quantum theory must be incomplete, that it had neglected local hidden variables that, when identified and incorporated into the theory, would dispel the strange non-locality predicted by quantum mechanics and would restore the continuity of spacetime. But decades of subsequent research have proven Einstein to be incorrect and, in so doing, have confirmed the non-locality of quantum entanglement.

After describing the historical background of the entanglement question, I proceed in chapter 5 to consider several models of entanglement. Once again, the Necker cube comes into play, along with its higher-dimensional counterpart, the Klein bottle. What we see from this is that particles that are entangled are not just closely related; they function instead as the *same* particle. This leads to an intriguing proposition considered in the final section of chapter 5.

We are to picture a pair of entangled photons and imagine that the members of this pair are sent to separate locations where they are viewed by separate observers. If the entangled photons, though separated in space, constitute an indivisible whole in which they function as the same photon, and if the observer of each photon is viewing that photon proprioceptively thus entering into an ontologically intimate relationship with it, *being* it, should these observers not become ontologically entangled with each other? This fascinating possibility can actually be tested and I offer a detailed proposal for an experiment that would do just that. Chapter 5 concludes with an intimation of what the social implications of observer entanglement could be.

The entanglement discussed in chapter 5 involves entangling only two particles. But it is possible to entangle larger numbers of particles and, in recent years, much research has been focused on that. The end goal is to create a large network of computers based on the principle of entanglement. This linking of quantum computers is expected to eventuate in a quantum internet spanning the globe. In fact, governments have already invested billions of dollars in these efforts. Bearing in mind the possibility of *observer* entanglement,

what we explore in the closing chapters of the book are the social consequences of the burgeoning quantum internet and the role it might play in creating a quantum society.

Quantum computing and the quantum internet constitute an important new technology and powerful new medium. With the guidance of media theorist Marshall McLuhan (1964), chapter 6 provides a historical context for the advent of this medium. "'The medium is the message'" says McLuhan, "because it is the medium that shapes and controls the scale and form of human association and action" (p. 24). Beginning with the European Renaissance, the "message" was conveyed by the print medium, which gained ascendancy with Gutenberg's fifteenth century invention of the printing press. In chapter 6, we see how printing was linked to uniformity and linear sequence, and to the rise of the detached individual, along with the classical sense of space as a continuum. All this is tied to the philosophy of objective realism (discussed above).

McLuhan referred to the age of print as the "mechanical age" and he showed how this form of communication began to be undercut with the dawning of the electronic age in the middle of the nineteenth century. In the course of chapter 6, we examine five major electronic media and their social concomitants: photography, cinema, television, the conventional computer, and the quantum computer. By the end of the chapter, it is clear that earlier advances in electronic technology, in challenging the old mechanical paradigm, have paved the way for the quantum medium. The contemporary emergence of quantum computing and the quantum internet in fact brings the electronic age to its culmination, for the quantum principles that underlie this whole era no longer operate merely implicitly but have now come to the fore and into their own in a medium that is expressly quantum.

However, Chapter 6 closes by asking the following questions: Is the old paradigm truly being left behind with the transition to quantum technology? Is the expected use of the new medium still not strongly influenced by the classical modus operandi? Underlying the conventional way of thinking about employing quantum technology is the stance of the detached observer. I end the chapter by contrasting this with the proprioceptive posture of the entangled observer that is deemed necessary for fully realizing the quantum internet's potential for social transformation.

Chapter 7 deals with the need for greater clarity on how the quantum transformation of society could unfold. For this I begin by turning again to the work of David Bohm. Bohm's approach to communication and dialogue can be taken as a forerunner of the kind of quantum interaction that can revolutionize the internet, and society at large.

More than being a renowned physicist and philosopher, Bohm was the pioneer of a social movement bent on overcoming the fragmentation that is splintering human relations and endangering the planet. In chapter 7, alongside McLuhan's commentary on how electronic media point beyond the mechanistic paradigm, we consider Bohm's own challenge to that paradigm, a social initiative in which the process of proprioception plays a critical role.

Bohm raised the question of whether we could somehow learn to communicate with each other in a less guarded, more transparent and receptive way, exploring together the basis of our discord. What evolved from this was a group practice that has come to be known as "Bohmian Dialogue" (see Bohm et al., 1991), or what I have called "Proprioceptive Dialogue" (PD; see Rosen, 2022). In previewing chapter 4, we considered the proprioceptive method of interacting with photons wherein the observer of the photon gains a sense of her own process of observing. With Proprioceptive Dialogue, this self-

reflexive methodology is applied to social interactions among human beings. A key question for chapter 7 is whether the emerging quantum internet, with its potential for proprioceptive social entanglement, can facilitate and be facilitated by PD.

The practice of PD is investigated in detail in the first two sections of chapter 7. We see that PD is not primarily a discussion of concepts or a forum for exchanging ideas. It is an experiment in "radical honesty" in which participants relate to one another based on an awareness of and willingness to share their hidden agendas. In this practice, participants go proprioceptively backward into themselves (as in the proprioceptive observation of photons), relating to each other by sensing in the moment their own bodily process of relating. In the course of sharing their proprioceptions, group members can find themselves interacting in resonant field-like coherence. Here they can engage in a kind of "dialectical jazz" in which fresh meanings evolve in an ongoing process of creative exploration.

Nevertheless, PD has its limitations. The primary issue is that when PD is conducted in person or through the conventional internet, it remains subject to headwinds from the classical paradigm. This prevents PD groups from experiencing coherent field relations more fully and consistently. What I propose is that the coherent entanglement of dialogue participants might be enhanced on the quantum internet by employing entangled photons to mediate the process.

Next, in seeking a better understanding of observer entanglement in the quantum medium, I return to the Klein bottle. Earlier I established the ontological nature of Kleinian relatedness and the Klein bottle's capacity to embody entanglement. In chapter 7, I suggest that participants in a PD group meeting on the quantum internet and tuning in to each other by proprioceiving Kleinianly entangled photons would constitute, in effect, an ontological community. From there I proceed to examine in depth the nature of ontological community, bringing out its prevalence in pre-Renaissance and non-Western cultures. The book ends with an attempt to anticipate concretely what the experience of Proprioceptive Dialogue might actually be like in a quantum context.

2. LIMITATIONS AND CHALLENGES

To realize my agenda within the covers of a single volume, at times it has been necessary for me to paint with a broad stroke. As noted at the outset and as is evident from my preview of the chapters, the book spans a multitude of disciplines: philosophy, psychology, physics, mathematics, sociology, anthropology, media technology, and others. Given the scope of the work, in no way would it have been possible for me to operate at the finely calibrated level of scholarly detail that the specialist can achieve in more tightly circumscribed areas of investigation. Still, I have made every effort to remain faithful to the facts that have been established in the fields I have broached. Beyond the criterion of consistency with external fact, it seems that a work of the present kind above all needs to be judged in terms of its *internal* consistency and its general coherence. On this count, validation is contextual; an idea gains credibility and weight to the extent that the integral role it plays within an overall network of interrelationships is plain to see. Since the clarity of the whole is at least as important as that of the separate parts in the present book, and since the parts are illuminated by the whole, my hope is that I have been skillful enough and passionate enough to make the whole transparent.

However, there is no denying that the agenda I have laid down is challenging. In exploring the curious nature of the quantum realm and the role we may play in it, we will need to think dialectically, engage in hybrid blendings of thought that transgress long-standing categories, indeed, that fly in the face of categorial thinking as such. Underlying assumptions that have always been taken for granted—assumptions about what we experience, about what is possible and what is not, about how the world works—will be opened to question. More than raising doubts about basic habits of thinking, habits of perception will be challenged as well in this book. Readers will be confronted with limitations in their ways of observing the world and each other that go beyond the content of what they see to their very manner of seeing. In the process, novel modes of observation will be proposed.

But why should we trouble ourselves with such probing and questioning? Don't our usual ways of thinking, perceiving, and operating still serve us adequately? The answer I suggest is that they do not. We are going to see that the worldview and fundamental paradigm that has held sway for many centuries is now unraveling. The consequences of this cannot be addressed in a constructive fashion without a deep understanding of what is happening to us. Only on that basis will we be able to meet the challenge of discovering new ways of functioning that supersede the old.

3. ACKNOWLEDGMENTS

The present book adapts, integrates, and significantly builds on three separate articles of mine published in *The Journal of Mind and Behavior* (the text used is reprinted with permission; see Rosen, 2021, 2022, 2023). The book advances work on topological phenomenology initiated in several previous volumes. The first of these, *Science, Paradox, and the Moebius Principle* (Rosen, 1994), is a book of my essays in which an earlier version of topological phenomenology is applied to various problems in science and philosophy. In *Dimensions of Apeiron* (Rosen, 2004), the role of topological phenomenology is explored philosophically in the broad context of historical and cultural change. Then, in *Topologies of the Flesh* (Rosen, 2006), I elaborate on my topological account, expanding it to offer a detailed exploration of hitherto unrecognized dimensions of human experience and the natural world. Two years later, I published *The Self-Evolving Cosmos* (Rosen, 2008), an application of topological phenomenology to modern theoretical physics that investigates the unification of the forces of nature and the evolution of the universe. While the present book focuses attention on the problems of quantum perception and entanglement, and their social implications, I would like to acknowledge applications of topological phenomenology to diverse fields of study by other researchers.

Mathematician Louis Kauffman (2015, 2025) provides insightful reflections on how mathematical self-reference is related to topology and phenomenological philosophy. Language theorist L. E. Maroski (2025) uses the Klein bottle as an image that steers her search for alternatives to the dualistic structures of conventional language. Specific applications of Kleinian philosophy to the natural sciences are proposed by physicist Diego Rapoport (2011, 2013, 2018). Anthropologist Don Handelman (2021), in his deep study of ritual practices, employs the phenomenology of Merleau-Ponty and is guided by the paradoxical structure of the Moebius surface (which is a close relative of the Klein bottle). Moebius phenomenology is prominent as well in the writings of feminist theorist Elizabeth

Grosz (1994) and it functions as a guiding framework for her book, *Volatile Bodies*. Another contribution to topological phenomenology comes from Jungian psychologist Nathan Schwartz-Salant (2007, 2017). Operating self-referentially, Schwartz-Salant employs Merleau-Ponty and the Klein bottle in characterizing the deep psychodynamics of human relationships, and he likens the fields operative in these paradoxical interactions to field processes in fundamental physics. In a similar vein, Jungian-oriented art therapist Susanna Ruebsaat (2019) draws on Merleau-Ponty and Kleinian imagery to plumb the depths of myth and dream. Phenomenology and the Klein bottle also play a role in philosopher James Schofield's (2021) revision of E. E. Harris's concept of dialectical holism. Phenomenological philosopher Olga Louchakova-Schwartz (2019) brings topology to bear in her perceptive studies of religious experience, and topological phenomenology finds another voice in semiotician Floyd Merrell's (1998) work on simplicity and complexity. Finally, independent researcher Anthony Judge (2009, 2011), in the course of investigating general knowledge structures and searching for ways of grasping their complexities and paradoxes, has written about topological phenomenology.

Speaking personally, I want to thank a number of people for the encouragement and support they have given me as I worked on preparing this book. Thanks go to Beth Macy for instigating this whole project by calling my attention to the research on single-particle perception that serves as my point of departure. I am especially grateful to Raymond Russ for his meticulous editorial guidance on the articles that gave rise to this book. In addition, I much appreciate the discussions and helpful comments about the book that were offered by my friend, Ben Shneiderman. And there is Geo N. Turner, my beloved sister, with whom I have had many stimulating talks that bear on my work.

I would also like to note that the discussion of Proprioceptive Dialogue featured in chapter 7 was inspired by my participation in numerous dialogue groups over the years, and, most recently, in the Vancouver and Victoria groups. Three individuals have been vital to the latter: Caroline Pawluk, David Schrum, and Sally Jeffery. One other dialogue group has been important to me, the online group originally hosted by Beth Macy and Linda Ellinor. I extend my thanks to all those involved in these experiments on a new form of communication that is much needed in today's world.

Let me single out a few other individuals whose assistance I gratefully acknowledge. I begin with two people who have gone to great lengths to call attention to my work: John Dotson (www.acharantos.com) and Hans Johansson. Then there are David and Jonas Dichelle, David and Cyndy Roomy, John R. Wikse, Ernest Sherman, Timothy J. Sullivan, Wally Glickman, Lloyd Gilden, Timothy Rogers, Jeffrey Kiehl, and Joel Kroeker.

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Chapter 1

A BRIEF INTRODUCTION TO QUANTUM PERCEPTION

For many decades it has been suspected that the human visual system is sensitive enough to be able to detect single particles of light. This hypothesis was confirmed by Tinsley et al. in 2016. Using a quantum light source capable of generating individual photons, they demonstrated that human beings can indeed detect solitary photons. The finding has gained additional support in the laboratory of Paul Kwiat and Rebecca Holmes (Holmes, Victora, Ranxiao, and Kwiat, 2018). It is noteworthy that researchers pursuing this line of investigation have not limited themselves to verifying the detectability of single photons but have set their sights on determining whether human vision can be pushed even further in the attempt "to probe the very foundations of quantum mechanics" (Ananthaswamy, 2018a, para. 2).

The prevailing approach to quantum mechanics is the Copenhagen interpretation. This outlook lends itself to the view that there is in fact no way of knowing the underlying reality giving rise to observed photons. The Copenhagen interpretation does posit a probabilistic quantum wave in which particle states are superposed, rather than the particle being definitively given in one state as opposed to another. When the particle is observed, the wave "collapses"; it is reduced so that the particle now appears in just a single state. Yet according to the Copenhagen approach, the quantum probability wave has no physical reality per se but is only a mathematical function. On this view, the quantum wave does not exist in a concrete sense but is merely the form taken by the abstract equation used to generate practical predictions about the behavior of particles. Nevertheless, research efforts such as those reported on by Ananthaswamy (2018a) would challenge the Copenhagen interpretation by exploring the possibility of actually observing the quantum wave. Thus, in speaking of the prospect of going beyond the detection of single photons to test "the perception of superposition states," Holmes et al. (2018) are indicating that we may be able to detect the photon wave while its quantum states are still superposed, before the wave collapses to give mutually exclusive states.

But there is a significant obstacle to this research, for it is by no means certain that a photon transmitted to the eye of an observer will actually register in the retina and be sent on to the brain for perception. Describing the work of physicist Alipasha Vaziri, Castelvecchi (2016) notes that "more than 90% of photons that enter the front of the eye never even reach a rod cell, because they are absorbed or reflected by other parts of the eye" (para. 7). Other experiments with single-photon detection encounter the same kind of drawback. Holmes et al. (2018) sum up the problematic nature of these studies: "The primary challenge for … single-photon vision experiments will be the low probability that a

photon is transmitted to the photoreceptors and detected in any given experimental trial (perhaps 5–10%, assuming a perfectly efficient source), and the corresponding requirement for a very large number of experimental trials" (Conclusions section, para. 1) to determine whether the statistics bear out that single photons are actually being detected, however small the effect.

In experiments such as these, certain tacit assumptions are made in accordance with long-held habits of observation. Whether hoping to observe a photon in a single state or as the superposed photon states of the quantum wave, the observer viewing the particle display is poised to encounter an object appearing in the space stretched out before him or her. The observer's implicit posture is thus externally oriented, set to take in what lies "out there," with the observer himself set apart from what is observed. This is how we normally take things in. We have been doing this for hundreds of years, both in everyday observation, and, especially, in empirical science. What I venture to suggest in this book is that, while we might indeed come to effectively observe (perhaps with special training) the quantum substrate underlying the photon, we will only be able to do so by changing the default setting long relied upon for our manner of observation.

Before we can fully appreciate what quantum perception might entail, we need to examine quantum theory in greater depth. In the next chapter, I explore various interpretations of quantum mechanics and their philosophical implications. Making no attempt to be exhaustive (something that would require a separate book), I consider several of the major interpretations within different philosophical traditions, then propose my own.

Chapter 2

QUANTUM THEORY

In a 1964 lecture, physicist Richard Feynman famously declared: "I think I can safely say that nobody understands quantum mechanics" (1967, p. 129). This appraisal seems to have held up fairly well. I noted in the introductory chapter that the minimalist Copenhagen interpretation is the standard approach to quantum mechanics. From its inception almost a century ago, the Copenhagen school apparently has been content to leave open the question of what quantum phenomena actually mean. The equations are not expected to provide insight into the physical structure of quantum reality but only to effectively predict particle behavior. As physicist David Mermin put it, "If I were forced to sum up in one sentence what the Copenhagen interpretation says to me, it would be 'Shut up and calculate!'" (1989, p. 9). It is not that alternatives to Copenhagen have not been offered. The proposals include a range of mind-independent (realist) views of the quantum domain, such as Everett's "many worlds" interpretation (1973), Bohm's pilot wave theory (1952), and the Ghirardi-Rimini-Weber (GRW) observer-independent model of quantum wave collapse (1986). There are also mind-dependent (immaterialist or idealist) approaches such as those of von Neumann-Wigner (von Neumann, 1932; Wigner, 1961), Wheeler (1990), and Goswami (1995). Nevertheless, after many decades, "the Copenhagen interpretation still reigns supreme" (Schlosshauer, Kofler, and Zeilinger, 2013). What this is telling us, in effect, is that the quantum domain remains a black box to most theoretical physicists. It is telling us what Feynman told us 50 years earlier: that a widely accepted understanding of quantum reality has not yet been achieved.

1. MIND-INDEPENDENT AND MIND-DEPENDENT INTERPRETATIONS OF QUANTUM MECHANICS

Let us take a deeper look at the Copenhagen interpretation. Is it actually as non-committal as it claims to be with regard to the nature of quantum reality? At the level of its explicit content, the answer is yes: advocates of Copenhagen maintain their silence on the quantum domain per se, treating it as a black box. However, when we consider the form taken by Copenhagen mathematics, we see that it implicitly enforces the same paradigm that underlies mind-independent, objective realist interpretations of quantum mechanics.

The realist paradigm is intuitively compelling in that it accords with our everyday experience of the world. What is real is seen to lie objectively "out there" in space, existing independently of the subject who perceives it. For the scientist employing this paradigm of "object-in-space-before-subject" (Rosen, 2004, 2008, 2015), space must be continuous, for it is only in a continuum that precise observations and measurements can be made of the objects and events appearing before the observing subject. The inherent *dis*continuity we find in quantum phenomena calls objective measurement into question, since it implies that, in microspace, in fact we *cannot* determine unequivocally the position of a system. How does quantum mechanics respond to this challenge?

A central feature of the quantum theoretic formalism employed by the Copenhagen school is analysis by probability. When quantum mechanics was confronted with the

inability to precisely determine a particle's location in space, it did not merely resign itself to the lack of continuity that creates this fundamental uncertainty. Instead of allowing the conclusion that a microsystem in principle cannot occupy a completely distinct position — which would be tantamount to admitting that microspace is not completely continuous — a multiplicity of continuous spaces was axiomatically invoked to account for the "probable" positions of the particle: "it" is locally "here" with a certain probability, or "there" with another. This collection of spaces is known as *Hilbert space*.

Just how effectively does Hilbert space preserve continuity and the underlying objectivism with which it is coupled? Each subspace of the multi-space expression is made continuous within itself to uphold the mutual exclusiveness of the alternative positions of the observed particle. Such subspaces must be disjoint with respect to each other, their unity being imposed externally, by fiat, rather than being of an internal, intuitively compelling order. So, in the name of maintaining mathematical continuity, a rather extravagantly *dis*continuous state of affairs is actually permitted in the standard formalism for quantum mechanics, an indefinitely large aggregate of essentially discrete, disunited spaces.

It is evident then, that continuity actually is not successfully maintained in quantum mechanics. Despite the artificial semblance of it, on the subtler level of the form that quantum theory takes, continuity is denied (Rosen, 1994, 2004, 2008). As a matter of fact, if we were to follow the full development of quantum mechanics, we would see that, in the end, even the *semblance* of continuity is lost in the failed attempt to arrive at an effective account of quantum gravity. For, at the submicroscopic scale where the challenge of unifying the quantum forces with gravitation is played out, infinite probability values turn up that render the equations useless. I've gone into this in detail elsewhere (e.g., Rosen, 2008) and will not expound further on it in the present book.

If the implicit objectivism of the Copenhagen mathematical program undermines the ability to adequately account for phenomena that do not conform to the expectations of objective realism, openly realist approaches to quantum mechanics certainly fare no better. Explicit forms of realism (Everett's "many worlds" interpretation, Bohm's pilot wave theory, etc.), in adhering to the paradigm of object-in-space-before-subject, thus can shed little light on the deep meaning of quantum reality.

Before proceeding to consider the mind-dependent approach to quantum mechanics, I want to emphasize that the microphysical challenge to classical continuity is at once a challenge to the separation of subject and object. Said separation was a defining feature of the fourteenth century European Renaissance. What the Renaissance brought forth was not only the emergence of a new space (the continuum) but also a newly autonomous subject who stood apart from that space and the objects therein. This is reflected in Descartes' dualistic philosophy, which posited the object as *res extensa*, a thing extended in space, and the subject as *res cogitans*, a "thinking thing" entirely without spatial extension, thus transcendent of space. By the end of the seventeenth century, the classical formulation was firmly entrenched in human affairs and had assumed the status of a self-evident intuition. All human perception was now generally organized in terms of objects appearing in space before the gaze of detached subjects.

This new reality was epitomized in the subsequent rise of empirical science. Here the spatial continuum rendered the object precisely measurable while, at the same time, the object was divided from the transcendent subject who performed the measurement as

if from outside of space. Because this pure act of measurement was assumed to leave the measured object completely unchanged, the observed properties of the object were regarded as reflecting what the object really was, independent of any distortive influence a less pristine, space-bound observer might exert. Thus the operations of empirical science were grounded in a mind-independent realism.

The phenomena of quantum physics that began to be investigated at the opening of the twentieth century fly in the face of realist assumptions about the world. The microphysical loss of continuity is accompanied by a merging of subject and object wherein the subject can no longer be taken as detached from a spatial continuum within which objects are contained. In quantum mechanics, the return to earth of the observing subject registers in the fact that the energy that must be transferred to a system in order to observe it, disturbs that system significantly. It was always tacitly granted that observing a system affects it, but the influence is negligible in macroscopic interactions and therefore could be overlooked in the classical idealization of the observer. Microworld observation is different. Here the idealized aloofness of the observer must give way to the recognition of its intimate interaction with the observed.

Of course, the long-dominant paradigm of mind-independence was not simply relinquished. Just as a semblance of continuity could be maintained in confronting quantum discontinuity, a way was found to maintain mind-independent "objectivity" when confronted with the quantum-level intimacy of subject and object.

There is a substantial difference between pre-quantum and quantum versions of the classical posture. In the former, we have objective events occurring in three-dimensional space before the detached gaze of an idealized subject. In the latter — where the observer's close involvement with the observed cannot merely be discounted, subjectivity itself is taken as object, with the "object" now being regarded as an *observational* event transpiring in *n*-dimensional Hilbert space. Whereas three-dimensional events are concretely observable, the dimensions of Hilbert space are sheer abstractions. And the idealized quantum observer of these n-dimensional acts of observation is a further step removed from the concrete reality that constrained his Newtonian predecessor. Nevertheless, in both cases, the traditional stance is strictly maintained. In both, we have object-in-space-before-subject.

Thus, objectivist quantum mechanics implicitly transforms the old subject into an object cast before a more abstract, higher-order subject.[1] In effect, the quantum mechanical researcher assumes a superordinate vantage point from which he is able to consider alternative acts of classical observation and weight them probabilistically, with each act corresponding to a different subspace of the Hilbert space. Here the "objects" to be analyzed are not mere concrete substances but observations themselves — what Max Planck called the "run of our perceptions" (quoted in Jahn and Dunne, 1984, p. 9). If the "scientific objectivity" of the quantum mechanical analysis of observation is to be maintained, the implicit observational activity of the *analyst* of observation must itself be exempted from the analysis. That is to say, two ontologically distinct levels of observational or subjective activity have to exist: that which is to be analyzed, and that through which the

[1] Einsteinian relativity performs the same sort of transformation. That is why Einstein's theory is no more "relative" than quantum mechanics is "subjective." See my comparative analysis of relativity and quantum mechanics (Rosen, 2015).

analysis is to take place. The former is constituted by the old subjective activity that is now objectified within the framework of the Hilbert space, whereas the latter corresponds to the more abstract, higher-order, wholly implicit activity of the quantum mechanical subject standing outside of Hilbert space. It is clear that this subject assumes the same detached, "purely objective" stance as did his Newtonian forerunner. Still operative in its essential relations is the basic formula of object-in-space-before-subject, though the natural intuitive appeal the formula had held in the classical context is now stretched into a counter-intuitive abstraction that, in the end, founders on the rocks of quantum gravity, as I intimated above.

Summing up, the quantum world entails a loss of spatial continuity coupled with an intimate fusion of subject and object that defies the classical order and its underlying objectivist paradigm. We have seen the means used by physicists to resuscitate this paradigm and I have questioned the effectiveness of these attempts. My conclusion is that the objectivist, mind-independent tradition does not appear equal to the task of accounting for quantum reality.

What can we say about the mind-dependent interpretation of quantum mechanics? This approach to modern physics puts mind before matter in attempting to understand the quantum world. Thus, according to the von Neumann-Wigner hypothesis (von Neumann, 1932; elaborated upon in Wigner, 1961, 1963, 1967), consciousness is necessary for collapsing the quantum wave. And in John Wheeler's (1990) hypothesis, the physical universe arises from information. How has the mind-dependent view been received by the scientific community? In 2011, an informal poll was conducted of physicists, mathematicians, and philosophers attending a physics conference and it was found that, of the 33 participants, only two were favorably disposed toward mind-dependence (see Schlosshauer et al., 2013). Why the distinct lack of enthusiasm for this view?

I noted above that the mind-independent paradigm is aligned with our everyday experience of reality as lying objectively "out there." Because the contrasting mind-dependent approach posits the equal or superordinate reality of the mind "in here," it runs counter to commonsense intuition and is therefore harder to accept. But the objection to the mind-dependent perspective runs deeper than that.

If the mind-dependent notion that consciousness causes quantum wave collapse is taken in the dualistic spirit of Cartesian interactionism, the notorious mind-body problem arises: How can such ontologically disparate entities as mind and matter interact? How is it possible for an entity without extension in space (*res cogitans*) to exert an influence on an entity extended in space (*res extensa*)? Descartes offered no convincing explanation for how this could happen nor has any been provided since his time.

Nevertheless, the mind-dependent view may alternatively be seen as an expression of the monistic philosophy of immaterialism. Direct metaphysical assertions of this doctrine (e.g., Goswami, 1995) have sometimes been met with skepticism and even dismissed as "quantum quackery" (Shermer, 2005), at least in part because many physicists find it uncomfortable to place physics squarely within an overarching metaphysical or religious context. A more subtle form of immaterialism was noted above, one that is more acceptable to mainstream physics: John Wheeler's "it from bit" proposition that the material world is built up from immaterial units of information. As Wheeler puts it, "every physical quantity, every it, derives its ultimate significance from bits, binary yes-or-

no indications, a conclusion which we epitomize in the phrase, *it from bit*" (1990, p. 309). Philosopher Christopher Timpson (2010) examines this proposition at length.

Timpson begins by noting that, on first appraisal, an informational approach to quantum mechanics does seem to resolve its central problem of measurement. He gives as an example the thought experiment known as "Wigner's Friend" (which is related to Schroedinger's famous cat paradox). Physicist Eugene Wigner has a colleague doing an experiment with particles in a closed laboratory. Wigner himself is outside the laboratory. When his friend reaches the point of measuring the spin state of a particle, the superposition of particle states collapses accordingly to yield a definite outcome. But Wigner himself is not privy to this finding so that, for him, the particle states are still in superposition. The question then concerns the time at which the superposition collapses. Was it when the friend made his measurement, or was it later, when Wigner became aware of the results? As Timpson puts it, "Does Wigner's friend see a definite outcome, or is he left suspended in limbo until Wigner opens the door to say hello?" This is the kind of paradox that arises when the quantum state is taken as representing "how things are in the world." But if we take it as representing the "information somebody possesses," the paradox evidently dissolves. There is no disagreement on when the collapse objectively occurs because the collapse is not taken as occurring objectively out there in the world. Wigner and his friend simply have access to different information and when Wigner's friend tells him what he observed, Wigner will update what he knows about the quantum state. This will occasion no mysterious change out in the world, since the update strictly concerns the information one has. Having laid out the informational interpretation in this way, Timpson goes on to express his doubts.

Echoing physicist John Bell, Timpson suggests the necessity of asking what quantum mechanical information *is about*. If it is simply about what the outcome of experiments will be, then we slide back into the Copenhagen school's noncommittal, instrumentalist approach to the meaning of the quantum world, which Timpson rightly finds uninteresting. The other alternative is that the information is about the "properties of a system which are possessed prior to measurement and which aren't described by the quantum state (in this case because the state doesn't have a world-describing role)" (2010, p. 214). Timpson views this interpretation of quantum information as implicitly leading us back to the search for variables hidden within the probabilistic quantum state. For Timpson, such a move is self-defeating because hidden variables have been found to behave "very badly…([displaying] non-locality [and] contexuality)" and "the whole point of taking the quantum state as information was to mollify its bad behaviour, its jumping here and there we know not when, its nonlocal collapse" (p. 214). Timpson's final conclusion: "The informational approach to the quantum state seems unable to survive the hidden variables/instrumentalism dilemma; and the thought that quantum information theory does lend support to a form of immaterialism really seems to have very little to commend it" (p. 225).

If Timpson's critique effectively dispatches the information theoretic mind-dependent approach to the Wigner's Friend thought experiment, it does not dispel the challenge the experiment's central paradox poses to the more influential mind-independent view. And this challenge to objectivism deepens significantly with the recent extension of Wigner's Friend.

Elaborating upon the original thought experiment, Frauchiger and Renner (2018) offer an arrangement that adds to Wigner and his friend a second pair of agents. If we label the first pair W and F, we can call the second W' and F'. In the extended experiment, both of Wigner's friends (F and F') make a measurement on a particular quantum system, while both Wigners (W and W') make a more complex quantum measurement on the friends themselves and the entire laboratory in which each is enclosed. Bypassing the fine details of the experimental design, let us cut to the chase. The bottom line is that agents can come to contradictory conclusions about an outcome that was observed by one of the friends in her laboratory. As Frauchiger and Renner (2018) put it, "We find that one agent, upon observing a particular measurement outcome, must conclude that another agent has predicted the opposite outcome with certainty. The agents' conclusions, although all derived within quantum theory, are thus inconsistent" (para. 1). This finding goes well beyond that of the original Wigner's Friend experiment, which revolved around the question of the time at which the outcome of a quantum measurement was obtained. What is called into question in the extended thought experiment is not merely the timing of an outcome but the outcome's veracity.

In their paper, Frauchiger and Renner (2018) set forth three basic assumptions ordinarily taken for granted in the application of quantum theory. The authors demonstrate that the result of their thought experiment implies that at least one of these assumptions is violated by established interpretations of quantum mechanics:

> This result can be phrased as a no-go theorem [that] asserts that three natural-sounding assumptions, (Q), (C), and (S), cannot all be valid. Assumption(Q) captures the universal validity of quantum theory …. Assumption (C) demands consistency, in the sense that the different agents' predictions are not contradictory. Finally, (S) is the requirement that, from the viewpoint of an agent who carries out a particular measurement, this measurement has one single outcome. The theorem itself is neutral in the sense that it does not tell us which of these three assumptions is wrong. However, it implies that any specific interpretation of quantum theory, when applied to the Gedankenexperiment, will necessarily conflict with at least one of them. This gives a way to test and categorise interpretations of quantum theory. (Frauchiger and Renner, 2018, para. 5).

The interpretation of quantum mechanics one prefers can be said to depend on which assumption one is most willing to give up. For example, if I can live with violating the assumption that quantum mechanics is applicable on all scales of nature, I can choose the spontaneous collapse interpretation (Ghirardi-Rimini-Weber, 1986) that posits the observer-independent collapse of the wave function in crossing a threshold from microworld to macroworld. On the other hand, if I am okay with giving up the assumption that a measurement yields only a single result, I might then prefer Everett's many worlds interpretation (1973), where the same quantum measurement yielding a certain outcome in one "world" yields a different outcome in another. Ananthaswamy cites Renner as saying that, with his theorem, "'We just know one of the three [assumptions] is wrong, and we cannot really give a good argument [as to] which one is violated …. This is now a matter of interpretation and taste'" (Renner quoted in Ananthaswamy, 2018b, para. 24). (See Table 4

in Frauchiger and Renner [2018] for a list of interpretations of quantum theory and the assumptions they violate.)

The extension of the Wigner's Friend thought experiment and its implications were explored at an award ceremony held on November 15, 2024. The occasion was the conferring of the Paul Ehrenfest Best Paper Award, an international prize presented annually for outstanding research in the foundations of quantum physics. Daniela Frauchiger and Renato Renner received the award for their 2018 paper. The prize was also bestowed on Časlav Brukner (2018) and Bong et al. (2020) for their related works. Formal presentations of the papers were preceded by an in-depth discussion of the Wigner's Friend extensions provocatively titled, "The End of Physics as We Know It?" The participants in the dialogue were Renner, Brukner, and Eric Cavalcanti, the latter representing the Bong et al. contribution. Moderating the videoed session was Hans Busstra (2024).

At one point in the discussion, Časlav Brukner noted that extensions of Wigner's Friend may put us in the position of having no way to describe what is objectively real for all observers. In such a situation, said Brukner, "there is no shared reality." Later, Renner echoed Brukner's concern regarding the whole enterprise of agreeing on conclusions about what is factual. Renner said, in effect, that we may have to get used to the counterintuitive idea that facts might not be absolute. Nearing the end of the discussion, the interlocutors mulled over physicist Lee Smolin's statement that the "world consists of nothing but a vast number of partial views of its past" (Smolin, 2022, p. 1). Cavalcante and Brukner concurred that these partial views cannot be put together in a unified whole; "it's much more fragmented or even incompatible," said Brukner. As regards the effect of the extended Wigner's Friend Gedankenexperiment on interpretations of quantum theory, Renner summed up his position: "My conclusion is that none of the existing interpretations gives a satisfactory answer to what happens in this paradox[-ical situation] so I'm pretty convinced that the answer lies somewhere else. It's outside the collection of interpretations currently available."

According to Ananthaswamy, physicist Matthew Leifer agrees and is holding out for something new: "'I think the correct interpretation of quantum mechanics is none of the above"' (Leifer quoted in Ananthaswamy, 2018b, para. 42). In the same vein, Leifer comments:

> "It's likely that we are making some implicit assumption about the way the world has to be that just isn't true … Once we change that, once we modify that assumption, everything would suddenly fall into place. That's kind of the hope. Anybody who is skeptical of all interpretations of quantum mechanics must be thinking something like this. Can I tell you what's a plausible candidate for such an assumption? Well, if I could, I would just be working on that theory." (Leifer quoted in Ananthaswamy, 2018b, para. 44)

In sum, the extension of the Wigner's Friend thought experiment has resulted in calling into question all mainstream interpretations of quantum theory. According to Leifer, physicists have been making a fundamental assumption that is flawed, and a new interpretation is called for that is not bound by that assumption. I submit that the assumption in question "about the way the world has to be" is that our world must adhere

to the paradigm of *object-in-space-before-subject*. I introduced this foundational formula near the beginning of the present section in identifying the basis of objectivism, the mind-independent outlook currently dominant in quantum mechanics (the interpretations of quantum mechanics listed in Frauchiger and Renner's Table 4 are primarily mind-independent). Contrary to the separation of subject and object inherent in the classical formula, I have proposed that the phenomena of the quantum world indicate a *fusion* of subject and object (or observer and observed). In the sections to come, this interpretation will be further developed. Eventually, it will become clear that the doubts raised by the extension of Wigner's Friend stem from adherence to a paradigm that is basically at odds with the underlying nature of quantum reality.

2. THE HUSSERLIAN INTERPRETATION

In the previous section, I mentioned a different version of the mind-dependent view, namely, the von Neumann-Wigner view of quantum mechanics, which was further developed by Wigner (1961, 1963, 1967). Philosopher Steven French (2023, p. 30) notes that Wigner's basic aim was to challenge Bohr's Copenhagen interpretation of quantum mechanics, replacing it with von Neumann's formulation, which Wigner interpreted as implying that consciousness causes the collapse of the wave function. Wigner thus promoted the idea that the physical quantum wave is collapsed by non-physical consciousness. In the absence of any real understanding of how this could happen, the action of consciousness takes on the appearance of operating as a phantasmal *deus ex machina*, inexplicably swooping in to effect change in the material world. It therefore seemed to many physicists (e.g., Putnam, 1964; Shimony, 1963) that, with approaches like Wigner's, the specter of Cartesian interactionism haunts the scene.

The tension between the Copenhagen interpretation and von Neumann's outlook revolved around the problem of quantum measurement, and French (2023, p. 5) brings out that both approaches drew on a work by physicists Fritz London and Edmund Bauer (1939/1983), described by Wigner as "a very nice little book … which summarizes quite completely what I shall call the orthodox view [of quantum mechanics]" (Wigner, 1963, p. 7). What French contends is that Wigner, "in effect, appropriated London and Bauer's 'little book' for his own ends, thereby obscuring its central message" (2023, p. 5). What is that message?

French observes that London, in particular, had been influenced by the phenomenological philosophy of Edmund Husserl (French, 2023, p. 89), wherein consciousness is regarded as acting *immanently*. And according to French, this is just what we see upon closely examining London and Bauer's pamphlet. Here we are taken beyond the naïve mind-body dualism in which consciousness acts on the physical world from outside it, and we can now apprehend its *internal* action.

In French's application of London and Bauer's approach, consciousness enters the quantum experiment not as some phantom from the beyond, but through the auspices of the experimenter's "objectifying act of reflection" (2023, p. 147). French holds that, in observing the quantum system, the observer is introspectively aware of herself doing so and, through observing herself in relation to the system being observed, she objectifies that system, i.e., reduces the wave function to a definite value. To support this view, French cites London and Bauer:

> ... it is not a mysterious interaction between the apparatus and the object that produces a new *y* for the system during the measurement. It is only the consciousness of an "I" who can separate himself from the former function $\Psi(x, y, z)$ and, by virtue of his observation, set up … a new objectivity in attributing to the object henceforward a new function $y(x) = uk(x)$. (1983, p. 252)

By thus internalizing consciousness, it appears to be brought into the quantum picture without falling prey to the problem of Cartesian interaction. This is surely an important step in addressing the shortcomings of the old realist paradigm. The classical inability to account for the action of consciousness on matter is phenomenologically remedied by regarding consciousness and the quantum system as correlated poles — the "subject-pole" and the "object-pole" — of a single relational act (see French 2023, p. 147). I would like to suggest, however, that, in the Husserlian approach to phenomenology, there is a sense in which the old paradigm actually persists, and this makes it difficult for such an approach to deal with the intimate fusion of subject and object found in the quantum world. Before I say any more about this, let me go more deeply into Husserl's outlook.

Proponents of traditional objectivism might be inclined to view Husserlian phenomenology as a lapse into fuzzy subjectivism. This cannot be further from the truth. Husserl was in fact seeking *greater* objectivity than what had been achieved in the natural sciences. In advocating "philosophy as rigorous science" (Husserl, 1911/1965, p. 71), he saw naturalism as contradicting itself because it operates subjectively to project an external reality that is then naively assumed to be simply independent of its subjective action. The projection must be withdrawn, says Husserl. In a fully objective science, "objectivity…must precisely become evident purely from consciousness itself" (1911/1965, p. 90).

Husserl's quest for an absolute scientific rigor that would bring apodictic knowledge did not end in 1911. It continued throughout his career. Philosopher Herbert Spiegelberg (1984) thus could assert that "Husserl's commitment to the ideal of a rigorous science never wavered." We see this evidenced in Husserl's unfinished and posthumously published volume, *The Crisis of European Sciences and Transcendental Phenomenology* (Carr, 1970). Here there are numerous references to the need for an ideal science that would transcend empirical and positivist science and bring rational thought to its culmination.

At the same time that Husserl concluded his life's work by reaffirming his goal of achieving a pure phenomenological science, he formally introduced his concept of the *lebenswelt* or lifeworld, emphasizing that "all of us together, belong to the world," that "in living together, [we] have the world pre-given in this together," that the world to which we belong is a "world for all" (Husserl, 1936/1970, pp. 108–109). Inhabitants of the lifeworld are seen as interdependent and as communicating with each other intersubjectively. It is through this process that they share knowledge and meaning. Therefore, from the first, the inhabitants of the *lebenswelt* dwell side-by-side, their lives closely linked in primal community. However, this dwelling together is of a prereflective sort. For Husserl, the lifeworld constitutes the pre-scientific, pre-theoretical ground of everyday life that constitutes the soil out of which objective science and abstract theory grow. The lifeworld

as understood by Husserl is therefore but a steppingstone for the eventual creation of the genuinely objective, absolutely rigorous science that he foresaw.

Toward that end, Husserl rejected mere empirical objectivism and, in so doing, he dispensed with the exterior space said objectivism requires for the observation and measurement of its objects. He replaced the external dimension with a wholly interior one, a space to be known through intuition rather than through sense perception; one that is neither physical nor empirically psychological but purely logical; a space wherein the perfectly self-consistent operations of consciousness are enacted. Of course, it is consciousness itself that is to observe these operations. Therefore, the observation in question is a *self*-observation, an intuitive self-reflection. And yet, the old categorical division of subject and object is still at play in this immanent realm. For, to know anything objectively, the knower or subject must be detached from what he knows. In the paradigm upon which scientific objectivism relies, the containment of an object in space and the detachment of the subject from that object are integral aspects of the same process: by the same act in which the object is sealed into space, the subject is sealed out, separated from that object. No less does this apply to Husserl's phenomenological version of scientific objectivism. If Husserl's "transcendental subject" is to gain purely apodictic knowledge of its object — which, in this case, is itself — it must become detached from that object. The internal division of consciousness into subject-qua-object and subject-qua-subject is implicit in philosopher and Husserl translator Quentin Lauer's (1965) comment that, for Husserlian phenomenology, "it is the object, not the subject, that determines what science must be," and that it "is the character of what is to be known, not the character of the knower, that makes phenomenology the only viable philosophical method" (p. 23).

Note the limitation of Husserlian intuition that results from its objectivism. It cannot take in the actual process by which it splits itself into subject-qua-object and subject-qua-subject because it has no access to the latter as such. In turning its attention to itself, to its own subjectivity, it must encounter it as an objectified subjectivity, not as subjectivity per se. In so encountering itself, it doubles itself, with the now objectified subject set before a new order of subjectivity that is necessarily concealed. Husserlian intuition is thus restricted to the object or objectified subject alone, which appears only after the division has occurred. It is in this way that the phenomenological *cogito* is divided, with one part of it — the part to be investigated — constituting an "interior logical object," and the other part of it — that doing the investigating — entailing a new, higher-order subjectivity that goes uninvestigated. This focus on the subject-qua-object assures the incompleteness of Husserl's "phenomenological reduction." For, in the attempt to reach objective closure on the "transcendental subject," an aspect of consciousness must go unnoticed, namely, the subject-qua-subject.

What are the implications of Husserlian objectivism for the question of quantum measurement? In the macroscopic quantum laboratory as understood through Husserlian phenomenology, the intuitive act of self-objectification collapses the quantum wave. This allows the conclusion that consciousness is the catalyst for collapse while effectively avoiding the problem of Cartesian interaction charged by critics such as Shimony (1963) and Putnam (1964). Yet here we gain no intuitive grasp of what is actually being collapsed: the quantum wave per se. That is because the submicroscopic quantum system defies that to which Husserlian intuition is limited: the macroscopic field of strictly objective relations, the field wherein subjectivity can be objectified but subjectivity *as such* remains hidden

from view. We know by now that at the heart of quantum reality is a heretical overlapping of subject and object that no form of objectivism is fully equipped to deal with. Husserlian phenomenology is no exception. But there is an alternative approach to phenomenology that may be better suited for plumbing the quantum depths. And this approach may suggest a mode of perception that can be employed effectively with the extension of perceptual experience to the microworld anticipated in the opening chapter.

3. ONTOLOGICAL PHENOMENOLOGY

Husserl's epistemologically oriented phenomenology was succeeded by the ontological phenomenologies of Merleau-Ponty and Heidegger. In their writings, the emphasis shifts from apodictic knowing to an investigation of being as such (this is especially true in the late works of these philosophers). For our purposes, ontological phenomenology can be seen most essentially as a critique of the classical trichotomy of object-in-space-before-subject. To Merleau-Ponty, the activities of the detached Cartesian subject are idealizing objectifications of the world that conceal the concrete reality of the *lifeworld*. Merleau-Ponty borrowed this term from Husserl, and he first used it in *Phenomenology of Perception* (1945/1962). In Merleau-Ponty's hands, the meaning of the term evolved in a subtle but significant way. No longer was the word limited to describing a world of closely correlated, intersubjectively communicating individuals who nevertheless retain their core individuality, thus retaining their ontological status as separate beings. In the *lebenswelt* as understood in his late works, Merleau-Ponty had increased his emphasis on the body and had ontologized it. The lifeworld now takes on flesh and he speaks of *la chair du monde*, "the flesh of the world" (Merleau-Ponty, 1968). In this world, the very beings of its inhabitants become concretely intertwined as a single Being, thereby challenging the old dualism of subject and object more radically than ever before:

> The flesh is not matter, in the sense of corpuscles of being . . . is not mind, is not substance. To designate it, we should need the old term "element," in the sense it was used to speak of water, air, earth, and fire, that is, in the sense of a *general thing*, midway between the spatio-temporal individual and the idea, a sort of incarnate principle that brings a style of being wherever there is a fragment of being. The flesh is in this sense an "element" of Being. (1968, p. 139)

The world thus enfleshed is the lifeworld portrayed by Merleau-Ponty and my subsequent use of the term will reflect Merleau-Ponty's ultimate understanding of it. In this world, the subject is a fully embodied, fully fledged participant engaging in transactions so intimately entangling that it can no longer rightly be taken as separated either from its objects, or from the worldly context itself.

It is clear that all three terms of the classical formula — object, space, and subject — are affected by this phenomenological move. In the traditional account, objects are taken as simply external to each other and as appearing within a spatial continuum of *sheer* externality, since the continuum is deemed infinitely divisible. As philosopher Milič Čapek put it in questioning the classical notion of space, "no matter how minute a spatial interval may be, it must always be an *interval* separating two points, each of which is *external* to the other" (1961, p. 19). Heidegger thus speaks of conventional space as the "'outside-of-one-

another' of the multiplicity of points" (1927/1962, p. 481). The agents operating upon the objects constitute a third kind of externality, acting as they do from a transcendent vantage point beyond the objects in space. It is this privileging of external relations that is counteracted by ontological phenomenology. Notwithstanding the Cartesian idealization of the world, in the underlying *lifeworld* there is no object with boundaries so sharply defined that it is closed off completely from other objects. The fleshly lifeworld is characterized instead by the *transpermeation* of objects (their "superposition," in quantum parlance), by their mutual interpenetration, by the "reciprocal insertion and intertwining of one in the other" (Merleau-Ponty, 1968, p. 138). With objects hence related by way of mutual containment, no *separate* container is required to mediate their relations, as would have to be the case with externally related objects. Objects are therefore no longer to be thought of as contained in space like things in a box, for, in containing each other, they contain themselves. At the same time, it must also be understood that, in the Merleau-Pontean lifeworld, there can be no peremptory division of object and subject. The lifeworld subject — far from being the disengaged, high-flying *deus ex machina* of Descartes or even Husserl's transcendental subject — finds itself down among the objects as "one of the visibles" (Merleau-Ponty, 1968, p. 135); it is itself always an object to some *other* subject, so that the simple distinction between subject and object is confounded and "we no longer know which sees and which is seen" (p. 139). The ontological grounding of the subject is thus indicative of the intimate interplay of subject and object in the lifeworld. Generally speaking then, what the move from classical thinking to ontological phenomenology essentially entails is an internalization of the relations among subject, object, and space.

4. THE DEPTH DIMENSION

The link between the fleshly lifeworld and the quantum world should already be broadly evident. With the former, the classical continuum is supplanted by an internally constituted space of superposed entities that features a core-to-core interaction of subject and object. A more specific articulation of the onto-phenomenological response to the problem of grasping quantum reality can be derived from another work of Merleau-Ponty. In his essay "Eye and Mind" (1964), his concept of *depth* provides an account of dimensionality that permits us to better understand the limitations of Cartesian space and to surpass them.

For Descartes, notes Merleau-Ponty, a dimension is an extensive continuum entailing "absolute positivity" (1964, p. 173). Descartes's assumption is that space simply is *there*, that it subsists as a positive presence possessing no folds or nuances; no shadows, shadings, or subtle gradations; no internal dynamism. Space is thus taken as the utterly explicit openness that constitutes a field of strictly external relations wherein unambiguous measurements can be made. Along with height and width, depth is but the third dimension of this hypostatized three-dimensional field. Merleau-Ponty contrasts the Cartesian view of depth with the animated depth of the lifeworld, where we discover in the dialectical action of perceptual experience a paradoxical interplay of the visible and invisible, of identity and difference:

> The enigma consists in the fact that I see things, each one in its place, precisely because they eclipse one another, and that they are rivals before my sight precisely because each one is in its own place. Their exteriority is known in their

> envelopment and their mutual dependence in their autonomy. Once depth is understood in this way, we can no longer call it a third dimension. In the first place, if it were a dimension, it would be the *first* one; there are forms and definite planes only if it is stipulated how far from me their different parts are. But a *first* dimension that contains all the others is no longer a dimension, at least in the ordinary sense of a *certain relationship* according to which we make measurements. Depth thus understood is, rather, the experience of the reversibility of dimensions, of a global "locality" — everything in the same place at the same time, a locality from which height, width, and depth [the classical dimensions] are abstracted. (1964, p. 180)

Speaking in the same vein, Merleau-Ponty characterizes depth as "a single dimensionality, a polymorphous Being," from which the Cartesian dimensions of linear extension derive, and "which justifies all [Cartesian dimensions] without being fully expressed by any" (1964, p. 174). The dimension of depth is "both natal space and matrix of every other existing space" (p. 176).

Merleau-Ponty proceeds to explore the depth dimension via the artwork of Cézanne. Through the painter, he demonstrates that primal dimensionality is *self-containing*. Cézanne works with a visual space that is not abstracted from its content but flows unbrokenly into it. Or, putting it the other way around, the contents of a Cézanne painting overspill their boundaries so that, rather than merely being contained like objects in an empty box, they fully participate in the containment process. Inspired by Cézanne's paintings, Merleau-Ponty comments that "we must seek space and its content *as* together" (1964, p. 180).

Merleau-Ponty also makes it clear that the primal dimension engages embodied subjectivity: the dimension of depth "goes toward things from, as starting point, this body to which I myself am fastened" (1964, p. 173). In commenting that "there are forms and definite planes only if it is stipulated how far from *me* their different parts are" (p. 180; italics mine), Merleau-Ponty is conveying the same idea. A little later, he goes further:

> The painter's vision is not a view upon the *outside*, a merely "physical-optical" relation with the world. The world no longer stands before him through representation; rather, it is the painter to whom the things of the world give birth by a sort of concentration or coming-to-itself of the visible. Ultimately the painting relates to nothing at all among experienced things unless it is first of all 'autofigurative.' . . . The spectacle is first of all a spectacle of itself before it is a spectacle of something outside of it. (1964, p. 181)

In this passage, the painting of which Merleau-Ponty speaks, in drawing upon the originary dimension of depth, draws in upon itself. Painting of this kind is not merely a signification of objects but a concrete *self*-signification that surpasses the division of object and subject.

In sum, the phenomenological dimension of depth as described by Merleau-Ponty, is (1) the "first" dimension, inasmuch as it is the source of the Cartesian dimensions, which are idealizations of it; (2) a self-containing dimension, not merely a container for contents that are taken as separate from it; and (3) a dimension that blends subject and object concretely, rather than serving as a static staging platform for the objectifications of a detached subject. Therefore, in realizing depth, we go beyond the concept of space as but

an inert container and come to understand it as an aspect of a self-containing, indivisible cycle of lifeworld action in which subject and object are integrally incorporated.

An action cycle of this kind lies at the core of quantum mechanics. The most basic equation of the quantum world is given by Planck: E = hv. This equation for the energy of the photon can be rewritten so that Planck's constant, h, expresses action. We do this by replacing frequency (v) with its inverse, namely, time. We then have E = h/T or h = ET, and in physics, energy multiplied by time is a measure of action. The *angularity* of quantized action, its internal "spin," is expressed by the application of phase, as given in the formula h/2Π = *ħ*. Here h is operated upon by a phase of 2Π radians, equivalent to a turn of 360°. In quantum mechanics, *ħ* is regarded as a fundamental "atom of process," one not reducible to smaller units that could be applied in its quantitative analysis. The discontinuity associated with quantized microphysical action bespeaks the fact that this indivisible circulation undermines the infinitely divisible classical continuum, and, along with it, the idealized objects purported to be enclosed in said continuum and the idealized subject alleged to stand outside it. The action in question entails the superposition of object, space, and subject — something utterly unthinkable when adhering to the classical formula. It is only through probabilistic artifice that such a dialectic can be accommodated while maintaining the old trichotomy. And just such a dialectic defines the depth dimension as described by Merleau-Ponty. Broadly speaking, this suggests that, if the quantum world is to be understood, a whole new basis for scientific activity is required, a new way of thinking about object, space, and subject, one cast along the lines of Merleau-Pontean depth.

Before concluding this chapter, I want to acknowledge an alternative path to ontological phenomenology that comes out of a relatively new interpretation of quantum mechanics known as Quantum Bayesianism, which, in its current form, is called QBism (pronounced "cubism," the term was coined in 2010 by Christopher Fuchs, a leading advocate of this viewpoint; see Fuchs et al., 2014). In general, approaches to quantum measurement that use Bayesian probability are based on an observer's degrees of belief about the likelihood of given measurement outcomes, with the probabilities of belief being updated when new information about the quantum system is acquired. Nevertheless, in conventional applications of Quantum Bayesianism, the quantum system itself is still regarded as belonging to the objectively existing order of the physical world. For its part, QBism renounces this objectivist way of grounding physics. Here the quantum system does not reflect some mind-independent reality "out there" but only the subjective beliefs and personal expectations of the individual agent. This strong emphasis on subjectivity has drawn criticism from several quarters. Among the critiques is Norsen's (2014) claim that, by denying an objective reality that lies beyond the perspective of the single individual, QBists flirt with solipsism. As regards academia's general perception of QBism, Glick (2021) observes that it is "commonplace among philosophers to take QBism to be opposed to scientific realism about quantum theory" (p. 2). In response to charges of anti-realism, QBists insist that their approach is indeed a form of realism, though it departs from conventionally objective realism to embrace what Fuchs (2017) calls "participatory realism." It is the French philosopher of science Michel Bitbol (2020) who brings ontological phenomenology into the debate in a paper on QBism and Merleau-Ponty. After laying out the basic tenets of Fuchs' participatory realism as applied to the quantum world and comparing them to the ontology of Merleau-Ponty, Bitbol declares it "a perfect match"

(2020, p. 240). Evidently, the match works so well because participatory realism does not simply choose subject over object, but chooses instead their ontological fusion. (For additional interpretations of QBism and phenomenology, see Berghofer and Wiltsche, 2024.)

At the end of section 1 of this chapter, we explored the implications of extending the Wigner's Friend thought experiment. Confronting the challenges posed by this research, physicists have been left to wonder whether their discipline can survive. Does the apparent breakdown of intersubjective agreement on the same facts spell "the of end physics as we know it?" (Busstra, 2024). I have proposed that these troubling contradictions ultimately derive from objectivism's core assumption of subject-object division, whereas the quantum world itself implies subject-object fusion. It was in offering an interpretation of quantum mechanics based on the latter principle that I turned to the ontological phenomenology of Merleau-Ponty and Heidegger. What would be the consequences of applying this phenomenological approach to the actual conduct of physics? I suggest that physicists involved in such a venture would be open to changing their basic stance as observers or agents. They would relax their commitment to the traditional posture of scientific objectivity and detachment and look to find a way of participating more fully in the embodied quantum lifeworld.

As the chapters of this book continue to unfold, we will begin to see better what this fundamental change may entail. In exploring the field of quantum perception, I will detail in chapter 4 the prospect of a new, phenomenologically oriented approach to scientific observation, and to science itself. Then, in examining the phenomenon of quantum entanglement in chapter 5, I will consider the possibility that observers adopting the novel methodology may themselves become entangled, sharing the same reality in ontological depth.

Chapter 3

MODELING QUANTUM PERCEPTION

Chapter 1 began with a brief description of research investigating the ability of human beings to detect single photons and possibly even to observe the underlying quantum realm itself. A key question for us is what this observation would involve. To facilitate an understanding of what quantum perception actually entails, chapter 2 was devoted to examining the quantum world more closely. This exploration led to the proposition that the submicroscopic domain is best comprehended in terms of Merleau-Ponty's ontological depth dimension. While the Cartesian intuition of object-in-space-before-subject makes it impossible to come to grips with the discontinuity and intimate subject-object interaction of the quantum realm, Merleau-Ponty's intuition gives us the insight we need. But can the philosophical notion of depth be brought into sharper focus to make it more relevant to the specific problem of observing the photon? For this we turn to a well-known figure from the psychology of perception.

1. THE NECKER CUBE: A PERCEPTUAL MODEL OF THE QUANTUM WAVE AND QUANTUM OBSERVATION

Over the years, there has been much research in the field of bistable perception: the dynamic oscillation of perceptual experience when an ambiguous stimulus is observed. Perhaps the most widely studied stimulus of this kind is the Necker cube (based on the 1832 observations of crystallographer Louis Necker). Atmanspacher, Filk, and Römer (2004) noted accordingly that the Necker cube is a "very simple and often investigated example of bistable perception" (p. 34).

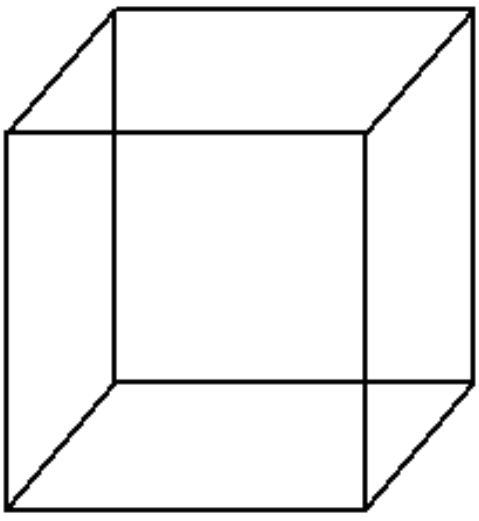

Figure 3.1: Necker cube.

The Necker cube (Figure 3.1) is a reversible figure that projects opposing three-dimensional perspectives from a two-dimensional plane. You may be perceiving the cube from the point of view in which it seems to be hovering above your line of vision when suddenly a spontaneous shift occurs and you see it as if it lay below. Two distinct perspectives thus are experienced in the course of gazing at the cube, yet the cube's reversing viewpoints overlap one another in space, are internally related, completely interdependent (think of what would happen to one perspective if the other were erased).

The Necker cube's quantum-like flipping of perspectives brings to mind the discontinuous phenomena of microphysics and, in fact, a number of researchers have systematically studied the relationship of the cube and similar ambiguous stimuli to quantum mechanics. Atmanspacher, Filk, and Römer (2004) used a "generalized quantum theoretical framework…to model the dynamics of the bistable perception of ambiguous visual stimuli such as the Necker cube" (p. 33). Likewise, Conte, Khrennikov, Todarello, Federici, Mendolicchio, and Zbilut (2009) concluded that "mental states, during perception and cognition of ambiguous figures, follow quantum mechanics" (p. 2). In the same vein, Caglioti, Benedek, and Cocchiarella (2014) asserted that, in "general terms we can say that perceptual *ambiguity* is equivalent in the microscopic world to the *superposition of quantum states*" (p. 37). More recently, Benedek and Caglioti (2019) reaffirmed that the perceptual reversal of the Necker cube "is controlled by the principles of quantum mechanics" (p. 161) and that "the observation of an ambiguous figure is apparently of quantum nature" (p. 165).

Of course, when we observe the cube, we ordinarily notice but a single perspective, not the state of ambiguity from which that perspective arises. The initially ambiguous situation may be taken as preconscious, as "the potential state of consciousness" (Conte et al., 2009, p. 10) from which a particular perspective of the cube is consciously actualized. In Conte's quantum mechanical formulation,

> we distinguish a potential and an actual or manifest state of consciousness. The state of the potential consciousness will be represented by a vector in Hilbert space. If we indicate for example a bi-dimensional case with potential states |1> and |2> , the potential state of consciousness will be given by their superposition: $\psi = a|1\rangle + b|2\rangle$. Here, a and b represent probability amplitudes so that $|a|^2$ will give the probability that the state of consciousness, represented by percept |1>, will be finally actualized or manifested during perception. Conversely, $|b|^2$ will represent the probability that state (percept) |2> of consciousness will be actualized or manifested during perception. It will be $|a|^2 + |b|^2 = 1$. (Conte et al., 2009, p. 10)

"Percept |1>" and "percept |2>" express opposing perspectives of the Necker cube (or of another such ambiguous stimulus). What we are seeing here is that, before a single perspective comes into conscious focus, it exists preconsciously as a potential that overlaps with its alter-perspective, analogous to the superposition of quantum states that comprise the not-yet-observed quantum wave. Then, upon observation, the cube collapses to a single perspective — a single quantum state, in the analogy. In keeping with Bohr's principle of complementarity rendering conjoined states mutually exclusive in their actualization, "we can be aware that multiple representations are possible but we can perceive them only one at a time, that is serially" (Conte et al., 2009, p. 9). And yet Conte goes on to comment that

quantum functioning "could explain the peculiar human ability to hold contradictory notions in mind simultaneously, although usually there is collapse to one state or the other" (p. 15).[2]

In past work, I have demonstrated that the strong tendency to consciously perceive only one perspective of the Necker cube at a time can indeed be overcome (Rosen, 1994, 2004, 2006, 2008). Instead of allowing our glance to alternate between the opposing perspectives of the cube, we can break this visual habit and view both perspectives at the same time. This possibility is confirmed in artist Bruno Ernst's (1986) study of the graphic work of M. C. Escher.

In analyzing an Escher work titled *Belvedere*, Ernst concludes that its design is based on the Necker cube. To bring out the underlying principle of *Belvedere*, Ernst provides his own diagram of the cube (Figure 3.2).

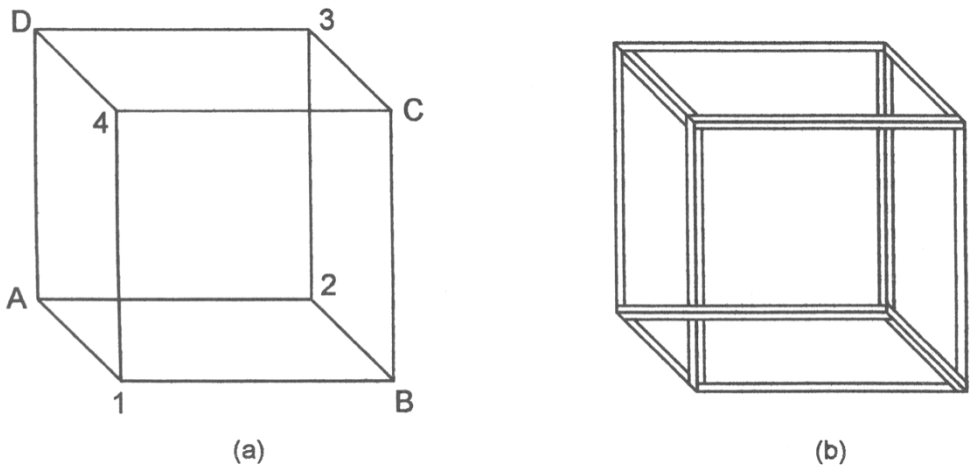

Figure 3.2: Bare Necker cube (a) and cube with volume (b)
(after Ernst, 1986, p. 86; reprinted with permission).

According to Ernst, the cube encompasses within itself,

> the projection of two different realities. We obtain the first when we assume that points 1 and 4 are close to us and points 2 and 3 are further away; in the other reality, points 2 and 3 are close and 1 and 4 further away .... But it is also possible to see points 2 and 4 in the front and 1 and 3 in the back. However, this contradicts our expectation of a cube; for this reason, we do not readily arrive at such an interpretation. Nevertheless, if we give some volume to the skeletal outline of the cube, we can impose said interpretation on the viewer by placing A2 in front of 1–4 and C4 in front of 3–2. Thus we obtain [Figure 3.2b] and this is the basis for *Belvedere*. (Ernst, 1986, p. 86; translated by M. A. Schiwy)

[2] For their more detailed mathematical formulation of the relationships among unconscious, preconscious, and conscious systems, see Conte, Kaleagasioglu, and Norman, 2017.

It is clear that Figure 3.2b "contradicts our expectation of a cube" because it brings together opposing "realities" (perspectives) that we are accustomed to experiencing just one at a time. When this happens, there is an uncanny sense of self-penetration; the cube appears to do the impossible, to go *through* itself (thus Ernst speaks of constructions based on the cube as "impossible"; 1986, pp. 86–87). If we imagine the bare cube (Figures 3.1 and 3.2a) as a solid object appearing in space, one whose faces are filled in, we find that perspectival integration has an interesting effect on those faces.

In the conventional, perspectivally polarized way of viewing the cube, when the shift is made from one pole to the other, all the faces of the cube that had been seen to lie "inside" presently appear on the "outside," and vice versa. But it is only at "polar extremes" that faces are perceived as *either* inside *or* outside. With the fusion of perspectives that discloses what lies *between* the poles, each face presents itself as being inside and outside at the same time. Therefore, the division of inside and out is perceptually surmounted in the creation of a *one*-sided structure whose opposing perspectives are simultaneously given.

Simultaneously? Well, that is not exactly the case. I am proposing that we can apprehend the cube in a manner in which its differing viewpoints overlap in time as well as in space. But what we actually experience when this happens is not simultaneity in the ordinary sense of static juxtaposition. We do not encounter opposing perspectives with the same immediacy as figures appearing side by side in ordinary space, figures that coexist in an instant of time simply common to them (as, for example, the letters of the words on this page). But there is indeed a coincidence in the integrative way of viewing the cube, for perspectives are not related in simple succession (first one, then the other) any more than in simultaneity. If opposing faces are not immediately co-present, neither are they given merely *seriatim*, in the externally mediated fashion of linear sequence. Instead, the relation is one of internal mediation, of the *mutual permeation* of opposites. Perspectives are grasped as flowing through each other in a manner that suggests a blending of space and time quite alien to our customary perception of these dimensions. You can see this most readily in viewing Figure 3.2b. When you pick up on the odd sense of self-penetration of this "impossible" figure, you experience its two modalities neither simply at once, nor one simply followed by the other, as in the ordinary, temporally broken manner of perception; rather, you apprehend the dynamic merging and separating of perspectives.

Taken as a model of photon perception, the perspectival integration of the Necker cube suggests that we could indeed consciously apprehend superposed states of the photon, observing their mutual permeation without collapsing the wave, thus gaining a glimpse of the underlying quantum reality. If the macroscopic perceptual model could be realized at the level of actual submicroscopic perception, would we observe photon states as superposed objects appearing before our detached gaze? Not if the quantum dimension is a dimension of onto-phenomenological depth as I have proposed.

Let us note how key properties of the Necker cube do model those of the depth dimension. Like the latter, the former can be described as self-containing. This can be illustrated in a simple way by comparing the cube with a square divided into two parts (Figure 3.3).

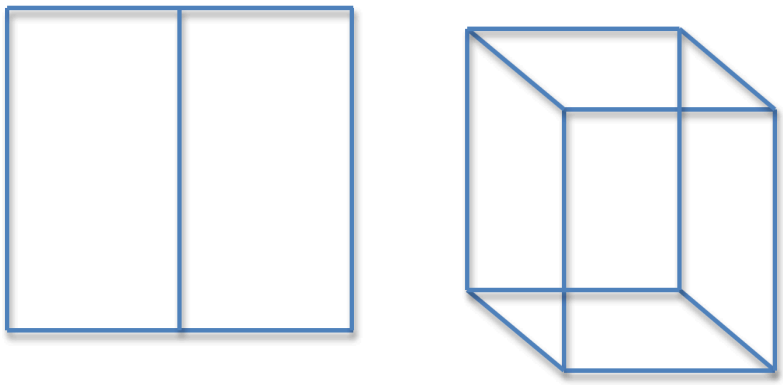

Figure 3.3**:** Divided square (left) and Necker cube (right).

Each rectangular part of the square (Figure 3.3, left) occupies just half the total area of the square and is simply contained inside it. By contrast, a given perspective of the cube (Figure 3.3, right) encompasses the entire configuration in expressing itself. This difference becomes obvious upon realizing that while you can erase one of the square's constituent rectangles without affecting the other, erasing one of the cube's perspectives erases the whole (as noted above). Each of the cube's perspectives thus contains the whole and, in so doing, contains itself.

Another principal feature of the Necker cube relevant to the depth dimension is its one-sidedness. We witnessed above how the perspectival integration of the cube creates a perceptual structure that fuses inside and outside. Is this not reminiscent of Merleau-Ponty's reflections on the painting of Cézanne discussed in the previous chapter? To repeat: "The painter's vision is not a view upon the *outside*, a merely 'physical-optical' [thus external] relation with the world. The world no longer stands before him through representation; rather, it is the painter to whom the things of the world give birth" (1964, p. 181). Of course, the intimate relationship between inside and outside implicit in this passage does not refer to the sides of an object in space, but to the subjectivity of the painter and his relation to the outer world. This speaks to the limitation of the perceptual model. The integrated cube appears in front of us as a macroscopic object embedded in the familiar two-dimensional space of the page. Obviously, the submicroscopic photon residing in a quantum dimension with the properties of Merleau-Pontean depth is no such object in space. So, while the fusion of Necker cube sides surely can be taken as modeling the depth-dimensional fusion of subject and object in the quantum world, it does not deliver that fusion in a tangible way. We are about to discover a mathematical counterpart of the cube that does possess the dimensional structure of depth. As we proceed, keep in mind two essential features of the integrated cube: its one-sidedness and its self-penetration.

2. TOPOLOGICAL PHENOMENOLOGY

A clue for tangibly articulating the depth dimension is found in the working notes of Merleau-Ponty's final volume, *The Visible and the Invisible*:

> Take topological space as a model of being. The Euclidean space is the model for [idealized] perspectival being [and is consistent] ... with the classical ontology .... The topological space, on the contrary, [is] a milieu in which are circumscribed relations of proximity, of envelopment, etc. [and] is the image of a being that ... is at the same time older than everything and "of the first day" (Hegel) .... [Topological space] is encountered not only at the level of the physical world, but again it is constitutive of life, and finally it founds the *wild* principle of Logos — — It is this wild or brute being that intervenes at all levels to overcome the problems of the classical ontology. (1968, pp. 210–211)

To conventional thinking, topology is generally defined as the branch of mathematics that concerns itself with the properties of geometric figures that stay the same when the figures are stretched or deformed. In algebraic topology, structures from abstract algebra are employed to study topological spaces. A more concrete approach to topology is exemplified by the practical experiments of mathematician Stephen Barr (1964). In either case, however, the underlying philosophical default setting tacitly operates, with topological structures regarded strictly as objects under the scrutiny of a detached analyst. Yet, in the passage cited above, Merleau-Ponty intimates a phenomenologically based, non-objectifying form of topology. As a matter of fact, when Merleau-Ponty metaphorically describes topological space as "the image of a being that…is older than everything and 'of the first day'" (1968, p. 210), we may be reminded of his earlier portrayal of depth: it is "a *first* dimension that contains all the others" (1964, p. 180); it is "both natal space and matrix of every other existing space" (p. 176). Can we sharpen our focus on the depth dimension by going further with topology? A well-known topological curiosity appears especially promising in this regard: the Klein bottle (Figure 3.4).

Elsewhere, I have used the Klein bottle to address a variety of philosophical issues (e.g., Rosen, 1994, 2004, 2006, 2015). For our present purpose, we begin with a simple illustration.

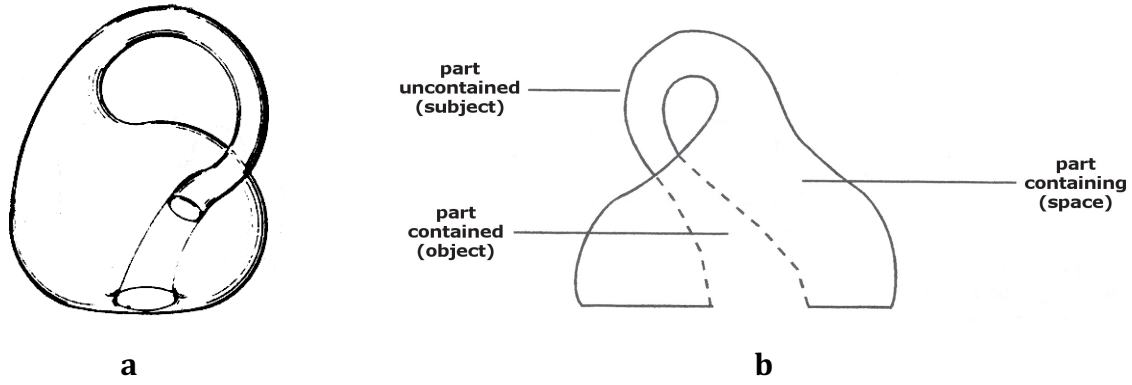

Figure 3.4: (a) Model of the Klein bottle (from Gardner, 1979, p. 151); (b) diagram of the parts of the Klein bottle (after Ryan, 1974, p. 111).

Figure 3.4b is my adaptation of communication theorist Paul Ryan's linear schemata for the Klein bottle (1974, p. 111). According to Ryan, the three basic features of the Klein bottle are "part contained," "part uncontained," and "part containing." Here we see how the

part contained opens out (at the bottom of the figure) to form the perimeter of the container, and how this, in turn, passes over into the uncontained aspect (in the upper portion of Figure 3.4b). The three parts of this structure thus flow into one another in a continuous, self-containing movement that flies in the face of the classical trichotomy of contained, containing, and uncontained — symbolically, of object, space, and subject. But we can also see an aspect of *dis*continuity in the diagram. At the juncture where the part uncontained passes into the part contained, the structure must intersect itself. Would this not break the figure open, rendering it *simply* discontinuous? While this is indeed the case for a Klein bottle conceived as an object in ordinary space, the true Klein bottle actually enacts a *dialectic* of continuity and discontinuity, as will become clearer in further exploring this peculiar structure. We can say then that, in its highly schematic way, the one-dimensional diagram lays out symbolically the basic terms involved in the "continuously discontinuous" dialectic of depth. Depicted here is the process by which the three-dimensional object of the fleshly lifeworld, in the act of containing itself, is transformed into the subject. This blueprint for phenomenological interrelatedness gives us a graphic indication of how the mutually exclusive categories of classical thought are surpassed by a threefold relation of mutual inclusion. It is this relation that is expressed in the primal dimension of depth.

When Merleau-Ponty says that the "enigma [of depth] consists in the fact that I see things...precisely because they eclipse one another," that "their exteriority is known in their envelopment," he is saying, in effect, that the peremptory division between the inside and outside of things is superseded in the depth dimension. Just this supersession is embodied by the Klein bottle. What makes this topological surface so surprising from the classical standpoint is its property of one-sidedness. More commonplace topological figures such as the sphere and the torus are two-sided; their opposing sides can be identified in a straightforward, unambiguous fashion. Therefore, they meet the conventional expectation of being closed structures, structures whose interior regions ("parts contained") *remain* interior. In the contrasting case of the Klein bottle, inside and outside are freely reversible. Thus, while the Klein bottle is not simply an open structure, neither is it simply closed, as are the sphere and the torus. In studying the properties of the Klein bottle, we are led to a conclusion that is paradoxical from the classical viewpoint: this structure is both open *and* closed. The Klein bottle therefore helps to convey something of the sense of dimensional depth that is lost to us when the fluid lifeworld relationships between inside and outside, closure and openness, continuity and discontinuity, are overshadowed in the Cartesian experience of their categorical separation.

At this point it should be clear that the self-penetrating, one-sided Klein bottle is the topological correlative of the perceptually integrated Necker cube. However, additional work is required to confirm that the Klein bottle is indeed depth-dimensional and not just an object in the three-dimensional space of classical experience.

Must the self-containing one-sidedness of the Klein bottle be seen as involving the *spatial* container? Granting the Klein bottle's symbolic value, could we not view its inside-out flow from "part contained" to "part containing" merely as a characteristic of an object that itself is simply "inside" of space, with space continuing to play the traditional role of that which contains without being contained? In other words, despite its suggestive quality, does the Klein bottle not lend itself to classical idealization as a mere object-in-space just as much as any other structure?

A well-known example of a one-sided topological structure that indeed can be treated as simply contained in three-dimensional space is the Moebius strip. Although its opposing sides do flow into each other, this is classically interpretable as but a global property of the surface, a feature that depends on the way in which the surface is enclosed in space but one that has no bearing on the closure of space as such. Here the topological structure of the Moebius, the particular way its boundaries are formed (one end of the strip must be twisted before joining it to the other), can be seen as unrelated to the sheer boundedness of the infinitely many structureless point elements tightly packed into the spatial continuum itself. So, despite the one-sidedness of the Moebius strip, the three-dimensional space in which it is embedded can be taken as retaining its simple closure. The customary maintenance of a strict distinction between the global properties of a topological structure and the local structurelessness of its spatial context upholds the underlying classical relation of object-in-space. Given that the Moebius strip does lend itself to drawing this categorical distinction, can we say the same of the Klein bottle? Although conventional mathematics answers the question in the affirmative, I will suggest the contrary.

The schematic representation of the Klein bottle provided by Figure 3.4b shows that it possesses the curious property of passing through itself. When we consider the actual construction of a Klein bottle in three-dimensional space (by joining one boundary circle of a cylinder to the other from the inside), we are confronted with the fact that no structure can penetrate itself without cutting a hole in its surface, an act that would render the model topologically imperfect (simply discontinuous). So the Klein bottle cannot be assembled effectively when one is limited to three dimensions.

Mathematicians observe that a form that penetrates itself in a given number of dimensions can be produced without cutting a hole if an *added* dimension is available. The point is imaginatively illustrated by mathematician Rudolf Rucker (1977). He asks us to picture a species of "Flatlanders" attempting to assemble a Moebius strip, which is a lower-dimensional analogue of the Klein bottle. Rucker shows that, since the reality of these creatures would be limited to *two* dimensions, when they would try to make an actual model of the Moebius, they would be forced to cut a hole in it. Of course, no such problem with Moebius construction arises for us human beings, who have full access to three external dimensions. It is the making of the Klein bottle that is problematic for us, requiring as it would a *fourth* dimension. Try as we might we find no fourth dimension in which to execute this operation.

However, in contemporary mathematics, the fact that we cannot create a proper model of the Klein bottle in three-dimensional space is not seen as an obstacle. The modern mathematician does not limit himself to the concrete reality of space but feels free to invoke any number of higher dimensions. Notice though, that in summoning into being these extra dimensions, the mathematician is extrapolating from the known three-dimensionality of the concrete world. This procedure of dimensional proliferation is an act of abstraction that presupposes that the nature of dimensionality itself is left unchanged. In the case of the Klein bottle, the "fourth dimension" required to complete its formation remains an *extensive continuum*, though this "higher space" is acknowledged as but a formal construct; the Klein bottle per se is regarded as an abstract mathematical object simply contained in this hyperspace (whereas the sphere, torus, and Moebius strip are relatively concrete mathematical objects, since tangibly perceptible models of them can be

successfully fashioned in three dimensions). We see here how the conventional analysis of the Klein bottle unswervingly adheres to the classical formulation of object-in-space. Moreover, whether a mathematical object must be approached through hyperdimensional abstraction or it is concretizable, the mathematician's attention is always directed outward toward an object, toward that which is cast before his subjectivity. This is the aspect of the classical stance that takes subjectivity as the detached position from which all objects are viewed; here, subjectivity as such is never opened to view. Thus, the posture of contemporary mathematics is faithfully aligned with that of Descartes and Newton in whatever topic it may be addressing. Always, there is the mathematical object (a geometric form or algebraic function), the space in which the object is contained, and the seldom-acknowledged uncontained subjectivity of the mathematician who is carrying out the analysis.

Now, in his study of topology, Barr (1964) advised that we should not be intimidated by the "higher mathematician…. We must not be put off because he is interested only in the higher abstractions: we have an equal right to be interested in the tangible" (p. 20). The tangible fact about the Klein bottle that is glossed over in the higher abstractions of modern mathematics is its *hole*. Because the standard approach has always presupposed extensive continuity, it cannot come to terms with the inherent *dis*continuity of the Klein bottle created by its self-intersection. Therefore, all too quickly, "higher" mathematics circumvents this concrete hole by an act of abstraction in which the Klein bottle is treated as a properly closed object embedded in a hyper-dimensional continuum. Also implicit in the mainstream approach is the detached subjectivity of the mathematician before whom the object is cast. I suggest that, by staying *with* the hole, we may bring into question the classical intuition of object-in-space-before-subject.

Let us look more closely at the hole in the Klein bottle. This loss in continuity is necessary. One certainly could make a hole in the Moebius strip, torus, or any other object in three-dimensional space, but such discontinuities would not be necessary inasmuch as these objects could be properly assembled in space without rupturing them. It is clear that whether such objects are cut open or left intact, the closure of the space containing them will not be brought into question; in rendering these objects discontinuous, we do not affect the assumption that the space in which they are embedded is simply continuous. With the Klein bottle it is different. Its discontinuity does speak to the supposed continuity of three-dimensional space itself, for the necessity of the hole in the bottle indicates that space is unable to contain the bottle the way ordinary objects appear containable. We know that if the Kleinian "object" is properly to be closed, assembled without merely tearing a hole in it, an "added dimension" is needed. Thus, for the Klein bottle to be accommodated, it seems the three-dimensional continuum itself must in some way be opened up, its continuity opened to challenge. Of course, we could attempt to sidestep the challenge by a continuity-maintaining act of abstraction, as in the standard mathematical analysis of the Klein bottle. Assuming we do not employ this stratagem, what conclusion are we led to regarding the "higher" dimension that is required for the completion of the Klein bottle? If it is not an extensive continuum, what sort of dimension is it? I suggest that it is none other than the dimension of depth adumbrated by Merleau-Ponty.

Depth is not a "higher" dimension or an "extra" dimension; it is not a fourth dimension that transcends classical three-dimensionality. Rather — as the "*first* dimension" (Merleau-Ponty, 1964, p. 180), depth constitutes the dynamic *source* of the

Cartesian dimensions, their "natal space and matrix" (p. 176). Therefore, in realizing depth, we do not just move away from classical experience but move back into its ground where we can gain a sense of the primordial process that first gives rise to it. The depth dimension does not complete the Klein bottle by adding anything to it. Instead, the Klein bottle reaches completion when we cease viewing it as an object-in-space and recognize it as the embodiment of depth. It is the Kleinian pattern of action (as schematically laid out in Figure 3.4b) that expresses the in-depth relations among object, space, and subject from which the old trichotomy is abstracted as an idealization. So it turns out that, far from the Klein bottle requiring a classical dimension for its completion, it is classical dimensionality that is completed by the Klein bottle, since — in its capacity as the embodiment of depth — the Klein bottle exposes the hitherto concealed ground of classical dimensionality. Here is the key to transforming our understanding of the Klein bottle so that we no longer view it as an imperfectly formed object in classical space but as the dynamic ground of that space: we must recognize that the hole in the bottle is a hole in classical space itself, a discontinuity that — when accepted in dialectical relation to continuity rather than evaded — leads us beyond the concept of dimension as Cartesian continuum to the idea of dimension as depth.

By way of summarizing the paradoxical features of the Klein bottle, I refocus on the threefold disjunction implicit in the standard treatment of the bottle: contained object, containing space, uncontained subject. (1) The contained constitutes the category of the bounded or finite, of the immanent contents we reflect upon, whatever they may be. These include empirical facts and their generalizations, which may be given in the form of equations, invariances, or symmetries. (2) The containing space is the contextual bounded*ness* serving as the means by which reflection occurs. (3) The uncontained or unbounded is the transcendent agent of reflection, namely, the subject. It is in adhering to this classical trichotomy that the Klein bottle is conventionally deemed a topological object embedded in "four-dimensional space." But the actual nature of the Klein bottle suggests otherwise. The concrete necessity of its hole indicates that, in reality, this bottle is not a mere object, not simply enclosed in a continuum as can be assumed of ordinary objects, and not open to the view of a subject that itself is detached, unviewed (uncontained). Instead of being contained in space, the Klein bottle may be described as *containing itself*, thereby superseding the dichotomy of container and contained. Instead of being reflected upon by a subject that itself remains out of reach, we may say that the self-containing Kleinian "object" is self-reflexive: it flows back into the subject thereby disclosing — not a detached *cogito*, but the dimension of depth that constitutes the dialectical lifeworld.

In closing the previous chapter, I noted the relationship between Merleau-Ponty's lifeworld dimension of depth and quantum physical action. Having now fleshed out that lifeworld dimension via Kleinian topology, the physical significance of the phenomenologically constituted Klein bottle is clear. The self-containing Klein bottle embodies $\hbar$, the quantum of action associated with the emission of radiant energy, of photons. In point of fact, this connection is already implicit in the standard formulation of the subatomic spin denoted by $\hbar$, though the relationship is well disguised.

Subatomic particles are endowed with internal angular momentum or spin, as I already indicated in chapter 2 for the photon. According to physicist Roger Penrose (1971), spin is the "most obvious physical concept that one has to start with, where quantum mechanics says something is discrete" (p. 151). The fundamental quantized action of spin,

indexed by $\hbar/2$, does not take the form of a simply continuous spinning in three-dimensional space. When Wolfgang Pauli sought to model quantum mechanical spin, he employed the mathematics of complex numbers, and in particular, the imaginary number *i*. This work derived from the investigation of hypercomplex numbers (sometimes called "hypernumbers") conducted by William Kingdon Clifford in the nineteenth century (see Musès, 1977; Applebaum, 2000). Mathematician David Applebaum observes that Clifford's abstract algebraic research had been "motivated by geometry…particularly the problem of trying to generalize the properties of complex numbers so as to be able to describe rotations in three dimensions" (2000, p. 3). Pauli used the "simplest non-trivial example of a Clifford algebra" (p. 4) to derive three matrices, which yield the three components of electron spin:

$$S_x = \hbar/2 \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$
$$S_y = \hbar/2 \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$
$$S_z = \hbar/2 \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix},$$

where $\hbar/2$ is the basic unit of electron spin.

Note that Pauli's spin matrices, in employing the most basic version of Clifford algebra, is limited to the simplest of complex numbers, the imaginary *i*. The mathematician Charles Musès worked with a more complicated variant of Clifford algebra that features a hypercomplex number that goes beyond *i*. Musès called this "hypernumber" ε, defined as $\varepsilon^2 = +1$, but $\varepsilon \neq \pm 1$ (1977, p. 71). But Musès was not satisfied with a merely algebraic expression of ε. Emphasizing the intimate relationship between algebra and geometry, he asserted that "geometry…can lead us to a deeper understanding" than the mere "brute facts" of algebra (1977, p. 77):

> The hypernumber *i* needs only a plane for visualization because, as it is multiplied by itself, it rotates in a plane as does a unit radius when a circle is drawn. But the hypernumber ε involves *reflection* …. It is clear that in order to turn a right hand into its reflected version (a left hand), more is required than sliding or rotation in tri-dimensional space. It can be shown that a right hand would be changed into a left hand if it were rotated 180° *out* of our triple dimensional space into four-dimensional space, and then back into our space again …. Therefore, because ε deals with reflections and not only with simple rotations as does *i*, its operations demand geometrically a four-dimensional space, whereas the simple, rotational character of *i*'s operations demands only two-dimensional space. (p. 77)

Elsewhere (Rosen, 2008), I linked the geometry of ε to the topology of the Klein bottle. Like ε rotation, Kleinian action can also be seen as involving a "successive rotation through a four-dimensional space and then back into ours" (Musès, 1977, p. 77). Moreover, the Klein bottle possesses the property of reflection that transforms left into right and vice versa.

The Klein bottle's left-right reversibility is related to its one-sidedness. Topological forms that are one-sided are also non-orientable. In traversing such structures, a fixed

directional orientation cannot be not maintained. This is most simply illustrated with the one-sided Moebius strip (Figure 3.5). To demonstrate the feature of non-orientability, we incorporate a test body into the Moebius model: an asymmetric profile.

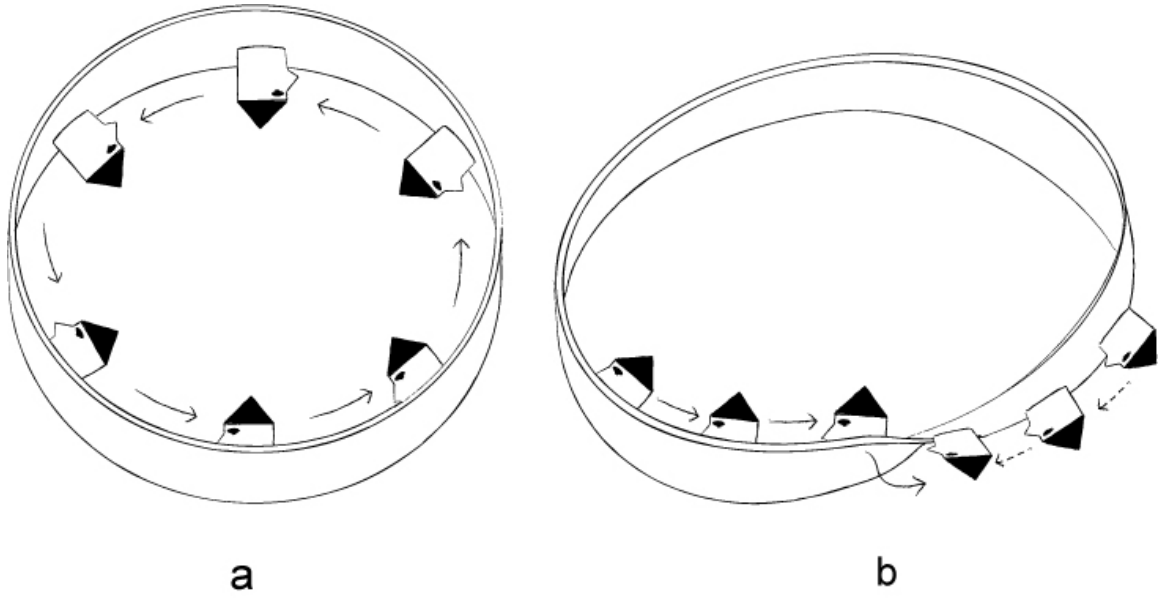

Figure 3.5. Revolution of asymmetric figure on cylindrical ring (a) and on Moebius strip (b)

Figure 3.5(a) shows a left-facing profile revolving in a counterclockwise direction around a cylindrical ring. It is clear that action on the simple ring will continue indefinitely in this manner, with the orientation of the profile never changing (though the half-face is turned upside down). In Figure 3.5(b), we see the profile moving counterclockwise about the Moebius strip. Entering the twist, the left-facing form is changed into a right-facing form, the transformation being completed after 360° have been travelled. The same transformation of left into right takes place with rotation about the Klein bottle. And in both cases, the transformation entails a twist into an added dimension. Whereas Moebius rotation involves a twisting from the two-dimensional plane of rotation into the third dimension, Kleinian movement brings a twist into a "fourth" dimension. I would maintain, of course, that the "extra dimension" into which Kleinian action flows is in fact no objectified fourth dimension but the sub-objective dimension of *depth*. This is the crucial distinction between the proposed phenomenological approach to the foundations of physics and the still-prevalent Cartesian one.

Now, Musès contended that the four-dimensional action of epsilon pertains to the spin of the electron (1977, p. 77). And yet, Pauli was able to account for the motion of the electron by using the simplest order of hypernumber, the imaginary *i*, which requires only two dimensions for its operation. What we have found in this chapter is that "four-dimensional" Kleinian action in fact is associated not with the electron but with the radiant energy of the photon. We can say then that, in the form of $\varepsilon\hbar$, the Klein bottle implicitly expresses the electromagnetic angular action that lies at the core of quantum mechanics. And recognizing the relationship between Kleinian depth and radiant energy prepares us to return to the question with which this book began.

Chapter 4

PROPRIOCEPTIVE QUANTUM PERCEPTION

1. INTRODUCTION

This book was inspired by research into the possibility that human beings can perceive single photons, and, in so doing, directly probe the underlying quantum reality. But, as we saw in chapter 1, the experiments have done no more than confirm that single photons are detectable; this is a far cry from establishing that photons can be consciously, accurately, and reliably perceived.

Biophysical anthropologist William Bushell (2016) has addressed this issue. Citing the research of Ericsson, Nandagopal, and Roring (2009) and Ericsson and Simon (1993), Bushell notes: "As Simon and Ericsson and colleagues have conclusively demonstrated, deliberate practice meeting the special criteria of 'expert and exceptional performance' can produce magnitudes of improvement in both qualitative and quantitative measures of performance in many areas, including performance in sensory–perceptual tasks" (2016, p. 33). Among Bushell's primary concerns is the perception of single photons and he observes that past studies of single photon detection fail to incorporate in their designs methods of extensive training and practice that could bolster photon perception (p. 33). Bushell goes on to discuss certain non-Western meditational practices that seem to significantly augment perceptual acuity. For example, the "specifically stated goal of the Indo–Tibetan yogic tradition is to directly perceive the miniscule, the microscopic, and beyond" (2016, p. 34). Bushell speaks in general "of how intensively trained individuals — adepts or virtuosi of special meditational techniques… appear to be potentially capable of radically enhancing their sensory perceptual capacities to the point of … directly perceiving light at the scale of single photons" (p. 31). While it is true that such attempts at refining micro-perception have yet to be studied in a systematic way and await further clarification and development, let us proceed from the premise that observers can indeed be trained to proficiently perceive at the scale of single photons and the quantum reality associated with them. What then?

Our conceptual exploration has led us to the conclusion that the photon's internal action is best understood as a spinning akin to the action of the Kleinian depth dimension — a dimension in which subject and object, observer and observed, are themselves superposed. What this suggests is that the photonic wave could not be observed directly while at the same time maintaining the objectifying stance of empirical tradition. It would be futile for the would-be observer of the wave to continue in the posture of a detached subject before whom objects are cast. In dealing with the depth-dimensional actuality of the photon, the observer evidently would need to enter into it with her own subjectivity. No longer could she remain a disinterested bystander, for her active presence would be required to make the observation in a concrete way. Therefore, rather than approaching the photon as an object from which she is detached, she would need to approach it phenomenologically, relating more intimately to it, immersing herself in its lifeworld. Here she would become "one of the visibles" (Merleau-Ponty, 1968, p. 135) and, in her interaction with the photon, she would no longer sharply divide the photon seen from

herself, the seer. What would such a radical change in observational posture specifically entail? We may begin to address this question by turning to the work of the philosopher of science Evelyn Fox Keller.

2. DYNAMIC OBJECTIVITY

Evelyn Fox Keller (1985) calls for a new form of scientific inquiry that she names "dynamic objectivity" (p. 115). The old approach, she says, involves a "static objectivity" in which "the pursuit of knowledge...begins with the severance of subject from object" (p. 117). In contrast, "dynamic objectivity aims at a form of knowledge that grants to the world around us its independent integrity but does so in a way that remains cognizant of, indeed relies on, our connectivity with that world" (p. 117). Elaborating further:

> Dynamic objectivity is…a pursuit of knowledge that makes use of subjective experience (Piaget calls it consciousness of self) in the interests of a more effective objectivity. Premised on continuity [of self and other], it recognizes difference between self and other as an opportunity for a deeper and more articulated kinship....To this end, the scientist employs a form of attention to the natural world that is like one's ideal attention to the human world: it is a form of love. The capacity for such attention, like the capacity for love and empathy, requires a sense of self secure enough to tolerate both difference and continuity." (1985, pp. 117–118)

Writing in the same vein, Fox Keller adduces Ernest Schachtel's distinction between "autocentric" and "allocentric" perception. Whereas the former is "dominated by need or self-interest," the latter "is perception in the service of a love 'which wants to affirm others in their total and unique being.' It is an affirmation of objects as 'part of the same world of which man is a part,'" one which "permits a fuller, more 'global' understanding of the object in its own right" (p. 119). Although Fox Keller pays scant attention to phenomenological philosophy, citing none of its leading figures, the main thrust of her presentation is much in keeping with phenomenology's central aim, as expressed in its well-known slogan: "To the things themselves!" And it seems clear that the world shared by the "allocentric" observer and the objects that she observes parallels the lifeworld of phenomenology.

Fox Keller helps us gain a better grasp of the new mode of scientific inquiry by offering a specific example of one of its premier practitioners: the Nobel prize-winning biologist, Barbara McClintock. In stark contrast to the detached, dispassionate attitude of the Cartesian scientist, McClintock speaks of obtaining an intimate feeling for the plants she works with: "'I don't feel I really know the story if I don't watch the plant all the way along….I know [the plants] intimately, and I find it a great pleasure to know them'" (Fox Keller, 1985, p. 164). It was this kind of knowledge that enabled McClintock to identify plant chromosomes with greater clarity:

> I found that the more I worked with them, the bigger and bigger [the chromosomes] got, and when I was really working with them I wasn't outside, I was down there. I was part of the system....As you look at these things, they become part of you. And you forget yourself. (McClintock quoted in Fox Keller, 1985, p. 165)

Fox Keller observes that McClintock's vocabulary "is consistently a vocabulary of affection, of kinship, of empathy," an empathy that constitutes "the highest form of love: love that allows for intimacy without the annihilation of difference" (p. 164). Here the word "love" is used "neither loosely nor sentimentally, but out of fidelity to the language McClintock herself uses to describe a form of attention, indeed a form of thought" (p. 164).

Fox Keller arrives at these conclusions:

> The crucial point for us is that McClintock can risk the suspension of boundaries between subject and object without jeopardy to science precisely because, to her, science is not premised on that division. Indeed, the intimacy she experiences with the objects she studies...is a wellspring of her powers as a scientist....In this world of difference, division is relinquished without generating chaos. Self and other, mind and nature survive not in mutual alienation, or in symbiotic fusion, but in structural integrity. (pp. 164–165)

McClintock's world of feeling and embodied empathy bears kinship with the depth-dimensional lifeworld of ontological phenomenology. It is a world in which the dialectic of difference and identity is enacted through an intimate knowledge of other that requires and is inseparable from the knowledge of self (Piaget's "consciousness of self"). McClintock's "revolution that 'will reorganize...the way we do [scientific] research'" (Fox Keller, 1985, p. 172) depends on relaxing our commitment to the classical ideal of object-in-space-before-subject and descending from the Cartesian stratosphere to immerse ourselves in a world where object and subject mediate one another internally in an encompassing circular flow.

Of course, while McClintock studied chromosomes, the central concern of the present work is with *photons*. Unlike the photon, the chromosome is not a native of the quantum domain and, although McClintock cultivated a uniquely intimate relationship with this molecular structure, other biological researchers have been able to strike a more dispassionate, conventional posture, treating chromosomes as objects from which these researchers are largely detached. Whereas the chromosome does allow for such treatment, the single photon does not. To sharpen our understanding of why this is so, let us take a closer look at the photon.

3. THE PHENOMENON OF LIGHT

Modern physics is a child of the electromagnetic age. Two of its greatest experiments centered on the phenomenon of light. The results of Max Planck's experiment on blackbody radiation provided the impetus for quantum mechanics, and an earlier experiment on light conducted by Michelson and Morley in 1887 created a puzzling problem subsequently addressed in Einstein's 1905 theory of relativity.

The Michelson-Morley research raised doubts about the luminiferous ether that Maxwell had imagined to be the medium for propagating electromagnetic energy. Just as relatively crude mechanical phenomena like water waves and sound waves could be taken as transmitted through Newtonian space via the media of water and air (respectively), Maxwell supposed that the subtler electromagnetic energy he was investigating was transmitted through the ether, a highly refined medium thought to pervade the whole

universe. Possessing few properties and no action of its own, the ether was presumed to serve exclusively as the framework within which the continuous motions of coarser substances could be measured and analyzed — including the motion of light. Maxwell's ether hypothesis reflected the underlying idea that light could be viewed as a mechanical force that passed through the Newtonian continuum like any other force — in other words, that light could be treated as an object in space that could be observed objectively by a Newtonian subject detached from that space. In so postulating the existence of a luminiferous ether, the old formula of object-in-space-before-subject was tacitly maintained. But the postulate proved untenable.

If it were true that light moved through a motionless ethereal continuum, then a key principle of classical mechanics should apply: the addition of velocities. Assuming light to propagate through the ether at the absolute speed of *c* (~186,000 mi/s), a traveler moving toward a beam of light should observe the beam to be approaching her at a velocity greater than *c*, her own velocity being added to *c* to obtain the higher relative velocity. Similarly, if the light beam and the observer are moving away from each other through the ether, the relative velocity of the light beam would be less than *c*, the observer's velocity now being subtracted from *c*. What Michelson and Morley discovered was that the velocity of light actually always appeared to be the same, regardless of its direction of motion relative to the observer. This astonishing result sounded the death knell of the ether theory.

The result of the Michelson-Morley experiment was indeed baffling to the classical "eye." Is it not an obvious fact of perception that, if I change my perspective on an object I am viewing, its appearance will change accordingly? What the experiment demonstrated in its abstract way was that, when the "object" being considered is *light*, the familiar principle of perspective does not apply. It would certainly look strange to me if I got up from this computer screen I am sitting at, moved all the way to the right of it so that I was viewing the screen at an acute angle, but found that the screen had the same full, square appearance as when I was sitting directly in front of it! Analogously, this is what Michelson and Morley "saw" when they looked at light from different "angles" (reference frames). This strange outcome made it clear that the phenomenon of light does not behave the way mechanical phenomena do, thus suggesting that electromagnetic phenomena are not strictly governed by the classical laws of Newtonian space.

But just why was it that the velocity of light did not change regardless of the frame of reference that Michelson and Morley adopted? Why did light "look" the same to them no matter what perspective upon it they assumed? I propose it was because, in confronting the phenomenon of light, they were not encountering an object to be seen, but that *by which* they saw. In this regard, cosmologist Arthur Young (1976) commented that while the conventional "scientist…likes to think of [a particle of] light as 'just another kind of particle,'…light is not an objective thing that can be investigated as can an ordinary object …. Light is not seen; it is [the] seeing" (p. 11). The physicist Mendel Sachs (1999) reached a similar conclusion in his inquiry into the meaning of light: "What is 'it' that propagates from an emitter of light, such as the sun, to an absorber of light, such as one's eye? Is 'it' truly a thing on its own, or is it a manifestation of the coupling of an emitter to an absorber?" (p. 14). Sachs's rhetorical question intimates that light — instead of lending itself to being treated as an object open to the scrutiny of a subject that stands apart from it — must be understood as entailing the *inseparable blending of object and subject* (Rosen, 2008, p. 164). This computer screen surely does not look the same to me from every perspective, but in

attempting to observe the light by which the screen is perceived, it seems I would be confronted with the prospect of "viewing my own viewing," and this would mean that I would not encounter the concrete variations in appearance that attend the observation of an object from a viewpoint that itself is not viewed. At bottom then, the finding of Michelson and Morley evidently called into question the classical intuition of object, space, and subject that had implicitly governed the work of science for many centuries.

It was in his attempt to come to terms with the enigma of light that Einstein posited his Special Theory of Relativity. To all appearances, Einstein's theory was a resounding success. However, when he unveiled this idea in 1905, he was well aware that it was incomplete. Einstein came to call his initial theory "special" because it was limited to the ideal case of coordinate systems that moved uniformly. In the real world, however, systems typically *change* their state of motion, speed up or slow down. With the Special Theory published, Einstein turned to the task of accounting for the relative motion of *all* reference frames, whether or not the motion is uniform. This effort eventuated in the 1915 publication of the General Theory of Relativity. By switching from the Minkowski flat space of Special Relativity to the far more general Riemannian manifold, Einstein could now explain the interaction of systems in non-uniform relative motion. The flexibility of Riemannian geometry permitted Einstein to gauge the degree of non-uniformity of motion in precise terms by associating it with the degree of curvature in the manifold. Space-time is without curvature for systems in uniform motion and becomes progressively more curved as the acceleration of the reference frame increases. Applying the principle of general relativity that establishes the equivalence of inertial and gravitational masses, space-time curvature is related to gravitational effects: the greater the gravitational mass of a body, the more curved is the space-time continuum.

Now, while Einstein found it necessary to adopt this approach, he soon realized that it had its limitations. For, there were solutions to the field equations of general relativity that predicted *infinite* curvature. That is, if a gravitational body were massive enough, the curvature of space-time would become so great that a singularity would be produced in the continuum. What this meant is that analytic continuity would be lost and the theory would fail! However, for that to happen, the mass density of the gravitational body indeed would have to be enormous. When the General Theory was first propounded in 1915, the existence of such astrophysical bodies was taken as purely hypothetical. But, as the twentieth century wore on, the possibility of stellar objects whose masses were sufficient to produce "black holes" in space began to be considered more seriously. This led physicist Brandon Carter (1968) to raise explicit doubts about Einstein's theory: Would it be able to survive its prediction of gravitational collapse? By the end of the twentieth century, empirical evidence for black holes had only grown stronger, and, now, in the new millennium, the evidence appears irrefutable. Let me now summarize the theory's course of development and reflect on its meaning.

Einsteinian relativity evolved out of the attempt to circumvent the "black hole" that was created when Michelson and Morley could not confirm the existence of the luminiferous ethereal continuum. The effect of Einstein's theory was to plug the implicit gap in three-dimensional space by postulating a four-dimensional space-time continuum. To generalize the new account to non-uniform motion, Einstein posited the curvature of space-time. What we are seeing, in effect, is that the four-dimensional approach used to compensate for the absence of continuity in three-dimensional space winds up re-

introducing *dis*continuity. Even though general relativity permits one to establish invariances involving non-uniform motion, invariances that presuppose continuity, the *greater* the non-uniformity, the greater is the curvature of space-time, and the closer one then approaches to the point where invariance breaks down and continuity is lost. So it seems that the moment curved Riemannian geometry was applied to generalize Einstein's remedy for discontinuity, a new order of discontinuity was presaged. In the end then, Einsteinian relativity does not effectively address the underlying crisis in theoretical physics precipitated by the Michelson-Morley experiment.

Interestingly, the topic of light plays a significant role in ontological phenomenology. We might say that Merleau-Ponty's study of Cézanne's "autofigurative" art essentially studies the paradox of light. Heidegger, for his part, is quite explicit about the importance of light to phenomenological thought. After acknowledging the contributions of Hegel and Husserl in surpassing the old mechanistic objectivism and making subjectivity the matter of philosophy, Heidegger (1964/1977) comments that — in thinking subjectivity into its own, "to its ultimate originary givenness…to its own presence" (p. 383), something remains *un*thought:

> What remains unthought in the matter of philosophy as well as in its method? [Hegel's] speculative dialectic is a mode in which the matter of philosophy [i.e. subjectivity] comes to appear of itself and for itself, and thus becomes present. Such appearance necessarily occurs in some light. Only by virtue of light, i.e., through brightness, can what shines show itself, that is, radiate. (p. 383)

Evidently then, what remains unthought in the history of philosophy is the phenomenon of light, or what Heidegger later calls *enargeia* ("that which in itself and of itself radiates and brings itself to light"; p. 385).

It is clear that, for Heidegger, *enargeia* or light is not merely a local, objectively observable phenomenon, not just a finite particular being. Heidegger (1964/1977, p. 390) implicitly associates light with *Being*, with "presence as such," rather than just with "what is present." And, according to philosopher Carol Bigwood (1993, p. 3), while Heideggerian "Being is not a being," neither is it a "God [or] an absolute unconditional ground…but is simply the living web within which all relations emerge." That is to say, *Be-ing* constitutes the dimension of dynamic life process, the fleshly lifeworld dimension. From this we can conclude that light, or, more generally, electromagnetism, indeed comprises a non-classical dimension unto itself, an entire world of intimate subject-object interaction. Thus, light as such (as opposed to that which merely is lit), light as quantized Kleinian action ($\varepsilon\hbar$), is the paradoxical phenomenon that gives physical significance to Merleau-Ponty's dimension of depth.

Now, the thought experiment illustrating the aperspectival nature of light implicit in the Michelson-Morley research brings to mind our perceptual experiment with the Necker cube (chapter 3). Ordinarily, we perceive one perspective of the cube at a time and, in shifting from one to the other, we observe the kind of difference we would expect to see in changing the angle from which we view a solid object: the faces of the cube that appeared inside before the shift now appear outside and vice versa, as if we had moved around a solid object and were viewing it from a different angle, one that had changed the visibility

of its surfaces, concealing some, uncovering others (the concealed surfaces of the solid object correspond to the interior faces of the Necker cube and the visible surfaces of the solid correspond to the exterior faces of the cube). But with the integration of the cube, perspectives are superposed upon each other. In penetrating one another, each perspective encompasses the whole cube so that the integrated cube can be said to penetrate itself.

Of course, there is the limitation of macroscopic perception noted in the previous chapter. Though the cube's perspectives are superposed to give a one-sided experience that can symbolize the integration of subject and object found in the depth-dimensional phenomenon of light, the cube appears before us as but an object in space. Clearly then, the classical formula holds sway in relation to the large-scale external world. Here the self-penetration of the integrated cube does not literally penetrate the one who views it. Here the observer does not draw back in upon herself to observe her own observing, uniting observer and observed in the process. Quantum physics tells us that it is in the submicroscopic realm that such a union can take place. This is where, in viewing the particle of light, one must view one's own viewing in a reflexive act of self-penetration, as we will soon see.

The difference between observing the submicroscopic photon and viewing larger scaled phenomena applies not only to the Necker cube but to McClintock's chromosomes as well. Like the cube, the chromosome appears before the observer as an entity in ordinary space. The chromosome is thus objectifiable, whereas the photon is not. This difference is ontological.

It was Heidegger (1927/1962) who emphasized the importance of what he called the "ontological difference." The crucial distinction is that between the "ontical" and the "ontological." Although Heidegger himself provided no explicit definitions of these terms, his translators did: "Ontological inquiry is concerned primarily with *Being*; ontical inquiry is concerned primarily with *entities* and the facts about them" (Macquarrie and Robinson in Heidegger, 1927/1962, p. 31, n.3). According to philosopher David Michael Levin (1985), while this "fundamental difference...between Being and beings...is both basic and simple, its articulation and understanding are matters of the greatest difficulty" (p. 10). Levin proposes:

> [A] fruitful way of formulating the ontological difference is to articulate it as the difference between the horizon, field, or clearing within which beings appear, and the various beings themselves; or as the difference between the ground of significance itself and the figures which appear in its setting and stand out from the ground. Being is not *a* being, but rather the dimensionality within which all beings are to be encountered. (p. 11)

The ontological difference can be clarified further by recognizing that, if Being is a dimensional context or background, it cannot be so in the same sense that classical space serves as background. For Being is not just the ground from which *figures* stand out; it is not merely that which functions as a framework or container of objects; rather, the objects *and* their spatial background emerge from Being, along with the detached subject who reflects upon those objects. In other words, what stands out from Being, what Being opens up and first makes possible, is object-in-space-before-subject.

The ontological difference is reflected in the difference between the ontical phenomena of the classical world and the ontological phenomena of the quantum world. We have seen that the quantum dimension is the "first dimension" (Merleau-Ponty, 1964, p. 180), the "natal space and matrix of every other existing space" (p. 176). Thus the large-scale Cartesian dimensions are first projected from the submicroscopic depth dimension. The ordinary course of perception follows this movement from the pre-objective domain into the familiar realm of object-in-space-before-subject. In moving out of the former, quantum reality is relegated to oblivion and perception implicitly becomes a process of objectification (as exemplified by the phenomenon of binocular convergence discussed in the next section). It seems then that, if we wish to reenter the quantum domain to observe the photon, we must reverse the long-dominant direction in which perception operates. The projection of object-in-space-before-subject must be withdrawn in an act that carries perception back to its ontological origin.

4. OBSERVING THE PHOTON THROUGH PROPRIOCEPTION

In this book, we are entertaining the possibility that the single photon and its associated quantum field can be consciously perceived. I have indicated that this would call for a radical change in the way in which observations are performed. In a recursive move, the observer would need to shift gears and bring his attention backward to the source of the observing process. Through this reversal, observer and observed would become intimately related; they themselves would become superposed. Or we could say — bearing in mind the *ontological* nature of light — that in order to see the photon, one would need to *be* the photon. I will now explore further what this new form of observation would entail.

The movement of perception away from its quantum ontological source into the ontical Cartesian realm is similar to the "from-to" action of experience described by the phenomenologist Drew Leder (1990, pp. 15–17). Ordinarily, in whatever we see, we "cannot see our own seeing" (p. 17), since our seeing is what we see *from*. By upholding the categorical distinction between *what* we see and what we see *from*, the subject-object dichotomy is enforced: sight is directed *to* an object seen, from an unseen subjective perspective. The movement is normally assumed to be irreversible, making it impossible to view subjectivity as such (see related discussion of Michelson-Morley experiment in the previous section).

In our bid to observe the ontological photon, are we presently looking to challenge the assumption of perception's irreversibility by transposing the subject-object relation in such a way that we can know the subject per se? It was Husserl who had hoped to know the subject (and with even greater "objectivity" than the object had once been known). Heidegger, for his part, did not merely call for a reversal of the inclination to pass from subject to object; he called for a reversal of the subject-object dichotomy, thereby enabling us to move back into "the living web within which all relations emerge" (Bigwood, 1993, p. 3), which is to say: into the quantum sphere of Being.

The *gearing* of awareness is all-important to the reversal in question. To see why this is so, let us consider the difference between gear and direction through the analogy of driving a car. I am driving along a highway in the forward gear from east to west when I suddenly realize that I left my wallet at home, so I make a U-turn. Having reversed my direction of movement, I am now traveling from the west but am facing the eastern sky.

Through it all, the car remains geared to move forward. Had I needed to move backward, I would have had to change the gears.

Applying this distinction to the matter at hand, in order to perceive the single photon, it is not enough to change the *direction* of perception; its "gear" must be reversed so that it is no longer simply moving ahead. Were we to proceed toward the photon in this "forward gear," we would be attempting to "turn around" upon this ontological source — like turning the car around so that it now faces the direction from which it was previously facing. In such a reversal, we would indeed be inclined to *face* the photon, to have it appear before us, over against our consciousness. With perception thus geared, we would still be trying to objectify the photon, but would only succeed in obscuring it — collapsing the ontological wave, rendering the quantum world ontical, rather than experiencing it in its actual form. We cannot know the photon by simply turning around upon it any more than turning a car 180° to face the direction *from* which it *had* been facing allows us to capture that "from" as it was initially experienced; such a turning merely turns the old "from" into a new "to" that is seen from a new perspective. It is clear that the attempt to grasp the "from" of the photon while maintaining the forward orientation is futile; to make such an effort is to "chase one's tail," to turn in a vicious circle.

The implication of Heidegger's work is that perception must shift into a different gear. If we are to apprehend the ontological photon as such, we must approach it in "reverse." Notice that, whereas turning a car around to face in the opposite direction turns us away from the original direction in which we faced, if we shift into reverse without turning, we continue to face in the original direction. A similar distinction can be made with respect to the ontological photon: in seeking to come "face-to-face" with it as that which integrates subject and object, we hope in vain to turn our backs on the subject-object dichotomy, to negate it. By contrast, the movement *backward* into the radiant quantum realm does not simply negate the classical formula but brings to light the non-classical ground from which it issues.

The backward movement of awareness required for the perception of the ontological photon may be understood as a form of *proprioception* (Rosen, 2008, 2004). Etymologically, to *per*ceive is to "take hold of" or "take through" (from the Latin, *per*, through, and *capere*, to take), and to *con*ceive is to "gather or take in." These activities correspond to the ordinary *from-to*, forward gearing of ontical consciousness. The term "proprioceive" is from the Latin, *proprius*, meaning "one's own." Literally then, proprioception means "taking one's own," which can be read as a taking of self or "self-taking." The term finds its most common usage in physiology where it signifies an organism's sensitivity to activity in its own muscles, joints, and tendons. But the physicist and philosopher David Bohm (1994) spoke of the need for "*proprioceptive thought*" (p. 229), which he viewed as a certain kind of meditative act wherein "consciousness ... [becomes] aware of its own implicate activity, in which its content originates" (p. 232). Years earlier, the social psychiatrist Trigant Burrow spoke similarly of the need for human beings to gain a proprioceptive awareness of the organismic basis of their divisive symbolic activity (Galt, 1995). What I am proposing is that observing the photon in its depths requires that the observer function proprioceptively, for such observation would not merely involve observing what is lit, as happens under the classical paradigm. Instead, it would reverse the gears of perception so as to bring awareness of the ontological lighting process per se. (We see proprioceptive observation modeled in the reflexive self-

penetration that takes place when integrating the perspectives of the Necker cube. To be brought to ontological fruition of course, the microworld self-penetration of the Klein bottle would be necessary.)

In observing the photon proprioceptively, the observer would maintain awareness of her own act of observing. Here attention would move counter to the direction in which conventional observation occurs. The ordinary movement of perception outward toward the photon would at once be accompanied by an inward passage to the source of observation. The observer thus would interact with the photon through an embodied sense of her own process of observing as it is occurring in the moment. Just as I can obtain a proprioceptive (or kinesthetic)[3] sense of the muscular activity in my fingers as I type these words, the photon's observer should be able to obtain a sense of the movement of her eyes as they attempt to engage with the photon (practice and training should enhance the observer's proficiency at this). In counteracting the outward movement of attention by simultaneously drawing perception back in upon itself, the observer would no longer be limited to viewing the objectified, already collapsed photonic wave. She could then gain a concrete sense of the otherwise unnoticed process by which the psychophysical wave has been collapsed, a view that would include the initial state of subject–object superposition. It is in this way that the collapse would be counteracted.

Let us now consider Trigant Burrow's approach in greater detail since it may help us better understand what is needed for observing the photon. We have found that, in the paradigm of object-in-space-before-subject, the subject plays the role of an idealized cogito standing apart from the world and acting upon it with impunity. Burrow's term for this Cartesian subject engaged in ceaseless acts of objectification is *"I"-persona*. For Burrow (1953), the functioning of the "I"-persona has a distinct anatomical locus. It is centered in what he called the "cerebro-ocular" region (p. 526), that is, in the cerebral cortex of the brain and in the organ of vision associated with it. Burrow pointed out that it was through the phylogenetic development of the brain's cortex that the perceptual, linguistic, and symbolic operations of the "I"-persona first arose. Therefore, to gain a tangible sense of this objectifying activity, it seems one would need to bring proprioceptive attention to one's cerebral cortex. But this conclusion was informed by more than a simple logical deduction. Burrow claimed to have had a spontaneous experience of the "I"-persona's bodily base, one that profoundly influenced all his subsequent research. After a prolonged period of interpersonal strife involving the members of the group that he had established to investigate such "I"-based conflict, he began to notice a distinctive pattern of tension around his eyes and forehead. Burrow recognized in this the bodily expression of the "I"-persona.

Burrow would caution us not to confuse the "I"-persona with the individual ego. We might say that this persona is the *species-wide* "subject" that lies behind the appearance of individual subjectivity. But while it is through the "I"-persona that we, as a species, create

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[3] Historian of science Roger Smith (2020) discusses the distinction between the terms "proprioception" and "kinesthesia." Strictly speaking, "kinesthesia" is a psychological term referring to conscious sensory awareness of movement in one's body, whereas "proprioception" is a physiological term indicating largely unconscious sensitivity to bodily activity (as noted above). However, Smith points out that the meanings of kinesthesia and proprioception are very often confused in the literature or taken as synonymous. In the present work, I do not generally use the word "kinesthesia." Instead I employ the word "proprioception" in Bohm's broad sense of self-awareness, which is grounded by the word's etymological meaning, "self-taking."

the impression of ourselves as merely isolated, disembodied subjects, the generic "I" itself is no disembodied subject. It is the *bodily process* that is central to human functioning as a whole. Therefore, when Burrow became proprioceptively attentive to the "I"-persona rather than continuing to be unwittingly governed by it, he experienced this palpable pattern of tension around the eyes and forehead against a background consisting of the "tensional pattern of the organism as a whole" (Galt, 1995, p. 31). He was thus presumably able to apprehend what he called the "solidarity of the species" (Burrow, 1953, p. 71) or the "phyloörganism" (p. 445), i.e., the organism of humanity at large. Burrow's research associate, Hans Syz (1961), in summarizing this attunement to the phyloörganismic background, spoke similarly of entering into "basic physiological harmony and feeling-continuity with the mother-organism and with the world" (p. 285). While Burrow was not a philosopher and did not spell out the ontological implications of this collective organicity, Syz (p. 288) implicitly related the phyloörganism to the phenomenological work of Erwin Strauss, and to the Heideggerian concept of being-in-the-world. I believe we may plausibly link the notion of the phyloörganism to the depth-dimensional lifeworld of which Merleau-Ponty (1968) spoke, where the subject is recognized as but "one of the visibles" (p. 135). Or we may correlate the generic human organism with the "living web within which all relations emerge" (Bigwood, 1993, p. 3) that Heidegger called Being. And this is the radiant quantum-ontological microworld that constitutes the dynamic substrate from which the ontical world of object-in-space-before-subject arises.

Following his first spontaneous glimmer of the phyloörganism, Burrow sought to cultivate the experience in a systematic practice he named "cotention" (1932). He described his procedure as one of setting aside daily experimental periods in which he "adhered consistently to relaxing the eyes and to getting the kinesthetic 'feel' of the tensions in and about the eyes and in the cephalic area generally" (1953, p. 95). Elsewhere (Rosen, 1999), I proposed a further specification of the tensions in question.

Normal binocular vision operates in such a way that our eyes function in concert to bring a particular object into focus, the figure standing out from its background. An example of this is our strong inclination to see either one perspective or the other when viewing the Necker cube. The tendency derives from the well-established neurophysiological habit of binocular convergence. It seems to follow from Burrow's analysis that binocular convergence is a process of visual objectification that is intimately associated with the symbolic operations of the cerebral cortex. Burrow came close to stating this explicitly when he related the advent of objectifying perceptual activity (what he called "ditention," i.e., divided attention) to the elaboration of cortically based linguistic operations, and related language to the movement of the musculature in and around the eyes. The ocular-facial movements described by Burrow thus can be said to entail the shifting of optical focus from this object to that, in continual acts of binocular convergence. And the proprioception of binocular convergence, as modeled by the perspectival integration of the Necker cube, is what is needed in the observation of the photon.

Burrow's initial efforts were followed by a program of research in which physiological measurements were made of subjects practicing cotention while engaged in activities such as reading and viewing pictures. Burrow and his colleagues (1953, chapter XI and Appendix) found changes in respiration, eye movements, and brain wave activity consistent with the idea that participants had become attuned to the phyloörganismic background. In Burrow's research however, there was no attempt to observe the

phyloörganism directly. Participants proprioceived the eye-brain nexus in the course of observing ordinary objects in a macroscopic setting. The ontological quantum realm we are associating with generic organicity thus came into play only as an obliquely perceived background of the everyday ontical world. By contrast, what we have been considering in the present investigation is the prospect of observing the quantum domain in an immediate way via the proprioceptive perception of the photon.

In the introduction to this chapter, I noted Bushell's (2016) claim that it is possible to train observers to perceive single photons. What I am presently suggesting is that such micro-perception would necessarily have to be proprioceptive if a simple objectification of the photon is to be avoided. Here, operating reflexively, the observer would direct his awareness to the eye-brain nexus as his optical muscles seek to fix the photon via binocular convergence. Whereas in ordinary perception the observer detaches himself from what he observes, with proprioception the observer's interior process is included, as is required for entering an ontological realm not amenable to the splitting of observer and observed. Attempts to observe the photon "objectively" would only collapse the radiant quantum wave, destroying its coherence.

Of course, the full-fledged integration of observer and observed also depends on the unique nature of the photon itself. We have seen that, for its part, the photon "is not an objective thing that can be investigated as can an ordinary object"; light "is not seen; it is [the] seeing" (Young, 1976, p. 11). Or, as Sachs (1999, p. 14) put it, light is not "a thing on its own," not an independent object; instead, it is the inseparable blending of subject and object. Therefore, in observing the photon micro-proprioceptively, when the observer would bring her attention to the convergent action of her eyes, the photon falling on her retina would not merely register as an objective phenomenon occurring separately from her subjective viewing process but would be recognized as an integral aspect of a process wherein subject and object are inseparable. "Seeing" the photon in this way, the observer would be seeing herself — and not as an object observed by a more abstract self (as in Husserlian introspection), but as "one of the visibles." In so observing the photon, she would *become* the photon.

Chapter 5

QUANTUM ENTANGLEMENT

The August Master of the Center … dwelling at the point of the splitting of the unitary energy of life, can be said to wield a divine sword which slices that energy into its two manifestations and thereby creates polarity. This deity, however, is the consummate swordsman who, although cutting into two, does so with such speed and precision that the fluid of life continues to flow between the resulting halves. They therefore remain continuous and intertwined.

The Looking-Glass God
Nahum Stiskin (1972, p. 90)

1. INTRODUCTION

At the beginning of the twentieth century, Max Planck's famous experiments on light precipitated a revolution that shook the foundations of physics. But it took another generation for the implications of Planck's findings to begin sinking in. While he had demonstrated that electromagnetic energy is distributed in discontinuous bundles (quanta), the deeper implication that quantum space itself is discontinuous was difficult to digest. I discussed this underlying discontinuity in previous chapters. According to physicist Erwin Schroedinger, it is related to a phenomenon that he described as "*the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought" (1935, p. 807). I am referring to the phenomenon of *entanglement*, a term that Schroedinger coined.

In the same year that Schroedinger proclaimed the central importance of quantum entanglement, Einstein, Podolsky, and Rosen (1935) investigated it through a thought experiment. They demonstrated that, if a pair of particles that are initially associated are then separated, quantum theory implies that the two particles would behave as if still connected. Therefore, a measurement made on one particle, say, its spin, would always be highly correlated with the measured value of its entangled partner, regardless of how far apart in space they were.

Einstein's thought experiment was motivated by his misgivings about quantum mechanic's apparent intimation of what he called "spooky action at a distance." For, if the measurement of one particle somehow instantaneously affects the value of another particle that is remote from it, this would seem to violate the fundamental principle of Einsteinian relativity that no signal can be transmitted faster than the speed of light. But an even more fundamental principle is at play here. The relativistic structure of spacetime that limits the transmission rate of energy or information presupposes spacetime's *continuity* and, in such a continuum, information can only be transferred from one local point of space to another.

On this view, entanglement appears "spooky" precisely because it evidently skips over the conventional requirement embraced by Einstein that, in the continuum, the spread of influence is limited to forces that operate locally. Given the paradox that Einstein, Podolsky, and Rosen uncovered with their thought experiment (the EPR paradox), and given their implicit commitment to the assumption of locality and its underlying principle of continuity, they reached the conclusion that quantum theory must be incomplete, that it had neglected local hidden variables that when identified and incorporated into the theory, would dispel the strange non-locality predicted by quantum mechanics and would restore the continuity of space.

Amid continuing doubts created by the EPR paradox, physicists grappled for almost 30 years with the question of whether a local hidden-variables approach could be used to complete quantum mechanics in a way that would make it less "spooky." It was physicist John S. Bell who paved the way for the issue to be resolved. Carrying forward the 1935 proposal of Einstein and his colleagues, Bell (1964) offered a theorem that amounted to the following: If entangled particles are separated and their states measured independently, then, when it is assumed that the outcome of the measurements depend on local hidden variables, a constraint is placed on the extent to which those measurements can be correlated. The constraint is expressed in the mathematical inequality that Bell employed, which imposed an upper limit on the correlation. Quantum mechanics predicted that the degree of correlation between measurements would exceed this upper limit, thereby violating the inequality and confirming the odd non-locality of entangled particles.

In the years following the appearance of Bell's theorem, researchers have tested the proposition time and again and repeatedly observed its violation. Bell's own comment on this outcome is interesting: "For me, it is a pity that Einstein's idea doesn't work. The reasonable thing just doesn't work" (quoted in Bernstein, 1991). Three physicists in particular played a prominent role in independently confirming violations of Bell's theorem and, in 2022, they were rewarded for their research with the Nobel Prize. The Nobel committee gave the Prize to Alain Aspect, John F. Clauser, and Anton Zeilinger for "experiments with entangled photons… [that pioneered] quantum information science" (Royal Swedish Academy of Sciences press release, 2022).

The phenomenon of entanglement indeed plays a crucial role in the new quantum technology currently being developed. Here information is processed not in bits with the definite values of 0 or 1, but in quantum bits or qubits, units of information in which 0 and 1 are superposed. In experiments with quantum networks, the aim is to create an internet based on the closely related quantum principles of superposition and entanglement. The quantum computers associated with this enterprise rely on the entanglement of information wherein the superpositions of separate quantum systems merge in a manner allowing them to literally function as a single system. This permits information to be transmitted instantaneously between widely separated processors in a procedure known as "quantum teleportation." These and other technological advances attendant to quantum entanglement are highly impressive. However, the present book is less focused on detailing the technical innovations arising from entanglement than on clarifying its psychological, social, and philosophical implications. To begin moving toward that end, I will offer several models of entanglement.

2. MODELING QUANTUM ENTANGLEMENT

Let us begin with the figure from the psychology of perception studied in chapter 3: the Necker cube (see Figure 3.1). In a paper relating complex self-organizing systems to quantum processes, cyberneticist Frances Heylighen (2023) focuses on the phenomena of entanglement and symmetry breaking. At one point, Heylighen offers the Necker cube as an example of symmetry breaking in which the cube's perspectives are initially "entangled" (p. 100) and bear a non-local relationship to each other reminiscent of what is found in the quantum world.

A more detailed analysis of Necker cube entanglement is provided by Atmanspacher and Filk (2013). Necker cube dynamics are predicted by a formal mathematical model, the Necker-Zeno model, employing non-commutative operators akin to those found in quantum mechanics. The researchers give particular attention to the possibility of *temporal* entanglement in viewing the Necker cube. Whereas quantum physical entanglement generally entails non-local correlations between spatially separated particles, Atmanspacher and Filk (2013) use their model to predict corresponding non-local correlations of mental states with respect to time. More specifically, Atmanspacher and Filk (2013) suggest that in observing the perspectives of the Necker cube, a strictly classical time ordering of observations may be violated. This can mean that the perceptual jump from one perspective of the cube to the other may take place in such a way that we cannot actually say that the observation of one perspective occurs *before* the other—at least not in the classical sense of temporal sequence wherein an observation occurring at t_1, a single instant of classical time, is followed by a subsequent observation at t_2, an instant later. In this sense then, the classically sequential instants of time are related non-locally, are "entangled" in observing the Necker cube.

The idea that the perspectives of the Necker cube are temporally entangled brings to mind the perspectivally integrated way of viewing the cube discussed in chapter 3. There I demonstrated the possibility of viewing the cube's perspectives in a manner that is conventionally deemed impossible: neither simply at once nor one simply followed by the other, as in the ordinary, temporally broken manner of perceiving the cube's perspectives. What is apprehended instead is the dynamic merging and separating of perspectives (see Figure 3.2 and accompanying text). Inasmuch as this experience contravenes the linear temporal sequencing of classical perception, we can say that it entails temporal entanglement. We might even go so far as to say that the practice of perspectival integration provides the viewer with a direct experience of the temporal entanglement inferred by Atmanspacher and Filk (2013). Let me propose then that, while the ordinary way of viewing the cube relegates the temporal entanglement of perspectives to the background of awareness, perspectival integration gives the viewer a conscious glimpse of it.

My own approach to modeling quantum entanglement is less formal than Atmanspacher and Filk's (2013). In it, I expand on my Necker cube account, enhancing it by employing qualitative topology, as I did for quantum perception in chapter 3. To set the stage for this, I will describe a few more attempts at modeling entanglement via the Necker cube.

In chapter 3, we saw that a number of researchers have employed the Necker cube as a model of quantum superposition. As noted above, the phenomenon of entanglement is

closely related to that of superposition. Just as different quantum states of the same particle are said to be superposed on one another in the coherent quantum wave ("Schroedinger's cat" is both "alive and dead," in the famous illustration), the quantum states of two different particles are understood as superposed in the case of entangled particles; in effect, the superposed states of entangled particles constitute a single system. What we're presently finding is that the phenomenon of quantum entanglement can also be modeled by the cube. Physicist John F. Lindner thus asserts that the "single ambiguous Necker cube is a metaphor for quantum superposition, while a pair of ambiguous Necker cubes is a metaphor for quantum entanglement" (2015, para. 2). Physicist Chad Orzel echoes Lindner in viewing a "pair of Necker cubes as a metaphor for entanglement" (Orzel, 2018, para. 8). Decades earlier, the physicist Fred Alan Wolf (1981) had already employed the cube as a model of entanglement and he noted that for entanglement to occur, particles have to have been previously associated. Wolf illustrated this with a diagram showing how juxtaposed Necker cubes split off into separate but "correlated quantum cubes" (Wolf, 1981, p. 180). Although these efforts employ the Necker cube imaginatively as a metaphor for quantum entanglement, none provide a definitive model of how correlated quantum particles arise from a source in which the particles are initially associated.

Entangled photons can be produced in the laboratory by a process known as spontaneous parametric down-conversion (SPDC). Here a laser device is employed to send a single "mother" photon into a crystal (an inorganic compound with crystalline structure) where it can be converted into a pair of entangled "daughter" photons, each possessing lower energy than the "mother." In the case of SPMP, the previous association necessary in order for particles to become entangled is their common origin within the "mother" (see Figure 5.1). Can the Necker cube provide an effective model for this process?

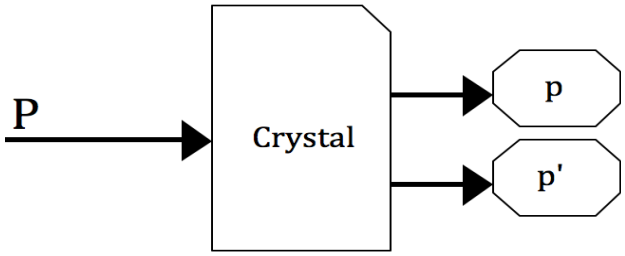

Figure 5.1: Through the process of Spontaneous Parametric Down-Conversion (SPDC), a single photon (P) is sent into a crystal and converted into a pair of entangled daughter photons (p and p').

We may regard the single Necker cube as internally entangled. This self-entanglement is evident from what we have already seen: opposing perspectives of the cube are superposed upon each other in space and time. The question then becomes one of how the self-entanglement of the single cube, which we are taking as our model of the single photon, can be externalized in the form of an entangled photon pair, as happens with SPDC. What we are about to see is that the most effective modeling of this requires that we appeal to a higher-order counterpart of the cube.

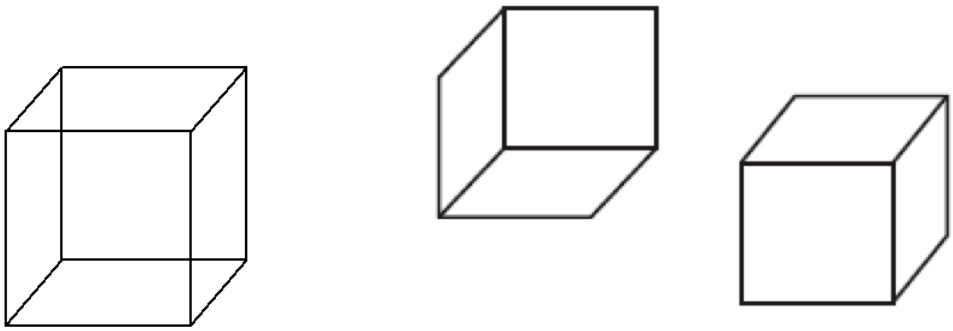

Figure 5.2. Division of Necker cube (left) into its constituent perspectives (right)

Figure 5.2 illustrates the division of the Necker cube into its constituent perspectives. The diagram is limited by the fact that we cannot actually perceive the separated aspects as entangled with each other; all that we can observe in the two-dimensional space to which the figure is confined is the disentanglement of the cube's perspectives, their initial superposition having been undone. Can the model be enhanced by making use of an added dimension?

To facilitate my modeling of quantum perception in chapter 3, I introduced the Klein bottle and explored its role as a higher-dimensional counterpart of the Necker cube. In that chapter, I also touched on the Moebius strip, an analogue of the Klein bottle. Both of these topological forms can be taken as higher-dimensional correlatives of the Necker cube. Presently, I will use the Moebius strip to better represent entanglement. What the Moebius model allows us readily to conceive is a structure that remains entangled even after being divided.

We know from chapter 3 that a primary characteristic of the Klein bottle is its one-sidedness, and that this property is mirrored in the perception of the Necker cube in which opposing sides are integrated. One-sidedness is a topological analogue of quantum superposition and, like the Klein bottle, the Moebius strip is one-sided: the two sides of the Moebius flow unbrokenly into each other to form a single side, without either side actually losing its distinctness. Therefore, were Schroedinger's "cat" situated on a Moebius strip whose opposing sides are taken as symbolic of life and death, we could only say that the "cat" would be both. In keeping with our understanding of the relationship between superposition and entanglement, we can say that the Moebius strip is self-entangled.

Let us examine the pattern of rotation on the Moebius (Figure 5.3(b)). To this end, it will be helpful to compare movement around the Moebius with rotation around a related structure, a two-sided cylindrical ring (Figure 5.3(a)). Both structures are simply fashioned by joining the ends of a narrow strip of paper, but, in the Moebius case, one end is twisted through an angle 180° before completing the union. If we begin circling the cylindrical ring from a point on one of its sides, after 360° of action we return to this point of origin without ever coming into contact with the other side. In the Moebius case it is different. While 360° of rotation *seem* to bring us back to our point of departure, a second look will disclose that we have in fact only been carried to the corresponding point on the opposite side of the surface. An additional 360° of rotation are required to arrive at the place from which we began. Moebius rotation thus entails traversing a double loop of 720°.

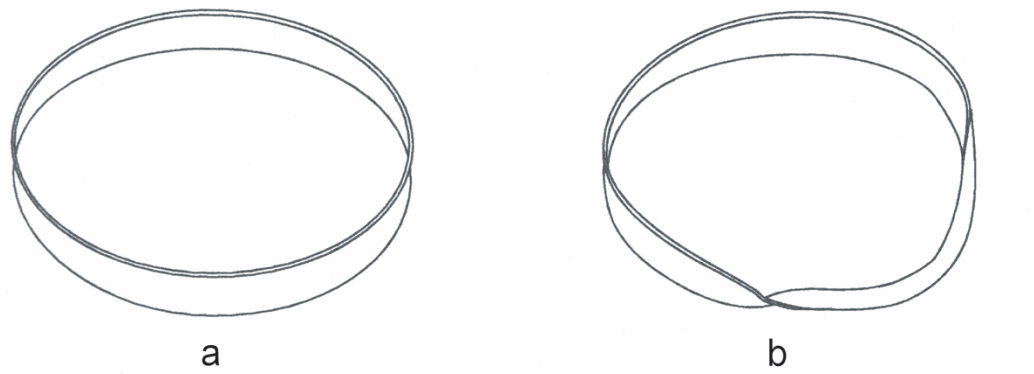

Figure 5.3. Cylindrical ring (a) and Moebius strip (b)

Now, what happens when we divide the Moebius strip along its length? Mathematicians have investigated the transformations that result from dividing topological surfaces (e.g., Barr, 1964; Hilbert, 1952). Let us compare the effect of longitudinally bisecting the Moebius with the same operation on the cylindrical ring. If we cut the ring down the middle proceeding along its full length, upon completing the 360° cut, the ring will simply break apart, falling into detached but identical narrower rings each possessing the same topological structure as the original. A more interesting result is obtained in bisecting the one-sided Moebius strip. Rather than falling into separate pieces as one might expect, the bisected surface retains its integrity but has now become the *two*-sided structure depicted in Figure 5.4.

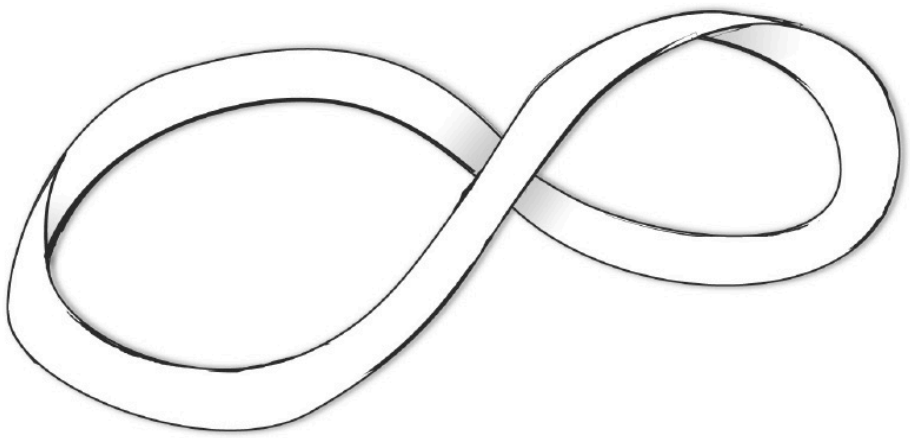

Figure 5.4. The bisected Moebius strip, also known as the lemniscate

Contrast a single side of the bisected Moebius strip (Figure 5.4) with a side of the cylindrical ring. Whereas revolution about the latter describes but one closed loop, traversal of the former gives us a doubly-looped, figure-8 pattern known in mathematics as a *lemniscate* (turned on its side, the lemniscatory surface resembles the familiar sign for infinity, ∞). The two patterns of movement are schematically contrasted in Figure 5.5.

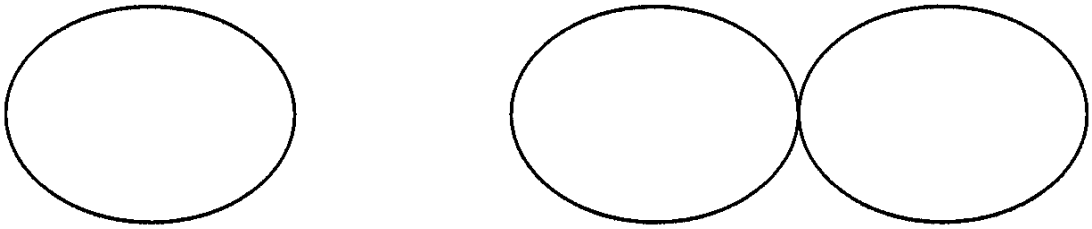

Figure 5.5. Schematic comparison of cylindrical rotation (left) and lemniscatory rotation (right)

What we find with the lemniscate is a 720° double circulation akin to what is observed with the intact Moebius strip (Figure 5.3(b)). When bisection of the Moebius transforms this paradoxical one-sided surface into a *two*-sided surface, its original integrity is lost. Yet these two sides mirror each other, each one following the lemniscatory pattern that constitutes its own order of paradoxical "unity-in-diversity." That is, on each side of the lemniscate, we have the 720° double cycle, these cycles being connected by a continuous movement through the central node of the figure-8. It is true that, with the lemniscate, there is no longer a complete overlapping of opposing sides, as there is in the Moebius case. The lemniscate thus could be said to have less internal cohesion than the Moebius. Be that as it may, a similar pattern of "transpolar flow" is evident in both structures.

Comparing the divided Moebius with the divided Necker cube, we notice a parallel phenomenon. Figure 5.2 illustrates the division of the cube into its constituent perspectives. If you focus your attention on either of the two single perspectives of the cube displayed on the right-hand side of the diagram, you should soon notice its orientation flipping from a perceptual form that seems to be concave to one that appears convex (or vice versa). Each separate perspective of the cube thus contains within itself an ambiguity comparable to the ambiguity of the original cube but one that is simpler, possessing less information. Therefore, in dividing the cube, in teasing apart its perspectives, they now appear as sub-cubes, each with its own superposed sub-perspectives. In like manner, the divided Moebius surface can be said to consist of "sub-Moebius" forms that mirror the mother structure from which they derive.

Now we can see more clearly why the Moebius strip serves as a better model of photon entanglement than does the Necker cube. For, when the self-entangled Moebius form is divided into its lemniscatory sub-forms, these sub-structures are not just detached from one another as are the divided perspectives of the Necker cube shown in Figure 5.2; instead, they are entangled as opposing sides of the very same super-structure (Figure 5.4). Of course, in making the transition from the self-entangled Moebius to the external entanglement of the sub-Moebial circulations positioned on separate sides of the lemniscate, a degree of entanglement is lost. The lemniscate does possess two discrete sides and these sides are not as intimately connected as are the sides of the one-sided, self-entangled Moebius. What all this points to is that, if the Moebius strip is taken as representing the photon, then the bisection of the Moebius into the two-sided lemniscate effectively models SPDC, the process whereby a photon is split into a pair of entangled daughter photons. In the model, the daughter photons correspond to the 720° circulations on the separate sides of the lemniscate.

Now, in chapter 3, I brought out a fundamental limitation of the Necker cube as regards its ability to give concrete expression to the photon. To reiterate: The cube appears in front of us as a macroscopic object embedded in the familiar two-dimensional space of the page. Clearly, the submicroscopic photon residing in a quantum dimension with the properties of Merleau-Pontean depth is no such object in space. So, while the perceptual fusion of Necker cube sides surely can be taken as modeling the depth-dimensional fusion of subject and object in an ontologically interpreted quantum world, it does not deliver that fusion in a tangible way.

We must come to the same conclusion with respect to the Moebius strip. Although the one-sided Moebius can indeed *symbolize* the quantum fusion of subject and object, like the Necker cube, the Moebius strip per se is but an object in classical space, as noted in chapter 3. What I showed in that chapter is that, although the Moebius can be contained as an object in our space of three dimensions, the Klein bottle requires a *fourth* dimension for its full expression, and that "fourth" dimension is the dimension of ontological depth. It is therefore the Klein bottle that we require in order to completely deliver the ontological phenomenon of quantum entanglement.

We have seen what happens when we bisect the Moebius strip. What about bisecting the Klein bottle? A key feature of my earlier work is my observation of a topological bisection series that includes the two-sided lemniscate, the one-sided Moebius surface, and the one-sided Klein bottle (see Rosen, 2006, 2008). These three forms are nested within each other such that, while bisecting the Moebius yields the mirror-opposed circulations of the lemniscate, bisecting the Klein bottle produces mirror-opposed Moebius structures.

But we must take into account the "ontological difference" discussed in chapter 4: "Ontological inquiry is concerned primarily with *Being*; ontical inquiry is concerned primarily with *entities* and the facts about them" (Macquarrie and Robinson in Heidegger, 1927/1962, p. 31, n.3). Whereas bisecting the Moebius is an action performed upon an ontical object in three-dimensional space, bisecting the Klein bottle entails the ontological realm — the same realm inhabited by the photonic wave. It is in moving from ontological "Being" to ontical "beings" (as Levin [1985] put it), that subject and object are split apart and the paradigm of object-in-space-before-subject takes hold. This paradigm cannot be applied to the depth-dimensional Klein bottle and its ontological Moebius daughters.

The Klein bottle (named after the German mathematician Felix Klein) is truly a *klein* bottle ("klein" being the German word for "small"). What I have proposed in preceding chapters of this book and elsewhere (see Rosen, 2008) is that the actual depth-dimensional Klein bottle (as opposed to its macroscopic, ontical glass model) is an ontological phenomenon of the quantum domain. In bisecting this self-entangled Klein bottle, the resulting Moebius opposites are entangled in the most intimate way, sharing as they do the same superposition of subject and object constitutive of the Klein bottle from which they arise. To distinguish the members of this Moebius pair from the ordinary Moebius strip, we may regard the former as the ontological counterpart of the latter.[4] The conclusion then is that, if the Klein bottle is what we require to embody the photon, then the bisection of the Klein bottle yields Moebius daughters that tangibly embody the entangled photons

[4] The relationship between the Moebius pair and the ordinary Moebius strip, and the relationships among all members of the topological bisection series, are further elucidated in Rosen, 2006 and 2008.

resulting from SPDC. Thus the process of Spontaneous Parametric Down-Conversion may be topologically expressed as a bisection of the Klein bottle.

3. CAN PROPRIOCEPTIVE OBSERVERS OF ENTANGLED PHOTONS BECOME ENTANGLED WITH EACH OTHER? A PROPOSED EXPERIMENT

In this section, we turn to the question of what the phenomenon of quantum entanglement implies for the proprioceptive observation of photons discussed in chapter 4. The onto-phenomenological interpretation of the quantum world I have described arrives at the conclusion that "seeing" the photonic wave requires *being* it. What we have learned is that such "seeing" must go beyond the conventional mode of observation; it can no longer divide observer and observed but must bring them together proprioceptively. In extending this ontological understanding to the question of entanglement, we bear in mind what we found in the last section: entangled photons share their superpositions; these photons are actually not separate particles but constitute an indivisible whole. So, in effect, entangled photons function as the *same* photon. My essential proposition then is this: *proprioceptive observers of entangled photons, in "being" the photons they are observing, would "be" each other.* To explore this hypothesis, I am going to propose an experiment in which entangled photons are proprioceptively viewed by remote observers.

The entanglement-generating SPDC procedure has been used in many experiments with photons, and Holmes et al. (2018) proposed an entanglement experiment involving human observers. Ordinarily, entanglement research makes use of electronic single-photon detectors. But assuming that the human visual system can detect single photons, Holmes et al. suggested replacing one of the electronic detectors with a human observer as a way of demonstrating that our eyes are sensitive enough to permit us to participate directly in tests of quantum mechanics that confirm the reality of entanglement. Since my own hypothesis is concerned with the relationship between observers of the same pair of entangled photons, photon detection must be left exclusively to the human eye.

The experiment I propose will involve two groups. In the experimental group, participants will be trained to observe photons in the proprioceptive manner that allows them to gain a sense of their own act of observing. The training will make use of Burrow's procedure of "relaxing the eyes and … getting the kinesthetic 'feel' of the tensions in and about the eyes and in the cephalic area generally" (1953, p. 95). Participants in the control group will receive no special training. For these observers, the assumption will be that they are operating in the default posture of viewing the photons transmitted to them simply as objects appearing out in front of them, objects from which they are detached. (Note that the proprioceptive training procedure just described and the procedures outlined below will be further refined in a pilot study once the experiment actually gets underway.)

Observers within each group will be paired off, with the members of each pair being sent to separate dark rooms to make their observations. Similar to an optometrist's method for testing optical functioning, observers will sit before a monitor with their heads steadied in a chin rest and one of their eyes fixed on crosshairs at the center of the screen. On each trial, an entangled photon pair will be created via SPDC and the members of the pair will be sent in different directions to the waiting observers (see Figure 5.6). The photons will arrive simultaneously at their destinations, having been directed either to the left or right side of each observer's eye, as randomly determined. A forced-choice method will be

employed (see Holmes, 2019; Tinsley et al., 2016) requiring the observer to say on each trial whether the photon appears on the right, on the left, or on both sides of her eye, even though photons are never actually sent to both sides.

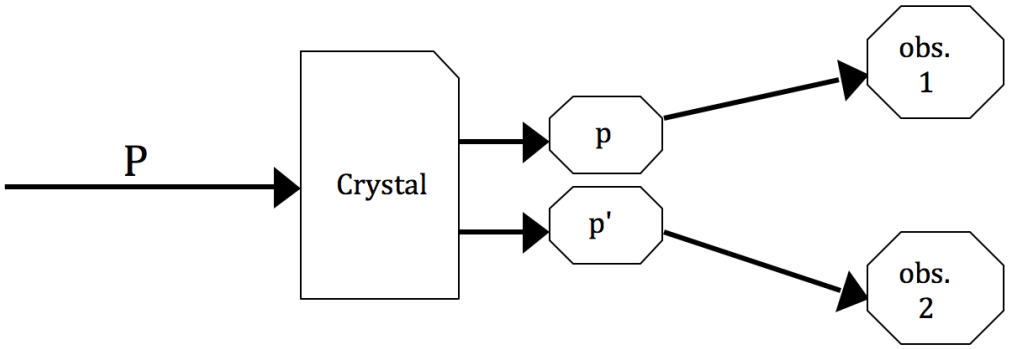

Figure 5.6: Set-up for observer entanglement experiment. Through the process of Spontaneous Parametric Down-Conversion, a single photon (P) is sent into a crystal and converted into a pair of entangled daughter photons (p and p'), which are then sent to separate observers (obs. 1 and obs. 2).

On the onto-phenomenological interpretation I have offered, the proprioceptive observer is ontologically identified with the photonic wave she is observing: instead of objectifying the photon, she *becomes* it. This leads to the proposition that paired proprioceivers of entangled photons, rather than functioning in a simply independent way, may become ontologically entangled with each other. It would then be possible that such observers, though well separated in space and out of contact with one another in the ordinary sense, could experience each other's optical perspectives as well as their own in viewing their respective photons.

With this in mind, consider a trial in which one photon is sent to the left side of a proprioceiver's eye and the partner photon is sent to the right side of the other proprioceiver's eye (see Figure 5.6).[5] In cases like this where entangled photons are sent to opposites sides of paired proprioceivers' eyes, the superposition of the proprioceivers' visual perspectives could bring them to choose the response option "both sides," despite the fact that photons have not been sent to both sides of either observer's eye. By contrast, the responses of the observers in the control group should largely be limited to "left" or "right," since these non-proprioceptive viewers would not be ontologically entangled and their observational perspectives therefore would not be superposed. The prediction then is that there will be a significantly greater number of "both" responses in the experimental group than in the control group. This is not to say that there will be no "both" responses at all in the control group. Such responses are far from impossible due to the tenuous nature of single-photon perception.

In the single-photon vision research of Holmes (2016, 2019), Holmes et al. (2018), and Tinsley (2016), photons do not appear to observers as solid, stable presences but are

[5] Note that even though only one eye is used in single-photon research, the binocular convergence response nevertheless occurs, with the unused eye still participating in the optical action (see Chirre, Prieto, and Artal, 2015). The persistence of binocular convergence can be expected, given that this automatic visual process is habitual and is deeply engrained in human physiology, originating in infancy (Horwood, 2018).

more ghostlike, often showing themselves as ephemeral flashes of light. Consequently, observers might not be entirely sure of the location of the photon they think they have seen and might even believe they have seen photons appearing on both sides of their eyes. As Holmes put it, "it's hard to be sure about such a tiny signal. Noise in the visual system — which can produce phantom flashes even in total darkness — also adds to the confusion" (Holmes, 2019, para. 10). For this reason, research on single-photon perception requires a great many trials in order to establish a statistically significant effect. It seems then that, in the experiment I am proposing, the "both sides" response could well be given in either the experimental group or the control group. Nevertheless, my hypothesis states that a significantly greater number of "both sides" responses will be found in the experimental group due to the superposition of proprioceivers' perspectives in that group.

We saw in chapter 1 a related limitation in experiments on single-photon vision. As Castelvecchi (2016) noted: "more than 90% of photons that enter the front of the eye never even reach a rod cell, because they are absorbed or reflected by other parts of the eye" (para. 7). It is the tenuous nature of single-photon perception in current research and the consequent requirement of large numbers of trials to confirm the statistical significance of weak effects that contributes to the wariness of some researchers to conclude that single photons can be seen at all, even though researchers like Holmes have been bullish on the prospect. Physiologist Kerry Kim (2021), for example, notes that while rod cells can *detect* single photons, the light the single photon generates is too weak for human beings to *notice* it (Kim, 2021, "Experiment" section, at 2:54 min.). Perhaps the lack of consensus on this issue is rooted in the subtlety of the distinction between physiological detection and cognitive recognition, a distinction that becomes especially elusive at the lower threshold of perceptual sensitivity. Still and all, while Holmes would agree that inferring single-photon perception from statistical analyses requiring large numbers of trials is far from ideal, she argues that "the data don't lie — if an observer is able to choose left or right with better than 50–50 accuracy and the effect is statistically significant, we know they must have been able to see the light (either that or they're psychic)" (Holmes, 2016, p. 30).

It seems clear that the investigation of observer entanglement I am suggesting would face the same kind of limitation that Holmes has faced. Could anything be done to mitigate the problem? Might it be possible to enhance an observer's perceptual capacity through some form of training that would allow the observer to see single photons more clearly and consistently?

In the introduction to chapter 4, I detailed the efforts of biophysical anthropologist William Bushell (2016) to address the issue. Bushell was optimistic about the prospect of meeting the challenge. He reported on research demonstrating that perceptual acuity can indeed be significantly enhanced by training and, in particular, that single-photon perception can be greatly improved. However, in commenting on Bushel, I also pointed out that such attempts at refining micro-perception have yet to be studied in a systematic way and they await further clarification and development. Moreover, for our purposes, the relationship of micro-perception to proprioceptive observation would have to be clarified and the proprioceptive training procedure itself would have to be refined, as I noted above. Much additional work would thus be required to overcome the limitations.

Nevertheless, let us keep in mind that the hypothesis of observer entanglement was not arrived at through casual speculation. The foundation for it was laid in the ontological analysis of proprioceptive quantum perception set forth in the previous chapter. In applying

that analysis to the phenomenon of quantum entanglement, we have been led to a plausible and rather remarkable proposition: if entangled photons function non-locally, essentially operating as the *same* photon; and if observers of these photons engage with them proprioceptively to become ontologically entangled with them; then these observers should become entangled with each other. Perhaps the impetus for developing the research methodology necessary to empirically confirm this supposition will come from understanding what the stakes might be. Contemporary society is heading into an era of quantum computing and a quantum internet that may well transform our culture dramatically. The phenomenon of observer entanglement could play a pivotal role in this. In the two final chapters, I will explore what that role might be. My hope is that this exploration of what may be possible will serve to motivate the research effort needed in order to corroborate the authenticity of observer entanglement.

Chapter 6

THE QUANTUM INTERNET: PRECURSORS AND SOCIAL IMPLICATIONS

1. INTRODUCTION

The entanglement discussed in the previous chapter involves entangling only two particles. But it is possible to entangle larger numbers of particles and much research has been focused on that. In the Netherlands, Hermans et al. (2022) have succeeded in entangling three particles, and successful multiple particle entanglement experiments have been carried out in Brazil (Marcio M. Cunha et al., 2019), China (Liang Huang et al., 2022), and elsewhere. Multiparticle entanglement initiatives are cropping up around the world, projects that are engaged in developing quantum networks that permit information to be "teleported," transferred from one network node to another in non-local fashion. As these efforts progress, the networks are becoming larger, with greater numbers of entanglement nodes and greater distances between them. Wehner, Elkouss, and Hanson (2018) demonstrated in depth how these activities prefigure the generation of a quantum internet that will eventually span the globe.

Bearing in mind the possibility of *observer* entanglement suggested by my proposed experiment, in this chapter and the next we are going to consider the implications for society of a worldwide quantum internet. To better understand this important new medium, I offer in the present chapter a detailed examination of its main precursors. Following media theorist Marshall McLuhan, we will see that "the medium is the message" (1964, p. 23). It is true that media such as movies, radio, and television are means of transmitting information, but beyond the particular content sent though a given medium, the medium itself can have a profound influence on society, culture, and the human psyche. "'The medium is the message'" says McLuhan, "because it is the medium that shapes and controls the scale and form of human association and action" (p. 24).[6]

In examining the precursors of the quantum medium, our point of departure is the print medium that came to prominence at the time of the European Renaissance. We consider how this form of communication later began to be undercut with the dawning of the electronic age in the middle of the nineteenth century. What will become clear as we proceed is that advances in electronic technology, in challenging the old paradigm of object-in-space-before-subject, have paved the way for the quantum medium. Indeed, these electronic innovations at bottom are governed by quantum principles that determine the behavior of electrons and other subatomic particles. In the end, we will see that the contemporary emergence of quantum computing and the quantum internet in fact brings

[6]In an earlier book (Rosen, 2004), I discussed the evolution of media in a broad cultural and historical context dating back to the ancient Greek principle of the *apeiron*. This account included a description of the emergence of modernism and postmodernism from the classical worldview.

the electronic age to its culmination, for the quantum principles that underlie this era no longer operate merely implicitly but have now come to the fore and into their own in a medium that is expressly quantum.

2. THE PRINT MEDIUM IN THE MECHANICAL AGE

McLuhan illustrates the great power of media in his discussion of the print medium, a form of communication spearheaded by Johannes Gutenberg's fifteenth century invention of the printing press. Prior to the Renaissance, manuscripts were written by hand and quite variegated in appearance, each being one of a kind. The lettering of a medieval text could be rather ornate and lacking in uniformity, with unique variations in shape and color. The "illuminated" manuscripts of this time were often elaborately illustrated. Moreover, an oral intimacy prevailed in the cloistered, close-knit communities of the Middle Ages so that texts were seldom read in silence but read aloud for everyone to hear. McLuhan describes how all this changed with the advent of printing.

Gutenberg's printed text stood in sharp contrast to the form of writing that preceded it. With its standardized set of moveable types, the printing press could churn out uniformly structured lines of print composed of letters and words whose sequence could be altered at will to convey the meanings desired. Such manuscripts no longer featured decorative elaborations that could tangibly enhance the physical appearance of the text. What was important was the conveyance of abstract meaning. Documents thus created could readily be reproduced and identical texts could now easily be disseminated far and wide to silent readers at remote locations.

According to McLuhan, typography "made possible the spread of the power that is knowledge, and shattered the bonds of tribal man, thus exploding him into an agglomeration of individuals" (1964, p. 156). A little later, McLuhan similarly says, "The tribe, an extended form of a family of blood relatives, is exploded by print, and is replaced by an association of men homogenously trained to be individuals" (p. 161). A heightened sense of individuality is of course a central feature of the European Renaissance and McLuhan sees the advent of print as playing a critical role in this cultural movement. He cites other key features of the Renaissance and their relation to print:

> Psychically, the printed book, an extension of the visual faculty, intensified perspective and the fixed point of view. Associated with the visual stress on point of view and the vanishing point that provides the illusion of perspective there comes another illusion that space is visual, uniform and continuous. The linearity, precision, and uniformity of the arrangement of movable types are inseparable from these great cultural forms and innovations of Renaissance experience. The new intensity of visual stress and private point of view in the first century of printing were united to the means of self-expression made possible by the typographic extension of man. (1964, p. 157)

McLuhan goes on to say that the "uniformity and repeatability of print permeated the Renaissance with the idea of time and space as continuous measurable quantities" (p. 160).

In McLuhan's account of some of the main characteristics of the Renaissance, you may recognize the realist paradigm of object-in-space-before-subject we have examined in this book. Here the individual being is a subject who, having become detached from other beings, now views them as objects appearing before him in a spatial continuum. An exemplar of this is the post-Renaissance scientist, an individual bent on making observations that depend for their precision on the continuity of the space in which they are made and on the "detachment and noninvolvement" (McLuhan, 1964, p. 157) of the observer.

Now, McLuhan asserts that the "printed book based on typographic uniformity and repeatability in the visual order was the first teaching machine, just as typography was the first mechanization of a handicraft" (1964, p. 159). Essentially, a machine is a device composed of separate parts to which power is applied (from a power source or engine) in order to induce a transfer of energy from one part to another so as to achieve a utilitarian end. Here the flow of energy is sequential in time and continuous in space. McLuhan frequently refers to the period of Western history following the Renaissance as the "mechanical age." Added to this is David Bohm's (1980) observation that the mechanistic order of influence is one in which entities "interact through forces that do not bring about any changes in their essential natures ... [they interact] only through some kind of external contact" (p. 173). Mechanical interactions can thus be said to be superficial. They are limited to surface exchanges rather than "involvement in depth" (McLuhan, 1964, p. 25).

3. PHOTOGRAPHY

McLuhan notes that the mechanical medium of typography and related media prevailed in Western culture until the nineteenth century, at which time a revolutionary new medium emerged, one that has had a profound impact on psyche and society. According to McLuhan, "the step from the age of Typographic Man to the age of Graphic Man was taken with the invention of photography." The advent of this medium was "decisive in making the break between mere mechanical industrialism and the graphic age of electronic man" (1964, p. 171).

The photograph makes use of an emulsion, a chemical preparation that, when applied to a strip of plastic or other flexible material, captures a phenomenon that is not mechanical but one that is ultimately governed by quantum principles. I am of course speaking of light, a form of electromagnetic radiation we explored in depth in previous chapters. The light waves reflected from an object onto the emulsion are fixed in the light-sensitive medium and a permanent image of the object appears on the film.

In McLuhan's view, photography has challenged mechanistic culture in two critical ways: it has upended the mechanical experience of space and time, and it has countered the posture of "detachment and noninvolvement" by bringing about an opposing tendency toward "involvement in depth" (McLuhan, 1964, p. 25). How is McLuhan thinking about the effect of photography on classical space? The photograph "wipes out our national frontiers and cultural barriers" (p. 177). To be able to sit in New York or Vancouver and view photographs of people in Buenos Aires or Nairobi contracts the physical and cultural space that once widely separated us from these people. In this way, photography "involves us in *The Family of Man*, regardless of any particular point of view" (p.177). In mentioning "point

of view," McLuhan is reminding us of the Renaissance use of perspective in art, which ties in with the classical experience of space. It is this experience that the photograph subverts.

How does the photograph undermine the classical sense of time? It does this "by creating a world of accelerated transience" (p. 176), says McLuhan. Popular culture is saturated with photographic images and McLuhan gives examples of the impact of this on temporal experience:

> If we open a 1938 copy of Life, the pictures or postures then seen as normal now give a sharper sense of remote time than do objects of real antiquity. Small children now attach the phrase "the olden days" to yesterday's hats and overshoes, so keenly are they attuned to the abrupt seasonal changes of visual posture in the world of fashions. But the basic experience here is one that most people feel for yesterday's newspaper…. nothing could be more drastically out of fashion. Jazz musicians express their distaste for recorded jazz by saying, "It is as stale as yesterday's newspaper." (1964, p. 176)

Let us go more deeply into the effect of photography on the experience of time. Before the photograph, if one sought to capture one's perceptions of the external, three-dimensionally experienced world on a two-dimensional surface, the process would "take time." That is to say, the act of reproducing objective reality necessarily would unfold over a substantial duration. In creating a painting for example, the artist typically would begin by making a charcoal drawing to produce a preliminary sketch. Then the pigments would be gathered and the paints mixed to prepare for the lengthy process of applying the brush through painstaking acts of accretion over a period of days, weeks, months, or longer.

With the photograph, the reproduction of the object literally occurs in a flash, in the fleeting instant required for the capturing of light. The subjective time sense of the photographer therefore is markedly different from that of the classical artist. True, the serious photographer may require an extensive period to *set up* a photograph. But the act of taking the photograph, considered in itself, implies a sense of time that was entirely new in the middle of the nineteenth century. The continuous flow from the past into the future that had characterized earlier temporal experience was ruptured by a decontextualizing perception of instantaneous leaping—a kind of "quantum leaping," we might say. Thus McLuhan could speak of photography's ability "to abolish time" (1964, p. 176).

Berger and Mohr (1982) elaborate on this, demonstrating that photography brings a sense of temporal discontinuity not only to the reproductive process, but to the resulting product as well (just as artistic works created in classical time bear the mark of past-to-future flow in their texture, unevenness, etc.):

> A photograph arrests the flow of time in which the event photographed once existed. All photographs are of the past [like all drawings and paintings], yet in them an instant of the past is arrested so that, unlike a lived past, it can never lead to the present. Every photograph presents us with two messages: a message concerning the event photographed and another concerning a shock of discontinuity. [1982, p. 86] …. An instant photographed can only acquire meaning insofar as the viewer can read into it a duration extending beyond itself. When we find a photograph meaningful, we are lending it a past and a future. (1982, p. 89)

In short, the non-mechanical, instantaneous flash that produces the "snapshot" (the chemically fixed record of an electromagnetic event) shatters the classical sense of temporal duration.

The level of commitment to the mechanical worldview should not be underestimated. That paradigm not only shaped a person's sense of space and time but also, one's core sense of identity as a separate individual detached from others and from nature at large. Given the challenge to classical ego autonomy posed by involvement in what McLuhan (1964) called "*The Family of Man*" (p. 177) or the electronic "global village" (p. 93), it is understandable that the emerging electronic revolution could not be fully accepted on its own terms. The implicit threat to the autonomous ego and its experience of space and time has been met with implicit countermeasures. By an artful cooptation of the new electronic medium, the old paradigm has been tacitly maintained.

4. CINEMA

Consider the transition from the photograph to cinema. The basic principle of the movie is simple and well known: an event is recorded by a series of still shots, each member of which, considered by itself, entails the photographic "shock of discontinuity" spoken of by Berger and Mohr. The shots are then exposed to the viewer in a mechanical sequence that is rapid enough to convey the impression of motion, a time-directed movement from past to future that reconstructs the event within a durational context in which the disjointed jumping from photograph to photograph is concealed. The "shock of discontinuity" inherent in the individual photograph is banished and the experience of a smoothly continuous flowing of time is restored.

Thus, when the mechanical order was challenged by the instantaneity of electromagnetism, the response was the invention of a whole new medium, the hybrid medium of the movie, described by McLuhan as "a spectacular wedding of the old mechanical technology and the new electric world" (1964, p. 249). McLuhan contends that film technology did much to "continue" and "surpass" the purely mechanical book technology (p. 255), that it "pushed this mechanism to the utmost mechanical verge and beyond" (p. 254), that cinema "was, as a form, the final fulfillment of the great potential of typographic fragmentation" (p. 257). The fundamental basis for the success of cinema is essentially that, while effectively accommodating itself to the electromagnetic revolution on one level, on another it managed to uphold the classical sense of reality, to preserve a semblance of the post-Renaissance ego's way of experiencing space and time. But I must stress that, while the cinematic medium maintains duration amidst electromagnetic instantaneity, it does so in an altered, abstracted form. Behind the simulated appearance of durational flow in the "reel world" (as McLuhan ironically calls it) there is but a compilation of frozen instants, a discontinuous series of durationless "nows." So it is not surprising that, to this day, we refer to the cinema as "the flicks": at bottom the movie is "a jerky mechanical ballet of flicks" (McLuhan, 1964, p. 254).

Perhaps most essentially, the gap in the continuum that cinema sought to fill was the psychic gap created at mid-nineteenth century when the autonomy of the classical ego was shaken by the arrival of the electronic age. Hollywood softened the shock by offering the classical ego a stopgap for its lost self-certainty: egoistic dreams of triumph; an endless

variety of "success stories"; countless tales of egos on the ascent with whom viewers vicariously could identify—egos that, if not transcendent in victory, were transcendent in defeat. Whatever the specific content of these films, the fundamental "triumph" of the egos they portrayed lay in the magical metamorphosis inherent to the medium: the transformation of the finitized, mortalized, hole-ridden nineteenth century individual into an abstract image of infinity, immortality, and wholeness. "The medium is the message" says McLuhan, and the essential message of the cinematic medium is that continuity can arise from discontinuity "without a flicker." According to McLuhan then, the cinema is a world of "canned dreams...an inward world of fantasy [in which the viewer]...sits in psychological solitude" (McLuhan, 1964, p. 255), "a sheer dream world of romantic illusions" (p. 254).

Nevertheless, the ego-inflating message of the cinema eventually started to wear thin. Two catastrophic events in particular contributed to bursting the cinematic bubble of romantic illusions. The incineration of millions by the Nazis during World War Two and the dropping of the atomic bomb on Japan at the end of that war gave dramatic testimony to the folly of the overblown ego. Exhausted and disillusioned, the now deflated ego dropped into a lower-key, darker mood, and the anti-hero replaced the hero in the theaters (think of movie characters played by actors like Humphrey Bogart, Marlon Brando, and James Dean). As this was happening, the proliferation of a new medium began to eclipse the cinema. I am speaking of television.

5. TELEVISION

TV's basic operating principles are not difficult to describe. The television camera contains a photosensitive surface upon which light reflected from the televised event continuously falls. Unlike the photographic plate wherein light waves are chemically fixed, the photosensitive TV plate is rapidly scanned by a moving beam of particles shot from an electron gun. Light waves are thus broken down into discrete electronic impulses, which are then transmitted over a distance via radio waves in the old broadcast TV, or wire in cable TV. At the receiving end, the electronic impulses are projected onto a luminescent screen upon which the original images are reconstructed in the process of viewing. So watching TV is an act of reconstructing deconstructed images from moment to moment, rendering continuous that which, an instant before, had been rendered discrete; each instant, the viewer must "put humpty dumpty back together again." Or in the words of McLuhan, "The TV image is not a *still* shot. It is not a photo…but a ceaselessly forming contour of things limned by the scanning-finger" (1964, p. 272).

To bring out the essential character of television, let me further refine what I said about photography. The image that results from trapping light waves in a chemical emulsion is flattened and time-discontinuous when compared to the perspectival drawing or painting of the mechanical age. Yet, compared with the television image, the leveling of perspective and interruption of time involved in photography is actually less complete. This distinction is implicit in McLuhan's comment that, whereas "film and photo…have a built-in angle of vision…the third dimension is alien to TV….[T]he TV image…is a [completely] flat two-dimensional mosaic" (1964, p. 273). Why does photography not flatten perspective and freeze the flow of time as completely as TV? Although the introduction of the former technique did mark the transition from the mechanical to the electronic age, photography is

not purely electronic but also involves chemistry. As a chemical recording of light waves, the photographic flash is a supra-atomic event entailing the molecular bonding of atoms. What is required for a more complete perspectival collapse and an even greater loss of temporal continuity, is the utterly discontinuous leaping of subatomic particles—as in fact is found in TV. Since photography stops short of this, a modicum of information is retained that is relevant to temporal flow. When light waves are fixed by chemicals and therefore not reduced to the informationless uniformity of microscopic particles, they preserve macroscopic relationships that permit some inferences to be made concerning angle, distance, and depth. More specifically, the photograph maintains a modest sense of the differences in the distances over which light was reflected from the various planes of the photographed object, and this conveys a sense of non-simultaneity, temporal differentiation—though a far weaker one than in the drawing or painting, to be sure.

It is in television, the purely electronic medium, that the freezing of classical time reaches fuller consummation. TV is thus a most ambiguous medium, one that "offers little detail and a low degree of information, much like the cartoon" (McLuhan, 1964, p. 273). With television, the gradations of classical experience—the textures, qualities, nuances, and meanings—are all greatly degraded. Quality is replaced by sheer quantity, empty repetition. This is the "message" behind the incessant electronic jumping of the "scanning-finger" from dot to dot across the luminescent screen.

The "message" was not as clear in the early days of television as it presently is. Superficially at least, TV can, after all, play the cinematic role of creating the illusion of durational flow (though the discerning eye will recognize that it does so in a strained, cartoon-like fashion). In its formative period, under the lingering influence of the medium it was succeeding, television did effect a "filmic" approach, miming the pseudo-continuities of the silver screen. Today this is no longer true. Today, television largely has "come into its own." What this means is that the medium, more and more, has become the message in a transparent way, that the content and form of the TV images presented to the viewer are coming to fully and openly reflect the "deep structure" of this medium, the underlying principle of radical discontinuity upon which it operates.

The fragmented pulse of contemporary television is so pervasive it hardly needs to be documented. The subliminal leaping of electrons constituting the fundamental event of the medium has been raised above the threshold of awareness, mirrored in the frenzied kaleidoscope of juxtaposed, overlapped images flooding the senses of viewers in too many programs to name. With abstracted movement as such gaining precedence over the concretely meaningful contents among which the movement occurs, ambiguity reaches a maximum. Consider a prime example of this: the programming of MTV (the Music Television Network). MTV gained its fame with music videos, discrete visual pieces of brief duration (normally not more than several minutes), each of which itself is highly fragmented into shots enduring for fractions of seconds. Little coherent relationship exists between these disjointed images—at least not by the old, literate standards of coherence that depend on syntactical continuity and discursive meaning. It is programming of this kind that prompted O. B. Hardison (1989, p. 178) to comment that television generally makes the discontinuities of Surrealist filmmakers like Jean Cocteau seem tame and old-fashioned.

6. THE DIGITAL COMPUTER

Let us now consider the groundbreaking medium that succeeded television. What we are going to see is that the digital computer goes even further than TV in bringing out the essence of the electronic age.

According to French philosopher Jacques Derrida, the programs that govern electronic computing entail a unique form of expression he calls "primary writing" (1976, p. 7) or "arche-writing" (pp. 56–57, 60, 68). Central to arche-writing is the idea of the *trace.* Derrida's translator explains that this "French word carries strong implications of track, footprint, imprint … [and therefore] presents itself as the mark of an anterior presence, origin, master" (Spivak, 1976, p. xv). It is clear though that the trace itself "cannot be a master-word" (p. xv), for it is only a surface effect. Derrida wants us to understand that arche-writing, lacking the solidity of the classical word, entails only the interplay of epiphenomenal traces. The traditional expectation is that primary causes underlie such secondary effects. For is it not intuitively obvious that, if a footprint is to be left, the anterior presence of a foot is required? Yes, this is surely a "self-evident truth" in the old way of thinking, but it is precisely such an intuition that Derrida calls into question. Accordingly, we are to grasp the play of traces in arche-writing as entailing aftereffects without antecedents. No "feet" precede these strange "footprints." Like the ghost of a being that was never alive, the trace is wholly ephemeral. Thought as a kind of pure play or "freeplay" (Derrida, cited by Spivak; 1976, p. xix), the game of the written trace is weightless, devoid of gravity (Derrida, 1976, p. 50). A principle of *levity* prevails here that brings to mind the smile of the Cheshire cat. Traces are bubbly, effervescent; they ceaselessly burst and reform in "mid-air." Nothing more sober lends ballast to this levity; there is nothing below the trace to provide it with a solid foundation; no sub-stantial presence to serve as its ground; no substratum to actualize its virtuality.

It is cybernetics that Derrida points to as a key example of the contemporary emergence of arche-writing, with its interplay of traces: "the entire field covered by the cybernetic *program* will be the field of [arche-]writing" (p. 9). Derrida explicitly associates cyberwriting with his notion of *différance*, the term he uses for the ceaseless movement of the trace: "This movement … is an emergence that makes the *grammè* [i.e., the minimal unit of written language] appear *as such*" (p. 84), which, for Derrida, means appearing in the form of the trace. (Note that I will use the term "cyberwriting" to cover both the writing of computer programs and computer writing such as I am presently engaged in, which depends on that programming.)

Speaking more generally, Derrida proceeds to tell us that computer innovations such as "electronic card-indexes and reading machines" (1976, p. 84) are currently breaking the hold of the old linear writing—writing that has been subordinated to the classical "ideal of continuous movement, straight or circular" (p. 86). The novel cybernetic writing is decidedly *non*linear; it is discontinuous or discrete (today we say *digital*); it is "pluri-dimensional" and thus is "not subjected to successivity, to the order of a logical time, or to the irreversible temporality of sound" (p. 85). Moreover, the "pluri-dimensional symbolic structure is not given within the category of the simultaneous. Simultaneity coordinates two absolute presents, two points or instants of presence, and it remains a linearist concept" (p. 85). Nevertheless, from Derrida's citation of André Leroi-Gourhan's prophetic

1965 anticipation of things to come, we can see that cyberwriting has its own kind of "simultaneity":

> "Scientific thought is…hampered by the necessity of drawing itself out in typographic channels and it is certain that if some procedure would permit the presentation of books in such a way that the materials of the different chapters are presented simultaneously in all their aspects, authors and their users would find a considerable advantage….A vast 'tape-library' with an electronic selection system will in the near future show pre-selected and instantaneously retrieved information." (1976, pp. 332–333)

The cyberspace "simultaneity" apprehended by Leroi-Gourhan must not be confused with that of *classical* space. Instead of constituting the actuality of what simply is co-present, it is a *potential* simultaneity, one in which information is not really "presented" (Leroi-Gourhan's questionable terminology notwithstanding), but is held in reserve for the *possibility* of presentation and use. This does not mean that the information reserve, while not being immediately present *to view*, is palpably present *elsewhere* in the computer; that, in this tangible form, it lies "somewhere inside the machine" just waiting to be drawn upon. Let us try to understand better exactly what it does mean.

The current chapter is largely concerned with the historical transition from the mechanical age to the electronic age. Alternatively, we may describe our electronic epoch as the age of *information*. Whereas classical machines entail palpable operations upon matter and energy, computers involve the subtler activity of information. To illustrate the essential difference, let me compare the word processing that I now am doing with the production of words on a mechanical typewriter.

The old typewriter is fitted with a fixed set of type bars, each with its own alphabetic or numeric character. The typefaces are actuated by stroking keys on a keyboard composed of corresponding characters. If, for example, I press the key marked "n," mechanical energy is imparted to the associated type bar causing it to rise out of its housing and strike an inked ribbon secured over a blank sheet of paper that is held in place on a cylindrical platen. In this way, the metallic typeface, "n," is made to leave its trace on the page. What process produces the letters now appearing before me on this computer display?

The close resemblance of my computer keyboard to that of the mechanical typewriter is deceptive. When I tap the "n" key on my word processor, I do not initiate a mechanical operation wherein an already present typeface is *re*-presented, transferred to a blank surface. Instead, I send an electronic impulse to a microprocessor that, in itself, possesses no such preexisting actualization of the letter "n." What we find in the hardware of the computer, in the silicon chip in which the computer's operations are carried out, are not so much material actualities as *informational potentials*. Physicist David Bohm explains: "in a computer, the information in a particular chip has a wide range of virtual or potential activities to which it may give rise. Only some of these are actualized in the activity of the computer as a whole, in a way determined by the overall context of the entire structure of the computer and by all the information that has been put into it" (1986, p. 125). According to Bohm, information is defined as "a *form* that literally 'informs' (i.e., forms from within) an 'unformed' energy to give rise to a corresponding determinate activity" (p. 126). And with respect to *computer* information, "the form in the state of the silicon chips enters into

the energy in the computer to 'give shape' to a corresponding activity" (p. 126). The chip is composed of a large array of tiny transistor switches each of which constitutes a basic unit (or "bit") of information in that it can answer the simple question of whether the switch is on or off, one or zero (more exactly, whether or not voltage is applied to the silicon diode in such a way that the flow of electrons is permitted). When I give the chip input by pressing the buttons on my keyboard, it responds to me by "flipping switches," choosing zeroes and ones, in accordance with the way it has been programmed. In the specific example, when I type the letter "n," the microchip creates a particular binary pattern of zeroes and ones as per the instructions it receives from the word processing program that I am using. It then transforms this pattern into a recognizable output that appears on the monitor as a visual display: "n." In this way, informational potential is actualized, activity is shaped that leads to the creation of meaning. Thus, whereas mechanical typewriting entails the transfer of an *already* actualized pattern of matter-energy (the typefaces) from one location in space to another (from the bank of type bars to the sheet of paper), electronic word processing involves an actualization *in-the-making* whereby a pattern of matter-energy is produced from an initially potential state, one in which the pattern does not yet exist. Since bits of information are not committed in advance to any particular combinatorial pattern, and since zeroes and ones can be combined in an indefinite variety of ways, meaning can be shaped in a highly flexible manner. For example, we are not limited to a fixed set of characters in word processing but can create any number of character sets and switch from one to another at the press of a button. The flexibility of word processing is greatly enhanced by the fact that the electronic meaning patterns appearing on the computer display are *virtual*. The patterns are not *fully* actualized until a final printout of hard copy is staged, and this permits the text to be sculpted in a far more fluid manner than is possible in typewriting or handwriting.

What it comes down to in Derrida's terms is that mechanical writing is governed by the "metaphysics of presence" (1976, p. 22) whereas cyberwriting is not. The typed or handwritten character is a squiggle of ink or graphite that functions as a substantive reality. Matter concretized in this fashion is certainly not immutable; it can be altered in a variety of ways via exchanges of energy. Nevertheless, the metaphysics of presence is enforced here by the first law of thermodynamics, which tells us that—however matter-energy might be continuously transformed—it cannot simply *vanish* from the space-time continuum; it can neither be destroyed nor created, we are told. Accordingly, the printed mark—as a material presence fixed upon the writing surface by the chemicals in its ink or graphite—cannot be eradicated without at least leaving some *trace*. This trace—say, in the form of a faint darkening of the page where a letter was erased, or a slight unevenness of the surface where correction fluid was applied, or perhaps in a form so subtle that a microscope would be required to detect it—attests to the fact that, although the sign has indeed been transformed in the attempt to erase it, it never completely disappears from the page.

But would the printed mark really need to be annihilated from space-time in order for it to be removed from the writing surface without a trace? In mechanical writing, the initial inscription of the sign is obviously no creation *ex nihilo*; it is a transfer of energy from a preexistent source (typeface, pen, pencil, etc.). Therefore, even if the first law of thermodynamics cannot be violated by destroying the printed mark altogether, could the mark not at least be transformed in such a way that it would revert to the form of energy in which it existed prior to the act of inscription? Would not such a reversal effectively remove

all traces of the inscription that had appeared on the writing surface? This is where the *second* law of thermodynamics enters the picture. According to the principle of entropy, the transformation of matter-energy from one state to another in fact *cannot* entirely be reversed. For instance, in burning a lump of coal, potential energy is converted into kinetic energy in such a way that an irreducible residue is left; the ashen byproduct of the transaction bears witness to the fact that the potential originally contained in the coal cannot be restored. In a similar way, once a sign is hard-printed onto a page, there is no going back to the state of affairs that existed prior to the inscription. This inability to totally reverse the engravement process affirms the "gravity" of such writing. Because mechanical writing bears the weight of substantival presence, the traces it leaves cannot fully be effaced.

It is evidently not like that with cyberwriting. Here inscriptions seem readily reversible; traces can be destroyed and created with equanimity in the virtual spaces of the cyberworld, for, as Derrida has intimated, the traces we work with are of presences that "never were."

The "free play" of the cyberwritten trace is reminiscent of the play of electrons that underlies the medium of television, as described above. Both TV and digital computing entail electronic activities that belie the apparent solidity of classical substance. Yet the computer goes even further toward bringing the electronic age to culmination. The technology of traditional television[7] operates in an essentially passive way: it cannot create content but can only transmit to TV receivers content that has been created by other means. It is through the computer that content can be electronically generated, arising from the potentialities of the silicon chip. If TV brings us closer to the "global village" of which McLuhan spoke by enhancing the depth and power of communication across the planet, the remarkable interactive capacity of the networked computer carries us considerably further. We see this with the medium currently so dominant in our everyday lives: the internet. Here television's passive transmission and reception of information has become an active sharing and cooperative shaping of information all around the world.

7. QUANTUM COMPUTING, THE QUANTUM INTERNET, AND THEIR SOCIAL IMPLICATIONS

What about the *quantum* computer? The parallel between cybernetics and quantum physics is brought out by Bohm (1986), who develops at length the analogy between the information potential inherent in the computer chip and that which is contained in the quantum physical wave function. As with the silicon chip, "the wave function contains information implying a vast range of potential or virtual activities" (1986, p. 126). However, despite this similarity, there is a feature of standard computing that adheres to the classical approach. Conventional computers code information by means of a binary system of values: zero or one. These values are mutually exclusive; a bit of information can only be one or the other. It is the quantum computer that is required in order to bring computers into closest alignment with quantum reality, thereby fulfilling the promise of the electronic epoch.

In chapter 3, I employed the Necker cube as a perceptual model of the quantum wave. There I presented a diagram (Figure 3.3) that illustrated the properties of the cube by comparing it with a square divided into two parts. That same diagram can now be used to

[7] The newest generation of televisions features "smart TVs," which have computer capabilities built into them.

contrast the binary feature of the conventional computer, its informational bit, with the qubit of the quantum computer.

In our repurposed illustration, each rectangular part of the square (see Figure 3.3, left) occupies just half of the square's total area. Picturing 0 in one rectangle and 1 in the other gives us a simple representation of the old either-or Boolean logic of the computer bit. The relationship between the parts of the square shares the property of the mechanical relationship discussed above, where parts interact in an external way and affect each other only superficially. This is made obvious in Figure 3.3 by noting that you can erase one of the square's constituent rectangles without affecting the other. Comparing this with the relationship between the perspectives of the Necker cube (Figure 3.3, right), we see that each one encompasses the entire configuration in expressing itself so that erasing one perspective erases the whole. If the parts of the divided square are related in the binary manner of classical computer bits, then the connection between Necker cube perspectives can be taken as representing the superposition of bits in the qubit. Indeed, in modeling the quantum wave in chapter 3, the cube did model its property of superposition.

It is the quantum medium that sends the strongest message of the electronic era, for it challenges most directly the paradigm underlying the mechanical order: object-in-space-and-time-before-subject. In entering the quantum domain, classical space, time, and subject-object separation are fully and tangibly called into question.

Above we saw that photography, film, television, and conventional computing are all electronic media that depart from the old order in their own ways, but have their limitations as well. Despite its "shock of discontinuity," the photograph still subtly hints at classical time flow. Movies, for their part, display photographic stills in rapid succession and in so doing, restore mechanically a certain superficial sense of pre-photographic temporal sequence. Television has brought the world into our homes as never before thus shrinking the space that had kept us apart, but it has achieved this in a passive fashion that has made contact with each other merely indirect. Only with the computer has it become possible for us to interact directly and almost instantaneously over distances that span the globe. And yet, because of its pre-quantum binary system of coding, conventional computing falls short of fully surpassing classical space and time, and the accompanying separation of subject and object (or of I and other). Space may have been "shrunken" by TV and the internet in the sense of allowing far more rapid passage through it, but the electronic signals that make television and ordinary computing possible are still subject to the constraints of air waves and cables that adhere to classical space's local character. There is no "spooky action at a distance" here. The established paradigm's assumption of locality is violated only in the transition from the binary bit to the quantum bit that brings forth the phenomena of superposition, entanglement, and quantum teleportation.

What happens to time in the quantum realm? An indication was given in chapter 5 in relation to our Necker cube model of quantum entanglement. There I cited the research of Atmanspacher and Filk (2013), who considered the possibility of *temporal* entanglement in perceiving the Necker cube. If we view spatial entanglement as a non-local relationship between separate points in space allowing them to behave as if they are the same point, then we can describe temporal entanglement as a non-local relationship between separate instants of time permitting them to behave as if they are the same instant. In the example of the Necker cube, we normally appear to view its opposing perspectives in classical succession, first one then the other. But the perceptual quantum jump from one perspective

of the cube to the other may take place in such a way that we cannot actually say that the observation of one perspective occurs *before* the other. Therefore, what seemingly occurs in separate instants of time may be entangled; the instants may overlap one another in violation of their temporal distinctness. In chapter 5 I went on to propose that while the ordinary way of viewing the cube relegates the temporal entanglement of perspectives to the background of awareness, the perspectival integration of the cube (described in chapter 3) may give the viewer a conscious sense of it.

The third major tenet of the post-Renaissance mechanical paradigm noted above is the separation of subject and object, or, in terms of human relations, of I and other. This is reflected in the dissolution of close-knit medieval communities and the heightened sense of insular individuality that arose with the European Renaissance. McLuhan emphasized this when he spoke of the individual's "detachment and noninvolvement" (McLuhan, 1964, p. 157). No doubt our physical detachment from each other has been lessened in the contemporary world by electronic media, and especially by the internet, which has brought us into closer proximity than ever before. Yet despite our impressive technological advances, there is an important sense in which we remain apart. For many of us, our electronic closeness is coupled with a feeling of remoteness that lends itself to alienated and/or anonymous communication. Therefore, while intimate encounters certainly occur on today's internet, we may well ask whether this global electronic "community" is an adequate substitute for authentic community.

At bottom, what limits realization of the global village envisioned by McLuhan are the limitations of the non-quantum electronic media, constrained as they still are by the continued operation of the classical order. In the prevailing formula—object-in-space-and-time-before-subject—space, time, and subjectivity are packaged together in such a way that the post-Renaissance notions of spatial continuity and temporal succession are inseparable from the subject's maintenance of a detached posture with regard to the objects before him—"objects" that include other human subjects. If the onto-phenomenological interpretation of the quantum domain proposed in chapter 2 is accepted, establishing a genuine global village would require that the dominant paradigm be surpassed by crossing the threshold into the quantum domain in a decisive way. For, on this interpretation, it is in the quantum realm that the relationship between I and other entails an ontological fusion. Recall from chapter 4 the more-than-intimate connection between subject and object, observer and observed, in the quantum world. Here, to observe the photonic wave directly prior to its collapse, the observer would have to *be* that photon. What would it mean to say that, in the anticipated quantum global village, the internet community now largely governed by relatively superficial relations would be superseded by a social network whose members are linked ontologically? I will begin my attempt to answer this question substantively in the following chapter. In closing the present chapter, let me pave the way for that attempt by considering what is necessary for decisively crossing the quantum threshold.

To be sure, the quantum computer brings us into the quantum realm more fully than the conventional computer. But is the old paradigm truly being left behind with this transition? Is the expected use of the new quantum medium still not strongly influenced by the classical modus operandi?

Much has been written about the social implications of the quantum revolution. The clear consensus is that quantum computing promises to have an immense impact on

society. Though the novel medium is still in its infancy and it is hard to know the exact nature of this impact, there is little doubt that quantum computing will bring exponentially faster and significantly more accurate and efficient information processing than is now possible with classical informatics. This, in turn, will result in fundamental changes in the social fabric. According to Hollebeek, "The benefits of quantum computing will extend to all aspects of society. Quantum computing will quite literally change the world in various sectors including privacy, finance, health care, entertainment and technology" (2021, para. 1). Expectations of this sort are echoed in a recent article by an expert panel of the Forbes Technology Council (2023), and by Roundy (2023), both of whom enumerate the prospective revolutionary advantages of quantum computing, as well as its challenges. Investment priorities underscore how seriously these possibilities are being taken: "Governments and private entities have invested in both research and development of quantum computing …. The United States passed the National Quantum Initiative Act in 2018 with a budget of more than $1 billion" (Burr, Parakh, and Subramaniam, 2022) and "the Chinese government has said it is pumping more than $15.2 billion into quantum research" (Metz, 2024, para. 7). In December of 2024, considerable excitement was generated when Google unveiled its new quantum computer and was able to claim "quantum supremacy" in demonstrating that its device could perform tasks not possible with any conventional computer (Metz, 2024, para. 17).

However, while the lives of individuals may be transformed by the quantum revolution, as long as society continues to be based mainly on interactions among separate individuals or exclusionary communities pursuing their separate goals, no bona fide social revolution will have been achieved. Indeed, this separative way of operating simply continues the manner of relating that arose with the Renaissance. What then would be required for the full impact of the emergent quantum medium to be beneficially felt? I suggest that, in order to fully realize a quantum revolution for society, social relations themselves must be brought to function in a quantum way. Therefore, if my proposed solution of the quantum enigma is correct and the underlying quantum world is essentially a realm of intimate ontological relations (Rosen, 2004, 2008, 2015, 2021), so must be society.

This is a far cry from the way society generally operates today, with its alienating zero-sum games and devious manipulations. It is easy to see how the superior speed, accuracy, and efficiency of quantum computing could be used to serve the aims of self-interested exploitation, and the consequences of this would be disastrous. In the end, the technological breakthrough may actually bring about a societal breakdown. It seems then that to reap the social benefits of the quantum transformation, we must move beyond using quantum technology to support the self-centered and objectifying way of relating to others long dominant in our culture, and employ quantum computing in a manner that would facilitate an ontological entanglement with others. How could this be implemented?

I proffered in chapter 4 that, by changing one's mode of engaging with the quantum system, by switching from the conventional posture of objectifying the photon to a proprioceptive mode of relating to it, one may counteract the collapse of the photonic wave and participate intimately with the photon, *become* the photon, in keeping with the ontological nature of the underlying quantum reality. And if participants thus engaged interact with photons that are entangled, the participants themselves might become

entangled, as suggested in the previous chapter. It is this possibility that would be tested by the outcome of the experiment I proposed there.

Anticipation is high that the small quantum networks of entangled particles now being developed will be expanded to larger networks and, ultimately, to a quantum internet (Metz, 2022). Let us suppose that users of this internet could adopt a proprioceptive posture that allows them to become entangled with each other. Could this not eventually create a kind of social entanglement that could foster a sense of intimacy and ontological linkage? Would such entanglement not fulfill the promise of the quantum revolution to transform society for the better? Would it not bring the electronic era to its climax?

I noted above that because quantum technology is still in an early stage of development, we cannot fully know how society will be changed by this new medium. Far less can we know with much specificity what might happen in a society whose social relations would be transformed via proprioceptive quantum engagement. Nevertheless, we may find some clues for how this might unfold by turning again to the work of David Bohm. In the chapter to come, I am going to show how Bohm's approach to communication and dialogue can be taken as a forerunner of a kind of quantum interaction that can revolutionize the internet and society as a whole.

Chapter 7

PROPRIOCEPTIVE DIALOGUE AND QUANTUM COMMUNITY

He tarries at the threshold.
He delays.
He sets out with trepidation, clinging to Her memory, leaves but does not.
Odysseus does not know that his moment of departure will bring him
home to Her.

— The Plight of Odysseus

David Bohm was a renowned physicist who made great contributions to his field of study (Bohm 1951, 1957; Bohm and Hiley, 1995). He was also a philosopher seeking to understand the inherent wholeness in nature behind its appearance of division (Bohm 1980). Finally, Bohm was the pioneer of a social movement bent on overcoming the fragmentation that is splintering human relations and endangering the planet. Let us consider alongside McLuhan's commentary on how electronic media point beyond the mechanistic paradigm Bohm's own challenge to that paradigm, a social initiative in which the process of proprioception plays a critical role.

1. THE PRACTICE OF PROPRIOCEPTIVE DIALOGUE

"Fragmentation is now very widespread … throughout society," Bohm said (1980, p. 1). He believed that the unraveling of social ties might begin to be addressed if we could somehow learn to communicate with each other in a less guarded, more transparent and receptive way, exploring together the basis of our discord. What evolved from considering this possibility was a group practice that has come to be known as "Bohmian Dialogue" (see Bohm et al., 1991), or what I have called "Proprioceptive Dialogue" (PD) (Rosen, 2022). In chapter 4, I introduced the proprioceptive method of interacting with photons wherein the observer of the photon gains an embodied sense of her own process of observing as it is occurring in the moment. With Proprioceptive Dialogue, this self-reflexive methodology is applied to social interactions among human beings. Can the emerging quantum internet with its potential for proprioceptive social entanglement facilitate and be facilitated by the practice of PD?

Let me say more about Proprioceptive Dialogue. It is not primarily a discussion of concepts or a forum for exchanging ideas. It is an experiment in "radical honesty" in which participants relate to one another based on an awareness of and willingness to share their hidden agendas: underlying assumptions and motives, feelings and projections, defensive maneuverings, etc. PD requires that we interact with each other by moving in the "opposite direction" from the one in which conventional discourse takes place. Rather than moving forward, moving out to you, authoritatively advancing my position on whatever we are discussing by simply and directly presenting it to you, I relate to you in a more circuitous, reflexive way, by going proprioceptively backward into myself. That is to say, in PD (as in the proprioceptive observation of photons), I relate to another by sensing in the moment my own bodily process of relating. In so doing, I may be able to obtain a proprioceptive

sense of my "reactions, impulses, feelings and opinions" (Bohm et al. 1991, "Suspension" section, para. 1). Sensing them in this manner, observing them as they are actually taking place within my own embodied psyche, allows me to share them with you, and have them be reflected back to me by you. Here I am not just presenting an abstract content, a collection of finished thoughts. Instead I am disclosing — to myself and to you — the thinking and feeling and sensing process that lies behind the finished products. If we can encourage each other to relate in this way, it should allow us to "see behind the scenes," to read the subtext of our discourse, to make transparent the core motives and concealed tactics that are normally invisible in the defensive posturing of ordinary interaction.

Proprioceptive Dialogue does pose a challenge to the mechanical communication that McLuhan (1964) described. To appreciate how post-Renaissance individuality is called into question in PD, consider the word "individual." This term derives from the Latin *individuus,* indivisible, not capable of being divided. A closely related word is "atom," which derives from the Greek, *atomos*, indivisible. The atomic core of the contemporary individual is armored so heavily that it appears indivisible. In interacting with others, individuals are not likely to undergo "any changes in their essential natures" (to echo the words of Bohm quoted in the previous chapter). These mechanical exchanges are indeed surface to surface not core to core, since the atomic core is well defended against outside influences. In contrast, PD looks to *split the atom*.

In the proprioceptive movement back into myself, I penetrate my own core. Like the splitting of the atom that gave rise to the atomic bomb, a colossal amount of energy can be released by this self-penetration, but contrary to the catastrophic events at Hiroshima and Nagasaki brought forth by the manipulation of objectified matter, PD's release of energy can be constructive, can lead to social healing and wholeness. For, by opening myself proprioceptively in the course of dialogue, I am opening myself to the other without objectifying her, as happens in the posture of defensive self-concealment.

The notion of a psychically based form of "atom splitting" in fact was advanced decades ago. In her writing on David Bohm, philosopher Renee Weber (1978a) spoke of "psychological atom smashing," suggesting the "analogy of the atom with thought, and with an alleged thinker who authors thought" (p. 20). In our terms, the thinker in question is the post-Renaissance ego. This thinker or ego, "mistakenly believing itself autonomous and irreducible, requires and hence squanders vast amounts of cosmic energy on this illusion" (p. 20). In *smashing* the atomically constituted ego, the energy liberated is "unbound and flowing, characterized by wholeness … and the force of compassion" (p. 21). Weber described this universal energy as "an energy of love" (p. 21). She further noted that while smashing the atom in conventional physics is a dualistic enterprise maintaining the division between subject and object, psychological atom smashing "necessarily involves the operator or experimenter himself" (p. 21). Weber's prime example of a "psychological atom smasher" was David Bohm.

In Weber's (1978b) subsequent interview with Bohm, the analogy between thinker and atom was carried forward. Here, Bohm spoke of the "'transformation of the atom,'" emphasizing the need for assembling a great enough number of "atoms" to reach the energy required for a "'chain reaction.'" Bohm believed that a *psychic* transformation of this kind would change "'the consciousness of mankind,'" bringing human beings into conscious "'contact with the implicate order'" (p. 40). But he proposed that no single individual is capable of attaining the requisite level of energy. What is needed is "'a number of

individuals who are in close relation and who have gone through this [transformative process on their own, though at lower levels of energy] …. If you had as many as ten people, or a hundred people … they would have a power immensely beyond one'" (p. 40). With this 1978 remark, Bohm foreshadowed the dialogue movement that was to gain momentum in coming decades. And I suggest that the key to the atom splitting that occurs in such dialogue groups is proprioception. The release of energy in Proprioceptive Dialogue and its consequences will be considered in detail in the next section. Note that while Weber and Bohm tended to frame psychological atom smashing in cosmic terms, I will presently take a more practical approach.

When I interact with others in ordinary discourse, the words at my command typically function in the service of the post-Renaissance ego. It is my determined use of language and speech that provides my ego's armoring. In PD's "splitting of the atom," what plays the decisive role is *silence*.

In what specific sense is silence essential to PD? Silence certainly has its practical advantages in a dialogue meeting. It gives participants a chance to process and digest what has been said, provides opportunities for less loquacious individuals to be heard, and so forth. But in PD, silence means more than that. It is not limited to a cessation of audible speech in which the stream of verbiage can nonetheless continue inwardly. Rather, it entails the *interior* silence that comes from shifting one's attention proprioceptively to the nonverbal concomitants of one's verbal narrative.[8] Suppose, for instance, that a dialogue participant says something that stirs me up so that a cascade of angry thoughts and words are inwardly unleashed. Though I might normally get caught up in such a reaction, in PD I bring my attention to the wordless workings of the body that accompany the irate words — my jaw clenches, perhaps; I fidget uncomfortably; my posture stiffens; my palms sweat.

In this regard, Bohm collaborator Lee Nichol (2005) noted Bohm's emphasis on attending to the body when practicing dialogue, so that dialogue is not just an intellectual exercise. According to Nichol,

> Bohm proposes that we use the body as a source of immediate, concrete feedback for our inquiry…. [He] suggests that we expand our attention — usually focused on our mental reactions arising from provocations to the ego — to include the physiological correlates of these reactions …. Honest attention to the signals in the body will often give a very different picture of what is happening in our experience than the ego would like to imagine …. [C]lose, sustained attention to the body, alert to signals like those mentioned above, makes it difficult to maintain the habit of obscuring the actual nature of our experience. One effect of giving attention to the body, thus, is to bring our conscious awareness more closely in line with what is actually occurring. (2005, pp. 22–23)

Therefore, in the example I gave of the physiological reactions accompanying my angry response to words spoken in dialogue — tense jaw, sweaty palms, nervous fidgeting

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[8] Perhaps a first step in directing attention beneath the bustle of thoughts to the silence within is slowing that thinking down. In his dialogical reading of Heidegger's "Conversation on a Country Path," philosopher Jack Wikse views the slowing down of thinking as integral to Taoist meditation practice. See Wikse's paper, "Slowing Things Down: *Gelassenheit* and the Somatics of Dialogue" (Wikse, 2003).

— my preverbal body might be telling me that the other's words in fact feel threatening to me. But I suggest that PD can take me even deeper into the preverbal body and, in so doing, further enhance my sense of what is actually happening within me and between us.

Eugene Gendlin (1978) described a proprioceptive practice he called *focusing*, wherein a psychological issue is addressed by tuning in to the body at a deep level in order to gain a *felt sense* of the problem. Applied to Proprioceptive Dialogue, group members can use focusing in relating to each other. In the example I've given, the proprioceptive challenge for me now would be to bring my attention from those angry words and associated bodily reactions still further down into the core of my lived body for a sense of their somatic base. What is the anger telling me down there? "Pay attention inwardly, in your body," Gendlin urges, "perhaps in your stomach or chest …. Sense within your body. Let the answers come slowly from this sensing" (Gendlin, 1978, p. 44).

At first, the answer my body gives me might be nothing more than a vague intimation of "what *all of the problem* feels like … an unclear sense of *all of that*" (p. 44). Here I feel only "the whole inner aura of the problem" (p. 53). This is the felt sense. But the initially nebulous understanding of my angry reaction can be brought into focus by finding a "handle" for it (pp. 55–57), a word or phrase that resonates with the body's preverbal stirring and gives voice to it. I might come to realize, for instance, that at bottom what triggered my outrage was an underlying feeling of shame. So what started out as anger projected onto another dialogue participant is transformed into an embodied realization about myself. Given some experience with focusing, such insights can come quickly enough to be shared with the group in the course of the dialogue session. By being radically open to ourselves in this preverbal way and sharing it with others who are doing the same, by listening deeply to one another in the course of our mutual sharing, PD fosters a sense of intimacy not possible in the verbal exchanges of conventional discourse. In sum, PD's paradigm of preverbal intimacy "splits the atom," calling into question the post-Renaissance individual's mode of communication wherein self and other are divided and interact superficially in a mechanical space of continuous speech.

2. THE ROLE OF POLARITY IN PROPRIOCEPTIVE DIALOGUE

In the previous section, I indicated that the healing that can be brought about by splitting the post-Renaissance atom entails the release of energy. Taking a closer look at what this process involves will further sharpen our understanding of PD.

Analogous to atomic fission, where the splitting of atoms leads to the buildup of nuclear energy, a certain kind of intrapsychic energy is built up in the practice of PD. As I have already indicated, in drawing back in upon myself proprioceptively, my attention moves against the grain of ordinary discourse. Instead of relating to you by simply projecting my thoughts outward in acts of speech that are oblivious to their preverbal origins, I counteract this outward thrust by moving my awareness inward so as to withdraw the projections. Why is intrapsychic energy generated by this operation? It is because the inward movement does not just come *after* the projection in a linear sequence. Rather, outward and inward movements are superimposed on each other and happen at once, and this polar opposition creates friction, an energy-bearing psychic tension. I often experience this tension in my practice of PD. Groping for a felt sense of the preverbal source of my onrushing words and thoughts feels like swimming against a strong current. But if I can

hold the tension, contain the psychic energy for a sustained period of time without letting it dissipate, the energy may be released in the form of a novel self-insight. In my example, I suddenly realize that it isn't so much anger that I'm experiencing — at bottom, it's shame. (In the metaphor of splitting the atom, for a critical mass to be reached that will eventuate in an energy-releasing chain reaction, the nuclear material must be compressed, held together to allow the energy to build.)

Beth Macy (2022) sees holding the tension of polar opposites as integral to Bohmian Dialogue. Working with philosopher Owen Barfield's concept of polarity, she gives a definition of it taken from Barfield's conversation with psychologist Shirley Sugerman (2008). Here polarity is seen as involving "'two counteracting and correlative forces that have separated themselves forming two poles'" (Macy, 2022, p. 52). Though the poles stand in opposition to each other, they are linked from within. Bohm illustrates this through his example of a magnet whose north and south poles are not separately existent but are aspects of "one unbroken magnetic field" (1985, p. 73). The interconnectedness of the field is evidenced by the fact that, if the magnet is broken apart, "you get two magnets, each of which has a north and a south pole" (p. 73). Mechanistic thinking would lead us to expect that, in breaking the magnet into two pieces, one piece would give only the north pole and the other only the south. But the field is not divisible in this way, for each piece of the magnet carries within it the north–south polarity of the whole field and, with opposite poles being thus connected to the whole, they are connected to each other.

Macy's idea of polarity applies to the tensions that come into play in dialogue meetings when feelings, thoughts, and conflicting assumptions rise to the surface. Initially these tensions may reflect no more than egoic projections uninformed by an awareness of their unconscious underpinnings. If the blind oppositional energies that have been constellated go unchecked for too long, the group container certainly could "explode." The group needs to hold the tensions long enough to transform them from merely external and potentially explosive oppositions, into *polar* oppositions wherein opposites are internally linked. In PD, the transformation happens through proprioception.

I have already described the intrapsychic polarity entailed in proprioception. I now suggest that proprioceptive activity of this kind where opposing movements of consciousness (projection and proprioception) are inwardly joined, sets the stage for *inter*psychic polar relations to form in the group field. It is by going against the grain of my projection that I can gain an insight into myself that can then be shared with the group, a gesture that invites others to reciprocate. In the group proprioception that ensues, the "atom" is split without explosion, for a field of intimate linkages among the participants has been created akin to the magnetic field described by Bohm. Instead of blowing apart, the group can now evolve as new meanings emerge that advance its creative exploration. For David Bohm (1991, "Purpose and Meaning" section, para. 5), collective innovation of this sort is a primary goal of dialogue.

To be sure, a dialogue group governed by polarity is not all sweetness and light. Tensions tend to persist. There are differences among the members that can bring friction and edginess. But proprioceptive sharing facilitates a cohesiveness that takes the group beyond the mechanical transactions of separate egos butting up against each other. These "atoms" have indeed been "split" and the energy thereby released enables the group to function more like jazz players in an improvisational jam session, with the individual

members spontaneously expressing their unique impulses and understandings while just as much being in dynamic flow with all the other players.

Macy emphasizes the paradoxical nature of dialogical polarity. Though polar opposites are interdependent and interpenetrating, "they embody the tension of their difference" (2022, p. 52). How can we clarify the enigmatic interplay of identity and difference that underlies the polarities of PD? To bring this paradoxical form of interaction graphically into focus, we turn to back to the Necker cube and to the process of integrating the cube's opposing perspectives. We found earlier that, with perspectival integration, there is a dynamic merging and separating of opposing perspectives, an intimate exchange between polar opposites "in which 'outer' and 'inner' are alternatingly both distinct and the same" (Schwartz-Salant, 1998, p. 13). This is essentially what happens with proprioception, where the movement of awareness inward to the preverbal body is an inseparable aspect of the projective movement outward into language. Here attention pushes back against itself creating intense polar opposition. If the tension can be held until a "critical mass" is reached, the intrapsychic energy that has been generated can be released as a novel insight. Even as my anger is projectively expressed in language, the proprioceptive passage to anger's preverbal source brings a tensive awareness that eventuates in a realization of my underlying shame.

We know, moreover, that PD carries this intrapsychic paradox into the paradox of field relations that develop in the group. In the course of sharing our proprioceptions, we merge dynamically even as we separate; we are "alternatingly both distinct and the same" as we strike new notes in our "dialogical jazz," evolve fresh meanings in the ongoing process of creative exploration.

3. PROPRIOCEPTIVE DIALOGUE IN QUANTUM COMMUNITY

I must confess that my above description of field relations in the dialogue group is something of an idealization. In the groups I have participated in over the decades, many members have acknowledged that they really do not understand the process. Despite countless reiterations of what PD is about, the explanation does not seem to sink in and there is a strong tendency for PD to drift into ordinary discourse. It therefore does not surprise me that the dropout rate in the groups I have attended is considerable. Evidently, people find it very difficult to withdraw their ego-based projections and challenge their own egoic ways of operating. This is a clear sign that we are still under the sway of the old paradigm.

In my own practice of PD, I have found that, despite all the years I have spent engaging in this, each new dialogue session brings the need to completely reorient myself, as if I'm performing PD for the first time. As I noted above, practicing PD feels to me like swimming against a strong current and, in an important sense I *am*: I'm moving against the prevailing current of the classical modus vivendi. So, yes, as long as that paradigm holds sway, it will be hard to actualize the ideal of merging our separate perspectives and flowing together in a paradoxical union that at the same time maintains our individual contributions to the group's coherence.

This is not to say that the ideal is never approached. In dialogue groups I have been involved with, there have been occasions when group coherence has been truly remarkable. But the headwinds that continue from the old way of operating prevent PD groups from

experiencing coherent field relations more fully and consistently. Can anything be done to heighten the coherence of the PD field? This is the role I envision for the coming quantum internet, assuming a proprioceptive approach is taken to it. The coherent entanglement of dialogue participants might be enhanced in the novel medium by employing entangled photons to mediate the process. This would be in keeping with the basic proposition that proprioceptive observers of entangled photons can become entangled with each other. How can we better understand this observer entanglement?

The limitations of pre-quantum PD that result from ongoing adherence to the established paradigm bring to mind the earlier discussion of the limitations of the Necker cube and Moebius strip, which are also attributable to the old worldview (see chapters 3 and 5). Fundamental to both is the underlying perception of any other being—whether another human being or a geometric figure—as an object appearing before us in classical space. In the case of the cube and the Moebius, we have already seen that however suggestive these structures are of quantum perception and quantum entanglement, they lack the dimensionality needed to embody the quantum reality. To overcome this impediment, I turned in chapter 3 to the higher-dimensional Klein bottle, recognizing that its "higher" dimension is in fact the ontological dimension of *depth* described by Merleau-Ponty (1964). Here I demonstrated the kinship of this dimension to the quantum of action at the heart of quantum physics. Then, in chapter 5, we saw that the Klein bottle embodies the phenomenon of entanglement that physicist Erwin Schroedinger described as "*the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought" (1935, p. 807). Therefore, if the depth-dimensional Klein bottle is the key to understanding entanglement in the most complete way, it can serve as the key to understanding the *observer* entanglement that would underlie the practice of PD in the emerging medium of the quantum internet.

Let us suppose that the experiment put forward in chapter 5 is conducted and results in providing support for the phenomenon of observer entanglement. Suppose further the existence of a quantum network in which distant observers are viewing their respective entangled photons proprioceptively. What does the Kleinian character of entanglement suggest about the way participants would relate to one another? Having established the *ontological* nature of Kleinian relatedness in chapter 3, I submit that participants in a PD group meeting on the quantum internet and tuning in to each other by proprioceiving photons that are Kleinianly entangled would constitute, in effect, an ontological community. What do we know of such communities?

It is clear that participants in communities like these are not merely separate individuals who at times may relate to each other intimately. Rather, in an ontological community, the identities of its members are joined at the core of their being. We may say that in a certain tangible sense, the members of the group *are* each other. This is what McLuhan was getting at when he suggested that, prior to the explosive rise of individuality at the time of the Renaissance, Europe was a "collective tribal world" (1964, p. 31). A vivid impression of pre-Renaissance communal experience was also conveyed by Owen Barfield. In the Middle Ages, said Barfield, "the world was more like a garment men [and women] wore about them than a stage on which they moved….Compared with us, they felt themselves and the objects around them and the words that expressed those objects, immersed together in something like a clear lake of…'meaning'" (Barfield, 1988, p. 95).

Equally vivid is the description of ontological community given in an essay by anthropologist E. Richard Sorenson (1998).

Sorenson's paper, titled "Preconquest Consciousness," stems from his research in New Guinea, Mexico, and elsewhere. In his essay, he recounts a form of awareness that existed in isolated communities around the world before the incursion of Western conquerors who brought with them the values, perceptions, and sensibilities of a highly individualistic, mechanistic culture. According to Sorenson, an "intuitive group rapport" prevailed in such communities that united "people without need for formal rules. The outstanding psychological condition is heart-felt rapprochement based on integrated trust" (1998, p. 80). Sorenson portrays the preconquest society as "sociosensual" (1998, p. 80). Its members were "held…rapturously together" (1998, p. 101) by an embodied intimacy, an ongoing sensual entanglement more tangible than the forms of intimacy known to us in the West. I suggest these communities may be taken as ontological. The members were not merely separate individuals in close affiliation; instead, they were involved in a "hypersensual interactive unity" (Sorenson, 1998, p. 90) in which their very identities were entwined at a bodily level.

The introduction to ontological phenomenology offered in chapter 2 actually already includes an introduction to ontological community. I am referring to Merleau-Ponty's intimation of the *lifeworld* (1945/1962, 1968). This is the fleshly realm of lived experience that has been obscured by the rise of detached individuality in the aftermath of the European Renaissance. In contrast to the aloof and objectifying subjectivity that came to prominence with the Cartesian splitting of subject and object, the inhabitants of the lifeworld encounter each other with such palpable immediacy that the subject dwells down among the objects as "one of the visibles" (Merleau-Ponty, 1968, p. 135). Here the subject is itself always an object to some *other* subject, so that the simple distinction between subject and object is confounded and "we no longer know which sees and which is seen" (p. 139). Stated a little differently, the intimately embodied, fleshly relation among lifeworld inhabitants involves a "reciprocal insertion and intertwining of one in the other" (Merleau-Ponty, 1968, p. 138).

By way of further elucidating the form that PD would take on the quantum internet, let me try to clarify the role that individuality would play in an ontological community of this kind. We know that the current, pre-quantum practice of PD is still under the influence of the dominant culture of individuality and therefore generally falls short of full-fledged ontological community. It is in the entangled quantum community I am envisioning that the collective aspect would come decisively to the fore. But this does not mean that individuality simply would be sacrificed. Rather, the "dialogical jazz" that Kleinianly blends communal and individual aspects would be brought to fulfillment.

To shed more light on this, we return to Sorenson. He notes that "preconquest groups are simultaneously individualistic and collective—traits immiscible and incompatible in modern thought and languages. This fusion of individuality and solidarity is another of the profound cognitive disparities that separate the preconquest and postconquest eras" (1998, p. 82). As an example of such fusion, Sorenson describes the relationship of intensifying rapport among adolescent boys who have been hunting together, with "each constantly enlivening the others by a ceaseless, spirited, individualistic input into a unified at-oneness" (1998, pp. 89-90). However, the preconquest fusion of

individuality and unity Sorenson refers to is not the kind of fusion I am proposing for quantum internet PD.

In a section titled "Sense of Name," Sorenson points out the following:

> In … preconquest regions of New Guinea names were rarely binding. What one was called varied according to time, place, mood, and setting. Names were improvised, not formally bestowed, and naming … was often a kind of humorous exploratory play. New names could be quickly coined, often whimsically from events and situations, with a new one coming up at any time…. Names were nicknames. They stuck for a while, then a new one came along. (Sorenson, 1998, pp. 93-94)

Though Shakespeare's Romeo may have asked Juliet rhetorically, "What's in a name?", in Western culture names fix our sense of individual identity. I, for example, am deeply identified with the name "Steven," and if people suddenly started calling me by different names in different situations, I would feel uncomfortable, to say the least (of course, this excludes the often-undignified nicknames assigned to me by my wife). From this we may infer that in preconquest culture, the fluidity of naming reflects a weaker sense of separate individuality than has developed in the West.

After commenting on the preconquest sense of name, Sorenson takes up the question of space and describes the "affect-space" (1998, p. 95) of preconquest people. What determined location in this space was based on feelings, not on the geographic maps of the conquerors. If judged by space as we have come to know it, "All boundaries, spatial and otherwise, were therefore hazy, inconsistent, and ambiguous" (Sorenson, 1998, p. 94). Does the undifferentiated nature of preconquest space relative to our own have further implications for the preconquest sense of individuality?

In the previous chapter, I recounted McLuhan's (1964) discussion of the close relationship between two emergent phenomena at the time of the European Renaissance: a new sense of individuality in which one became detached from the community to stand on one's own, and a new sense of space as a well-differentiated continuum that could be mapped and used for precise observations and measurements. This watershed in the development of Western culture has been widely acknowledged by many students of history and it plays a central role in my own formulation of the post-Renaissance paradigm in terms of object-in-space-before-subject. Thus, in the course of writing about McLuhan, I noted that space and subjectivity are packaged together in such a way that the post-Renaissance notion of spatial continuity cannot be separated from the subject's maintenance of a detached posture with regard to the objects before him. Indeed, the subject's fixed point of perspective centers his individuality and it is from this point of view that the spatial continuum opens out to him. From what I could tell in reading Sorenson's account of space, the preconquest individual was not centered in his own unique viewpoint but in what Sorenson called a "center … of rapport" (1998, p. 94). This suggests to me that the center of preconquest experience lay in the group more than in the individual. In sum, both the sense of name and sense of space in preconquest society evidently indicate a subordination of individuality to the collective.

Given the pervasive sense of community in preconquest cultures and the merely embryonic sense of individuality there, is it not misleading to assert that "preconquest groups are simultaneously individualistic and collective" (Sorenson, 1998, p. 82) without

acknowledging that the aspect of individuality is overshadowed by the collective aspect? Does Sorenson even recognize the disparity between aspects? He seems to implicitly give them equal weight and then comments that when trying to describe their fusion in English, "the words bump up against each other as if contradictions—as in individualistic unified at-oneness, a phrase self-contradictory in English" (1998, p. 90). Yet the apparent contradiction or paradox loses its force when we realize that, in the preconquest situation, we are not dealing with a union of equally strong and diametrically opposed forms of awareness. With preconquest self-awareness not primarily grounded in the sense of separate individuality but in the life of the community, only one form of awareness effectively holds sway: the collective.

The real paradox of fusing individualized awareness with collective connectedness arises as a critical issue in the dilemma we confront at the present juncture of our history. Let us take some time to think this through.

Human beings have come a long way from the preconquest world, from the pre-Renaissance world, from the lifeworld. Much time has passed since our once deep ties to the community gave way to a powerful sense of ourselves as separate individuals. With the burgeoning of detached individuality, societies were held together by social contracts that were agreed to in order to prevent excessive individualism from wreaking havoc. Eventually, when the sense of separation had deepened past a certain point, the social contracts began to unravel and social fragmentation set in. Thus Bohm could say, as noted earlier, that "fragmentation is now very widespread … throughout society" (1980, p. 1). Entering the twenty-first century, the effects of this breakdown have metastasized in various devastating ways. We are presently witnessing a descent into chaos, from the coming to prominence of (would-be) dictators too inept to put their narcissistic power dreams into orderly effect, to the proliferation of states that have failed outright and have fallen into sheer anarchy. In the course of these catastrophic developments, long-held values, standards of behavior, and codes of decency are crumbling.

We know from McLuhan that the rule of the detached individual had already begun to be questioned in the middle of the nineteenth century when, on the threshold of the electronic age, the first doubts were being raised about the mechanistic nature of science and society. Nevertheless, despite McLuhan's optimism that electronic technology might help us return to tribal solidarity on a global scale (the "global village") and restore the "Family of Man," we are still in the grip of the individualistic paradigm that has been keeping us apart for centuries. As a matter of fact, even as modern technology has brought us closer together in certain limited respects, our underlying sense of separation from each other has only increased. Pre-quantum technologies, especially the conventional internet, have actually contributed to this social malaise by accentuating our ontological division. How does this happen?

In the previous chapter we found that computer-generated text and images do not arise from what already is substantially present, but from absence, from the equipotentiality of the virginal chip. This underlying lack of substance peculiar to the virtual realm accords with Jacques Derrida's (1976) view of cybernetic activity, including both the writing of computer programs and the activities that go on in a cybernetic milieu ultimately dependent on these programs. On Derrida's interpretation, at the heart of all cybernetic writing is the *trace*, the spectral form of inscription I contrasted with traditional writing in chapter 6. Devoid of solidity, substance, or foundation, communication via the

trace is an ungrounded, free-wheeling, evanescent game. And this "freeplay" (Derrida, cited by Spivak; 1976, p. xix) that characterizes the interaction of traces is reflected in the interactions among participants in the medium of the internet.

If the medium is the message, in a medium based on the "free play" of traces, interactions may tend to be fleeting and flighty whatever their content, and the laws of social gravity may be defied. Participants may be inclined to keep their commitments casual, making and breaking commitments with relative ease. Attachments may be sidestepped, entanglements shunned, and relationships may only skim the surface. People might seek to maintain their anonymity in this environment, so that the consequences of the games they play don't have to be faced. If participants cannot be held accountable for irresponsible behavior, they can indulge themselves to the point of becoming brutally abusive. They may "flame" each other and shame each other with impunity. Among the victims of this abuse, the more unstable, impressionable, and vulnerable might even be driven to the point of suicide. Since people have no skin in the game in this disembodied medium, there is little to hold them to account. Beyond that, there is the reckless confusion of half-baked opinions with hard facts, with no shared sense of the truth. On the pre-quantum internet then, social interactions are apt to be capricious and unmoored. And if we feel more detached from one another when online than in other settings, it is because the internet is essentially a social space with the peculiar property of bringing us together as ontologically detached.

If internet transactions mirror the Derridean trace in their spectral insubstantiality and disconnection from the lifeworld, we might expect that those engaged in such transactions would themselves be ghost-like beings, hollowed out and feeling empty at their core. We may call them "hungry ghosts," a Buddhist term for beings who are forever attempting to fill the emptiness they feel but never really succeeding, because their superficial efforts can never bring them solid satisfaction.[9] It seems that people simply cannot get enough nourishment in their online interactions. This is surely not to say that business as usual cannot effectively be conducted online. Nor is it to say that transactional social exchanges cannot take place where detached egos can massage each other while retaining their ontological isolation: "You look great!," "You're unbelievable, yourself," "You do that so well," and the like. As separate egos, we may engage in far more subtle and apparently more satisfying transactions of this kind, yet, at some level of awareness, we may still be haunted by feelings of core emptiness and dissatisfaction. Where do these feelings come from? I suggest they lie in the fact that, in such transactions, we are not connected to each other in a deep enough way; not connected in blood, flesh and bone; not ontologically entangled in community. We know that with the European Renaissance and the conquest of indigenous peoples around the world, transactions among insular egos have supplanted entanglement in lived community. The fullness of communal connection has suffered in the process. Now, with the internet, the repression of the lifeworld has reached new heights, despite the fact that the internet has brought separate egos into closer electronic proximity than ever before.

[9] Physician Gabor Mate (2010) used the term "hungry ghost" in his study of addiction.

I am proposing that the lifeworld has been repressed, but this surely does not mean it has been eliminated. After all, the Merleau-Pontean lifeworld is ontological; it is an expression of Being, [10] and I would hold that Being cannot simply be effaced.

To repeat the words of Carol Bigwood cited in chapter 4, Being is "the living web within which all relations emerge" (1993, p. 3). Being is a concrete, dynamic unity, an ongoing process of communion that pre-dates the subject-object split and continues in an overshadowed form after the division has taken place. Heidegger made it clear that Being cannot be relegated to some bygone epoch of history, as if it once was, but no longer is. To negate something in this manner is to end its existence. Recalling the ontological difference of which Heidegger spoke (see chapter 4), though the existence of all *ontical* beings begins at some point in time and ends at a later time, this does not apply to the ontological because Being is not temporal in this linear way. Rather, Being is that which first gives rise to time as we know it, and while it is in Being that time-bound ontical beings originate, Being itself is ever-present—it is an *ever-present origin* (the foregoing term was adopted by philosopher Jean Gebser [1985] for the title of his magnum opus). Thus, Heidegger often spoke of the forgetfulness of Being, but never of its elimination. And if Being cannot simply be eradicated, neither can the separative individuality that has arisen to eclipse Being. In fact, the emerging of separate individuals has not taken place in mere opposition to Being but as part of Being's own process so that the concealment of Being is in fact a *self*-concealment. Heidegger suggested accordingly that "self-concealing, concealment, *lethe* [i.e., forgetfulness of Being], belongs to *a-letheia* [the unconcealment of Being] not just as an addition, not as a shadow to light, but rather as the heart of *aletheia*" (1964/1977, p. 390). And Heidegger's words bring us back to the critical paradox of individuality and communality we have been contemplating.

The detached ego is now largely unrestrained, running rampant, and wreaking havoc. Restoration of the "Family of Man" is nowhere in sight. Our dilemma is that we cannot continue much longer in this way, but neither can we drop our egoic detachment from each other and return to the ontological community of old. What I propose we need to do instead is embrace the paradoxical fusion of individuality and communality. Although it is true that we can't just go back to an earlier time in order to negate individuality, we may be able to lift the repression of our ontological entanglement while at the same time maintaining our well-developed sense of distinctness. Following Heidegger's lead, let us say that individuality, when *fully* developed, is not merely opposed to ontological communality but lies at its "heart."

The idea may be clarified by considering depth psychologist C. G. Jung's concept of *individuation* (1934/1950). For Jung, the process of individuation is certainly not limited to developing an enhanced sense of the ego's individuality that differentiates it from what lies outside its boundaries. Rather, individuation entails an integration of the conscious ego with the collective unconscious of humanity at large. Jung moreover emphasized the importance of the *coincidentia oppositorum*, the paradoxical union of opposites, in the work of individuation. Here, "[t]he union of opposites … plays … a great and indeed decisive role" (1967, p. 341). Importantly, it is only in merging with the collective that the individual aspect is wholly realized.

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[10] If we wished to emphasize the communal aspect of Being, we might use a term suggested by the Buddhist philosopher Thich Nhat Hanh (2017): *interbeing*.

For another illustration of such a merger, we go back to our discussion of Proprioceptive Dialogue and the potential it holds for engaging in "dialogical jazz." In an improvisational jam session, jazz players fully express their individuality while at the same time intimately participating in the collective performance of the group. We might go so far as to say that a limited kind of individuation can occur in such a setting, since the unique self-expression of each individual player is realized most fully when giving himself or herself to the collective. This is a model of what can happen with the paradoxical field polarities that can develop in the Proprioceptive Dialogue group. PD has indeed been an effort to embrace the paradox of individuality and communality.

Recognizing that we are increasingly living our lives in cyberspace and that our ontological detachment from each other has only gotten worse there, I have sought to address the problem by initiating the practice of PD on my website (embodyingcyberspace.com). Of course, the conventional internet is still under the influence of the classical paradigm and this limits the degree of ontological connectedness that can be achieved, even when practicing PD. That is why we need the *quantum* internet. Only by immersing ourselves in the quantum world can we move far enough beyond the mechanistic order to recover ontological community through an act of individuation. If quantum reality is as I have interpreted it—as the lifeworld dimension of depth that surpasses the division of subject and object—entering consciously into that reality should lift the repression of Being and open the way to an ontological community that at once brings individuality to fruition.

Let us now try to sharpen our understanding of what the experience of ontological community would be like on the quantum internet. Broadly speaking, we know that PD seeks to transcend mere exchanges among detached egos, each with their own separate perspectives, each operating as free agents. An essential aim is to achieve an integration of perspectives, while paradoxically maintaining one's individual perspective as well. We also know that when pre-quantum PD is practiced most effectively, a paradoxical field relation can occasionally arise in which participants who are sharing their proprioceptions might momentarily experience perspectival fusion. In *quantum* PD, we should be able to take this further. Dialoguers would become ontologically entangled, with headwinds from the egoic paradigm dissipating to allow perspectival integration to be sustained for longer periods of time and to take on a deeper, more tangible quality. The basic proposition then is that quantum PD would permit participants to engage in a form of dialogue in which their perspectives would become completely integrated without sacrificing their individuality. With participants now being ontologically entangled, each would express their uniqueness in coherent relation to the whole quantum field. In this manner, the performance of "dialogical jazz" would be consummated.

What of the Klein bottle? Earlier in the present chapter, I noted that this topological form can help us better comprehend the observer entanglement that is the basis of quantum PD. We are already aware of the Kleinian character of the ontological community, and we can refine our understanding by exploring in a little more detail the nature of the boundaries that structure interaction in this community. Unlike the social boundaries existing within preconquest or medieval communities where members melt into each other in a largely undifferentiated way, the boundaries that set off participants in the quantum community would not be fuzzy or porous. But neither would these boundaries function to categorically divide participants from each other, as happens when individuals are set apart

in classical space. Rather, quantum boundaries would be Kleinian in nature. It is with paradoxical boundaries such as these that "'outer' and 'inner'" would be "alternatingly both distinct and the same" (Schwartz-Salant, 1998, p. 13). In my ontological entanglement with the other, the other would be entirely outside of me, yet wholly inside of me as well. I would literally *be* the other, while at once being myself—*fully* myself, in this moment of individuation.

Although the Klein bottle gives the topological structure of the interrelational boundaries in quantum PD, we still only have a general idea of how these relations would be experienced. Of course, this is something we cannot know in advance of actually experiencing them. The first step is to conduct the experiment proposed in chapter 5. If positive results are obtained, this would confirm the phenomenon of observer entanglement on which the ontological quantum community would be based. With confirmation in hand, we would then be able to refine the research and carry it forward. The process would require employing methods that would enhance the visual acuity of observers of photons, and that would enable observers to interact proprioceptively with photons in a reliable way (see chapter 5). With all this accomplished, we could go on to explore in concrete detail what it would really mean to participate in an ontological community that would be established on the quantum internet.

With billions of dollars being invested in the development of this radically new medium, its arrival seems inevitable. In my reading, the quantum medium promises to finally overcome the ego-based limitations of the mechanical age and bring the electronic age to its culmination. However, this would not happen if the quantum internet were employed to promote "business as usual." As of the present writing, the expected use of the new medium remains strongly influenced by the old mechanical paradigm. On the most obvious level, this means that internet operators would continue engaging in zero-sum games so as to gain advantage for themselves through enhanced computing speed, accuracy, and security. Beyond that, far more subtle forms of self-interested action would be possible and would be manifested among quantum internet users who consciously or unconsciously hold to the classical orientation of the detached ego. It is certainly true however, that classical users of the quantum internet would be employing a technology that is essentially dependent on the non-classical phenomenon of entanglement. How would they manage to do this? The conventional attitude to the quantum internet is analogous to that of the Copenhagen interpretation of quantum mechanics explored earlier.

Recall our chapter 2 discussion of the difficulty of comprehending the quantum world that led physicist Richard Feynman to declare: "I think I can safely say that nobody understands quantum mechanics" (1967, p. 129). Even though Feynman asserted this decades ago, it evidently applies to today. The still dominant approach to quantum mechanics is the Copenhagen interpretation, where grasping the deep structure of quantum reality is taken as out of reach and is bypassed in favor of focusing solely on predicting the behavior of particles. Here the basic message to physicists is "'Shut up and calculate!'," as Mermin (1989, p. 9) put it in his characterization of the Copenhagen view. And this is similar to what we currently find in the mainstream outlook on the use of quantum technology.

As with the Copenhagen approach, developers of the quantum computer and internet generally seek to avoid direct encounters with the deep core of the quantum

system while reaping the benefits of the system's computational power. In fact, the motivation for this avoidance behavior is even more compelling for quantum internet physicists than it was for the earlier generation of physicists. That is because any attempt to look inside the "black box" and directly engage with the quantum wave will collapse that wave and, as a consequence, the particle entanglement on which quantum computing depends will be lost. Therefore, not unlike the Copenhagen stance, the rule of thumb is to "shut your eyes and calculate." That is, give your attention to what you put into the black box and to what you take out, but don't look inside the box itself.

For my part, I propose that we do look inside the box, but look differently—look proprioceptively, rather than objectifyingly. But can we not reap the benefits of the quantum internet without looking? It all depends on which "benefits" we are seeking to reap. Still adhering to the classical formula of object-in-space-before-subject, we may wish to gain benefit for the detached ego. In that case, we will divert our eyes from the non-egoic quantum core and continue in the posture of objectification. But how beneficial is this? Does it really serve our interests to continue in this way? Or is clinging to a worldview that is failing us not counterproductive—no, *tragic*, given the chaos in which we are currently embroiled? What I am suggesting is that, by looking inside the black box proprioceptively, we can sustain the quantum wave coherence needed for observer entanglement. How is this beneficial? It is observer entanglement that provides the basis for the ontological quantum community that would fulfil the promise of the electronic age.

Since 1947, *The Bulletin of the Atomic Scientists* has maintained a figurative "doomsday clock" that symbolically indicates our closeness to global catastrophe (nuclear, environmental, etc.). It seems hard to deny that we are getting closer and closer to "midnight," a movement significantly accelerated by the increasing breakdown in human communication and community. Today it is necessary, I believe, that we go beyond mere applications of quantum technology for old purposes to full-fledged participation in a quantum society that will bring to fruition McLuhan's vision of the "global village." And entering the "global village" requires entering the black box.

Epilogue

Closing the Circle of Moebius

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

Four Quartets
T. S. Eliot (1943)

1. MOEBIUS TRIP

Years before the internet came into widespread use around the world, I wrote *The Moebius Seed* (Rosen, 1985), a philosophical science-fiction novel that concludes by envisioning a worldwide computer forum set up as an open-ended cultural exchange. In this work of fiction, individuals and groups from far and wide freely contribute information, images, music, and ideas to the forum on a broad range of holistic, spiritual, and process-oriented themes: ecology, new physics and cosmology, non-linear evolution, non-local connectedness, chaos theory, creative transformation, global healing, and the like. The novel reaches its climax with the dramatic transformation of the global network. Conventional electronic communications among participants are spontaneously surpassed and sites across the planet become instantaneously linked in a kind of universal telepathy. That book is of course science-fiction but with current developments in quantum science and technology, something like it might conceivably become science fact.

The global electronic forum portrayed in the novel was intended as a model of collective creativity and planetary interrelatedness that could address the widespread fragmentation gripping us at every level of human and world affairs. Beyond the chaotic developments mentioned in the last chapter we may add the following: disintegration of families and other social institutions; ethnic conflicts raging around the world; growth in international banditry and terrorism; world markets reaching new levels of erratic fluctuation; nuclear weapons and waste proliferating out of control; ecosystems strained to the breaking point, unleashing natural catastrophes with devastating consequences (floods, famines, epidemics, tsunamis, hurricanes, etc.). Beset by multiple crises, people are feeling more and more challenged to shoulder an overwhelming array of burdens and responsibilities, more and more fearful of others they perceive to threaten their interests, or even their lives—with fear breeding hatred, hostility, and violence. In short, humanity seems in the process of coming unglued, and taking the rest of the planet with it (I can hear the "doomsday clock" ticking). Could a global computer forum along the lines described in my novel help mitigate this dire situation? Perhaps it is magical thinking to believe that the participants in a forum like the one envisioned in the novel could become ontologically entangled, but with a quantum internet based on the "magical" principle of entanglement could it not be possible? And if it is true that, at bottom, the crises we are facing essentially

reflect a loss of ontological community, then the quantum internet, approached proprioceptively and holding the prospect of observer entanglement, could possibly help us reestablish that community, albeit with a Moebial twist.

Recall from chapter 5 the manner in which traversing the Moebius strip returns the traveler to her point her origin while at the same time paradoxically carrying her to the point furthest away from the origin, the point on the opposite side of the surface. In fact, this odd journey describes my personal Moebius trip, returning to a fictional account of non-local computer connectedness I wrote 40 years ago only to find that—with assistance from the remarkable new quantum medium—there is now a chance that the fiction might sooner or later indeed become fact. As for regaining ontological community through a global quantum forum, the Moebial twist is that it would happen without losing individualized consciousness. The community envisaged would close the Moebius circle by returning to pre-Renaissance/pre-conquest communality while at once *departing* from it, since the aspect of individuality, instead of being erased, would be brought to fruition in the process of *individuation* I discussed in the previous chapter. We would thus "arrive where we started and know the place for the first time."

2. CHALLENGES OF THE BOOK

I am certainly aware of the demands this book makes on our powers of conceptual imagination. Let me review some of the fundamental expectations and assumptions that are challenged between these covers, and some of the deepest puzzles that are explored. Firstly, one normally assumes that the human eye is not capable of detecting an object as small as a single subatomic particle. But the opening chapter of the book brings out that research does support this ability. In chapter 2, we confront the mysterious realm that physicist Richard Feynman said "nobody understands." Here I propose a phenomenological interpretation of this quantum domain that, in the absence of any other definitive interpretation, seems most aligned with the quantum phenomena themselves. However, my interpretation does depart significantly from conventional wisdom. Chapter 3 examines models of quantum perception and among its challenging findings is the possibility that the opposing perspectives of the Necker cube can be viewed in the same glance, thereby symbolizing the perception of the quantum wave before it collapses. It was in response to the limitations of the Necker cube model that the paradoxical Klein bottle was introduced. Chapter 4 addresses the need for a whole new mode of observation in the quantum realm and, in so doing, proposes the self-reflexive method of *proprioception*.

In chapter 5, the exploration of the quantum is extended to the mind-boggling phenomenon lying at the heart of quantum physics, that of *particle entanglement*. We have seen that this "spooky action at a distance" deemed impossible by Einstein has nonetheless survived decades of rigorous testing, has led to three Nobel Prizes, and is the basis for billions of dollars of investment in the quantum internet. Perhaps we can say that once scientists are able to accept the reality of quantum entanglement, it may free them to anticipate and credibly speculate upon what its implications might be. What I have done in chapter 5 is apply my investigation of quantum perception to the issue of entanglement and from this has come the possibility of *observer* entanglement. Let me reiterate the reasoning behind this extraordinary prospect: If entangled photons function non-locally, essentially operating as the *same* photon; and if observers of these photons engage with them

proprioceptively to become ontologically entangled with them; then it appears that these observers would become entangled with each other. Chapter 5 concludes with a detailed proposal for an experiment that would test this proposition.

The two closing chapters of the book focus on the potential implications for society of a quantum medium that employs observer entanglement. It is of course difficult to anticipate how any new medium will operate upon reaching maturity because, initially, it is subject to the lingering influence of the medium it succeeds. An example pointed out in chapter 6 is that television, in its formative years, had the look of cinema in its appearance of continuously flowing images. Only when TV came into its own did its underlying discontinuities come to the surface with programs like MTV. But the quantum internet is something else again, since it operates on a "spooky" principle that defies classical assumptions more deeply and directly than do cinema and television. The quantum internet thus breaks with the past more decisively, and this heightens the challenge of foreseeing its development.

If "it is the medium that shapes and controls the scale and form of human association and action" (McLuhan, 1964, p. 24), then the medium is what shapes society. We have considered the shape that society would be given by a quantum medium that at bottom constitutes a fleshly lifeworld, a world of ontological entanglement. This would extend McLuhan's dream of the future to a *quantum* global village whose nature tests the limits of our prescience. In the final chapter of the book, our powers of imagination are further stretched in an attempt to clarify how the quantum transformation of society might actually play out. We see how the quantum observer's proprioceptive interaction with the photon discussed in earlier chapters could be applied to interactions among participants on the quantum internet that could bring about their ontological entanglement. The climactic vision of the book is of participants in a worldwide quantum village engaged in an intimate process of Proprioceptive Dialogue.

3. WRITING BETWEEN MEDIA

Let me end my presentation by stating the obvious. In writing about the transformative new medium of the quantum internet, I write in an *old* medium, the medium of the traditional book (whether bound in paper or formatted electronically). Therefore—if the medium is the message—in every sentence I have written about overcoming the division between subject and object and realizing our entanglement in ontological community, the division has been covertly reinforced by this medium's implicit message of detached individuality. And, in every word I have stated about surmounting the limits of classical space and time, the old spatial continuity and temporal sequencing have been upheld in the medium's unspoken modus operandi. What, then, is the role of this writing I have done?

I suggest that, in writing as I have about the new medium, I have been writing *between* media. Because I have used the old medium in what I have said about the new, my talk of the coming quantum medium and its prospects for providing a forum for a global village is clearly an abstraction. It can only become a concrete reality when expressed through a medium that has itself reached fruition in quantum fashion, allowing for a kind of

quantum "writing"[11] to become possible, so to speak. For this to happen, it would not be enough just to have the quantum internet technically at one's disposal. On my interpretation, realizing ontological community requires that we engage with this internet in a quantum way, since, at its core, the quantum is itself an ontological lifeworld. Therefore, if it is ontological community we are after, we cannot look to avoid the quantum core in order to seek benefits for the ontologically detached individual. What I propose instead is that we enter the "black box" and participate proprioceptively with its entangled photons, thereby becoming entangled with each other (the experiment I recommended in chapter 5 hopefully will confirm the phenomenon of observer entanglement). Until the goal of proprioceptive participation is achieved and a quantum form of writing becomes feasible, I will continue writing between media.

[11] A probing investigation of "quantum writing" is beyond the scope of this book, but it seems a worthy project for a future occasion.

BIBLIOGRAPHY

Ananthaswamy, Anil. (2018a, July 10). The human eye could help test quantum mechanics. Retrieved from *Scientific American*: https://www.scientificamerican.com/article/the-human-eye-could-help-test-quantum-mechanics/.

———. (2018b, December 3). New quantum paradox clarifies where our views of reality go wrong. Retrieved from *Quanta Magazine*: https://www.quantamagazine.org/frauchiger-renner-paradox-clarifies-where-our-views-of-reality-go-wrong-20181203/

Applebaum, David. (2000). Dirac operators—From differential calculus to the index theorem. Based on inaugural lecture as Professor of Mathematics at the Nottingham Trent University. http://www.facct.ntu.ac.uk/staff/personal/dapplebaum/absconc.pdf (link currently dead).

Atmanspacher, Harald, Thomas Filk and Hartmann Römer. (2004). Quantum Zeno features of bistable perception. *Biological Cybernetics*, *90*, 33–40.

Atmanspacher, Harald and Thomas Filk. (2013). The Necker–Zeno model for bistable perception. *Topics in Cognitive Science, 5*, 800–817.

Barfield, Owen. (1988). *Saving of appearances.* Middletown, Connecticut: Wesleyan University Press.

Barr, Stephen. (1964). *Experiments in topology*. New York: Dover.

Bell, John S. (1964). On the Einstein-Podolsky-Rosen paradox. *Physics Physique Fizika*, 1, 195–200.

Benedek, Giorgio, and Giuseppe Caglioti. (2019). Graphics and quantum mechanics — the Necker cube as a quantum-like two-level system. In L. Cocchiarella (Ed.), *ICGG 2018 – Proceedings of the 18th International Conference on Geometry and Graphics* (pp. 161–172). Cham, Switzerland: Springer.

Berger, John and Jean Mohr. (1982). *Another way of telling*. New York: Pantheon Books.

Berghofer, Philipp and Harald A. Wiltsche, Eds. (2024). *Phenomenology and QBism: New approaches to quantum mechanics.* London: Routledge.

Bernstein, Jeremy. (1991). *Quantum profiles*. Princeton: Princeton University Press.

Bigwood, Carol. (1993). *Earth muse*. Philadelphia: Temple University Press.

Bitbol, Michel. (2020). A phenomenological ontology for physics. In H. A. Wiltsche and P. Berghofer (Eds.), *Phenomenological approaches to physics* (pp. 227-242). Cham, Switzerland: Springer.

Bohm, David. (1951). *Quantum theory*. Englewood Cliffs, N.J.: Prentice-Hall.

———. (1952). A suggested interpretation of the quantum theory in terms of "hidden" variables. 1. *Physical Review*, *85*(2), 166–179.

———. (1957). *Causality and chance in modern physics*. London: Routledge and Kegan Paul.

———. (1980). *Wholeness and the implicate order*. London: Routledge and Kegan Paul.

———. (1985). *Unfolding meaning* (D. Factor, Ed.). Gloucestershire, England: Foundation House Publications.

———. (1986). A new theory of the relationship of mind and matter. *American Journal of Psychical Research*, 80(2), 113–136.

———. (1994). The Bohm/Rosen correspondence. In S. M. Rosen (Ed.), *Science, paradox, and the Moebius principle* (pp. 223–258). Albany: State University of New York Press.

Bohm, David, Donald Factor and Peter Garrett. (1991). Dialogue: A proposal. Retrieved from http://davidbohm.net/dialogue/dialogue_proposal.html.

Bohm, David and Basil J. Hiley. (1995). *The undivided universe*. London: Routledge.

Bong, Kok-Wei, Aníbal Utreras-Alarcón, Farzad Ghafari, Yeong-Cherng Liang, Nora Tischler, Eric G. Cavalcanti, Geoff J. Pryde, and Howard M. Wiseman. (2020). A strong no-go theorem on the Wigner's friend paradox. *Nature Physics*, *16*, 1199–1205.

Brukner, Časlav. (2018). A no-go theorem for observer-independent facts. Retrieved from Cornell University Archive: https://arxiv.org/abs/1804.00749

Burr, Joseph, Abhishek Parakh and Mahadevan Subramaniam (2022, August 17). Quantum internet. Retrieved from *Ubiquity*: https://dl.acm.org/doi/10.1145/3547493

Burrow, Trigant. (1932). *The structure of insanity*. London: Kegan Paul, Trench, Trubner and Co.

———. (1953). *Science and man's behavior*. New York: Philosophical Library.

Bushell, William. (2016). Can long-term training in highly focused forms of observation potentially influence performance in terms of the observer model in physics? Consideration of adepts of observational meditation practice. *Cosmos and History*, *12*(2), 31–43.

Busstra, Hans. (2024). The end of physics as we know it? Video retrieved from The Essentia Foundation: https://www.essentiafoundation.org/the-end-of-physics-as-we-know-it/seeing/

Caglioti, Giuseppe, Gorgio Benedek and Luigi Cocchiarella. (2014). The perception of ambiguous images as a quantum information process. *Istituto Lombardo (Rendiconti di Scienze)*, *148*, 35–40.

Čapek, Milič. (1961). *Philosophical impact of contemporary physics*. New York: Van Nostrand.

Castelvecchi, Davide. (2016, July 19). People can sense single photons. *Nature News*, July 19, 2016. Retrieved from https://www.nature.com/articles/nature.2016.20282.

Chirre, Emmanuel, Pedro Prieto and Pablo Artal. (2015). Dynamics of the near response under natural viewing conditions with an open-view sensor. *Biomedical Optics Express*, *6*(10), 4200–4211.

Conte, Elio, Andrei Yuri Khrennikov, Orlando Todarello, Antonio Federici, Leonardo Mendolicchio and Joseph P. Zbilut (2009). Mental states follow quantum mechanics during perception and cognition of ambiguous figures. Retrieved from Cornell University Archive: https://arxiv.org/abs/0906.4952v1, 1–21.

Conte, Elio, Ferda Kaleagasioglu and Rich Norman. (2017). The quantum statistical mechanics in the analysis of the context dependence in quantum cognition studies: May a quantum statistical analysis connect the science of complexity? *Chaos and Complexity Letters*, *11*(2), 203–218.

Cunha, Márcio M., Alejandro Fonseca and Edilberto O. Silva. (2019). Tripartite entanglement: Foundations and applications. *Universe*, *5*(10), 209.

Derrida, Jacques. (1976). *Of grammatology* (G. C. Spivak, Trans.). Baltimore: The Johns Hopkins University Press.

Einstein, Albert, Boris Podolsky and Nathan Rosen. (1935). Can quantum-mechanical description of physical reality be considered complete? *Physical Review,* 47(10), 777–780.

Eliot, T. S. (1943). Little Gidding. In T. S. Eliot (Ed.), *The four quartets* (pp. 138–145). New York: Harcourt, Brace and Company.

Ericsson, K. Anders, Kiruthiga Nandagopal and Roy W. Roring (2009). Toward a science of exceptional achievement. *Annals of the New York Academy of Sciences*, *1172*(1), 199–217.

Ericsson, K. Anders and Herbert A. Simon. (1993). *Protocol analysis: Verbal reports as data* (Rev. ed.). Cambridge, Massachusetts: MIT Press.

Ernst, Bruno. (1986). *Der zauberspiegel des M.C. Escher*. Berlin: Taco.

Everett, Hugh, John A. Wheeler, Bryce S. DeWitt, Leon N. Cooper, Deborah Van Vechten and Neill Graham (1973). *The many-worlds interpretation of quantum mechanics*. Princeton, New Jersey: Princeton University Press.

Feynman, Richard. (1967). *The character of physical law*. Cambridge, Massachusetts: MIT Press.

Forbes Technology Council (2023, April 18). 15 significant ways quantum computing could soon impact society. Retrieved from *Forbes Magazine*: https://www.forbes.com/sites/forbestechcouncil/2023/04/18/15-significant-ways-quantum-computing-could-soon-impact-society/?sh=385d9914648b.

Fox Keller, Evelyn. (1985). *Reflections on gender and science*. New Haven, Connecticut: Yale University Press.

Frauchiger, Daniela and Renato Renner. (2018). Quantum theory cannot consistently describe the use of itself. *Nature Communications*, 9, 3711.

French, Steven. (2023). *A phenomenological approach to quantum mechanics*. Oxford: Oxford University Press.

Fuchs, Christopher A. (2017). On participatory realism. In I. T. Durham and D. Rickles (Eds.), *Information and interaction: Eddington, Wheeler, and the limits of knowledge* (pp. 113–34). Cham, Switzerland: Springer.

Fuchs, Christopher A., N. David Mermin and Rüdiger Schack. (2014). An introduction to QBism with an application to the locality of quantum mechanics. *American Journal of Physics, 82*, 749–754.

Galt, Alfreda. (1995). Trigant Burrow and the laboratory of the "I." *The Humanistic Psychologist*, *23*, 19–39.

Gardner, Martin. (1979). *The ambidextrous universe*. New York: Charles Scribner's Sons.

Gebser, Jean. (1985). *The ever-present origin*. Athens, Ohio: Ohio University Press.

Gendlin, Eugene T. (1978). *Focusing*. New York: Bantam.

Ghirardi, Giancarlo, Alberto Rimini and Tullio Weber. (1986). Unified dynamics for microscopic and macroscopic systems. *Physical Review D*, *34*(2), 470–491.

Glick, David. (2021). QBism and the limits of scientific realism. *European Journal for Philosophy of Science 11*(53), 1–19.

Goswami, Amit. (1995). *The self-aware universe*. New York: Tarcher.

Grosz, Elizabeth. (1994). *Volatile bodies*. Bloomington, Ind.: Indiana University Press.

Hahn, Thich Nhat. (2017). The insight of interbeing. Retrieved from the Garrison Institute: https://www.garrisoninstitute.org/insight-of-interbeing/

Handelman, Don. (2021). *Moebius anthropology*. New York: Berghahn Books.

Hardison, O.B. (1989). *Disappearing through the skylight.* New York: Viking Press.

Heidegger, Martin. (1962). *Being and time* (J. Macquarrie and E. Robinson, Trans.). New York: Harper and Row. (Originally published 1927)

———. (1977). The end of philosophy and the task of thinking. In D. F. Krell (Ed.), *Martin Heidegger: Basic writings* (pp. 373–392). New York: Harper and Row. (Originally published 1964)

Hermans, Sophie L. N., Matteo Pompili, Hans K. C. Beukers, Simon Baier, Johannes Borregaard and Ronald Hanson. (2022). Qubit teleportation between non-neighbouring nodes in a quantum network. *Nature,* 605, 663–668.

Heylighen, Frances. (2023). Entanglement, symmetry breaking and collapse: Correspondences between quantum and self-organizing dynamics**.** *Foundations of Science, 28*(1), 85–107.

Hilbert, David and Stephan Cohn-Vossen. (1952). *Geometry and the imagination.* New York: Chelsea Publishing.

Hollebeek, Timothy. (2021, March 12). The impact of quantum computing on society. Retrieved from DigiCert, Inc.: https://www.digicert.com/blog/the-impact-of-quantum-computing-on-society.

Holmes, Rebecca M. (2016). Seeing single photons. *Physics World*, *29*(12), 28–32.

———. (2019, April 24). Seeing the quantum. Retrieved from *Aeon*: https://aeon.co/essays/an-eye-on-experiments-that-make-quantum-mechanics-visible.

Holmes, Rebecca M., Michelle M. Victora, Ranxiao Francis Wang and Paul G. Kwiat (2018). Testing the limits of human vision with quantum states of light: Past, present, and future experiments. Retrieved from https://arxiv.org/abs/1806.08430.

Horwood, Anna. (2018). Binocular convergence: babies, children and adults. Retrieved from The Free Library: https://www.thefreelibrary.com/Binocular+convergence%3A+babies%2C+children+and+adults.-a0559356722

Huang, Liang, Xue-Mei Gu, Yang-Fan Jiang, Dian Wu, Bing Bai, Ming-Cheng Chen, Qi-Chao Sun, Jun Zhang, Sixia Yu, Qiang Zhang, Chao-Yang Lu and Jian-Wei Pan (2022). Experimental demonstration of genuine tripartite nonlocality under strict locality conditions. *Physical Review Letters,* 129, 060401.

Husserl, Edmund. (1965). Philosophy as rigorous science. In Q. Lauer (Trans.), *Phenomenology and the crisis of philosophy* (pp. 71–148). New York: Harper and Row. (Originally published 1911)

———. (1970). *The Crisis of European Sciences and Transcendental Phenomenology: An Introduction to Phenomenological Philosophy* (D. Carr, Trans.). Evanston, Illinois: Northwestern University Press. (Originally published 1936)

Jahn, Robert and Brenda Dunne. (1984). *On the quantum mechanics of consciousness* (Appendix B). Princeton, New Jersey: Princeton University School of Engineering/Applied Sciences.

Judge, Anthony. (2009). Klein bottle: enacting a cognitive process. Retrieved from https://kairos.laetusinpraesens.org/globald_0_glo_h_2

———. (2011). Reformulation: Klein Bottle as a catalyst for cognitive enhancement. Retrieved from https://kairos.laetusinpraesens.org/kleincat_1_h_6

Jung, Carl G. (1950). A study in the process of individuation. In R. F. C. hull (Ed.), *The archetypes and the collective unconscious, CW 9, Part 1* (pp. 290–354). London: Routledge & Kegan Paul. (Originally published 1934)

———. (1967). *Alchemical studies: collected works*, *volume 13* (R. F. C. Hull, Trans.). Princeton, N.J.: Princeton University Press.

Kauffman, Louis H. (2015). Self-reference, biologic and the structure of reproduction. *Progress in Biophysics and Molecular Biology*, *119*(3), 382–409.

———. (2025). Cybernetics of language – From naming to naming the self. *Constructivist Foundations*, 20(2), 72–78.

Kim, Kerry. (2021). Can we see single photons? Video retrieved from https://www.youtube.com/watch?v=BbhrHRsK1S4.

Lauer, Quentin. (1965). Introduction. In E. Husserl, *Phenomenology and the crisis of philosophy* (pp. 1–68). New York: Harper and Row.

Leder, Drew. (1990). *The absent body*. Chicago: University of Chicago Press.

Levin, David M. (1985). *The body's recollection of being*. London: Routledge and Kegan Paul.

Lindner, John F. (2015). ER = EPR? *Wooster Physics Blog*. Retrieved from https://woosterphysicists.scotblogs.wooster.edu/2015/11/26/er-epr/

London, Fritz, and Edmund Bauer. (1983). The theory of observation in quantum mechanics. In J. A. Wheeler and W. H. Zurek (Eds.), *Quantum theory and measurement* (pp. 217– 259). Princeton, New Jersey: Princeton University Press. (Originally published 1939)

Louchakova-Schwartz, Olga. (2019). *The problem of religious experience*. Cham, Switzerland: Springer.

McLuhan, Marshall. (1964). *Understanding media*. New York: New American Library.

Macquarrie, John. (1968). *Martin Heidegger*. Richmond, Virginia: John Knox.

Macy, Beth. (2022). Polarity: Dialogue's underlying dynamic. *Pari Perspectives*, *11*, 49–58.

Maroski, L. E. (2024). *Embracing paradox, evolving language.* Longmont, Colorado: Untimely Books.

Mate, Gabor. (2010). *In the Realm of Hungry Ghosts: Close Encounters with Addiction*. Berkeley, California: North Atlantic Books.

Merleau-Ponty, Maurice. (1962). *Phenomenology of perception* (C. Smith, Trans.). London: Routledge and Kegan Paul. (Originally published 1945)

———. (1964). Eye and mind. In J. M. Edie (Ed.), *The primacy of perception* (pp. 159–190). Evanston, Illinois: Northwestern University Press.

———. (1968). *The visible and the invisible* (A. Lingis, Trans.). Evanston, Illinois: Northwestern University Press.

Mermin, N. David. (1989). What's wrong with this pillow? *Physics Today*, *42*(4), 9–11.

Merrell, Floyd (1998). *Simplicity and complexity*. Ann Arbor, Mich.: University of Michigan Press.

Metz, Cade. (2022, May 25). "Quantum internet" inches closer with advance in data teleportation. Retrieved from *The New York Times*: https://www.nytimes.com/2022/05/25/technology/quantum-internet-teleportation.html

———. (2024, December 9). Quantum computing inches closer to reality after another Google breakthrough. Retrieved from *The New York Times*: https://www.nytimes.com/2024/12/09/technology/google-quantum-computing.html

Musès, Charles. (1977). Explorations in mathematics. *Impact of Science on Society,* 27, 67–85.

Necker, Louis-Albert. (1832). Observations on some remarkable optical phenomena seen in Switzerland; and on an optical phenomenon which occurs on viewing a figure of a crystal or geometrical solid. *The London and Edinburgh Philosophical Magazine and Journal of Science*, *1*(5), 329–337.

Nichol, Lee. (2005). Wholeness regained: Revisiting Bohm's dialogue. In B. Banathy and P. M. Jenlink (Eds.), *Dialogue as a means of collective communication* (pp. 17–28). New York: Kluwer Academic.

Norsen, Travis (2014, November 27). Quantum solipsism and non-locality. *International Journal of Quantum Foundations*. John Bell Workshop. Retrieved from: https://ijqf.org/wp-content/uploads/2014/12/Norsen-Bell-paper.pdf

Orzel, Chad. (2018). What is a quantum computer? The 30,000 foot overview. Retrieved from *Forbes*: https://www.forbes.com/sites/chadorzel/2018/10/15/what-is-a-quantum-computer-the-30000-foot-overview/

Penrose, Roger. (1971). Angular momentum: An approach to combinatorial space-time. In T. Bastin (Ed.), *Quantum Theory and Beyond* (pp. 151–80). Cambridge: Cambridge University Press.

Putnam, Hilary. (1964). Comments on comments on comments: A reply to Margenau and Wigner. *Philosophy of Science*, *31*(1), 1–6.

Rapoport, Diego L. (2011). Surmounting the Cartesian cut through philosophy, physics, logic, cybernetics, and geometry: Self-reference, torsion, the Klein bottle, the time operator, multivalued logics and quantum mechanics. *Foundations of Physics*, *41*, 33–76.

———. (2013). Klein bottle logophysics: A unified principle for non-linear systems, cosmology, geophysics, biology, biomechanics and perception. *Journal of Physics: Conference Series*, *437*, 012024.

Rapoport, Diego L. and Jean-Claude Pérez (2018). Golden ratio and Klein bottle logophysics: The keys of the codes of life and cognition. *Quantum Biosystems*, *9*, 8–76.

Rosen, Steven M. (1985). *The Moebius seed*. Walpole, N.H.: Stillpoint.

———. (1994). *Science, paradox, and the Moebius principle*. Albany, New York: State University of New York Press.

———. (1999). Evolution of attentional processes in the human organism. *Group Analysis*, *32*(2), 243–253.

———. (2004). *Dimensions of apeiron*. Amsterdam: Brill.

———. (2006). *Topologies of the flesh*. Athens, Ohio: Ohio University Press.

———. (2008). *The self-evolving cosmos.* Hackensack, New Jersey: World Scientific.

———. (2015). Why natural science needs phenomenological philosophy. *Progress in Biophysics and Molecular Biology*, *119,* 257–269.

———. (2021) The strange nature of quantum perception: To see a photon, one must *be* a photon. *The Journal of Mind and Behavior*, 42(3–4), 229–270.

———. (2022). Splitting the atom: The paradox of proprioceptive dialogue. *The Journal of Mind and Behavior*, 43(3), 171–184.

———. (2023). The strange nature of quantum entanglement: Can observers of entangled photons become entangled with each other? *The Journal of Mind and Behavior*, 44(3–4), 157–170.

Roundy, Jacob. (2023, February 10). Explore 7 future potential quantum computing uses. Retrieved from TechTarget: https://www.techtarget.com/searchdatacenter/tip/Explore-future-potential-quantum-computing-uses.

Royal Swedish Academy of Sciences (2022, October 4). The Nobel Prize in physics 2022 [Press release]. Retrieved from https://www.nobelprize.org/prizes/physics/2022/press-release/

Rucker, Rudolph. (1977). *Geometry, relativity, and the fourth dimension*. New York: Dover.

Ruebsaat, Susanna. (2019). *Mourning the dream — amor fati*. Eugene, Oregon: Pickwick Publications.

Ryan, Paul. (1974). *Cybernetics of the sacred.* New York: Anchor.

Sachs, Mendel. (1999). Fundamental conflicts in modern physics and cosmology. *Frontier Perspectives*, *8,* 13–19.

Schlosshauer, Maximillian, Johannes Kofler and Anton Zeilinger (2013). A snapshot of foundational attitudes toward quantum mechanics. *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, *44*(3), 222–230.

Schofield, James. (2021). *A phenomenological revision of E. E. Harris's dialectical holism*. Cham, Switzerland: Palgrave Macmillan.

Schroedinger, Erwin. (1935). Die gegenwärtige situation in der quantenmechanik. *Die Naturwissenschaften* 23(50), 807–12; 823–28; 823–28; 844–49.

Schwartz-Salant, Nathan. (1998). *The Mystery of human relationship*. London: Routledge.

———. (2007). *The black nightgown*. Wilmette, Illinois: Chiron.

———. (2017). *The order-disorder paradox*. Berkeley: North Atlantic.

Shermer, Michael. (2005). Quantum quackery. *Scientific American*, *292*(1), 234.

Shimony, Abner. (1963). Role of the observer in quantum theory. *American Journal of Physics*, *31*, 755–777.

Smith, Roger. (2020). Kinaesthesia and a feeling for relations. *Review of General Psychology*, *24*(4), 355–368.

Smolin, Lee. (2022). Views, variety and celestial spheres. Retrieved from Cornell University Archive: https://arxiv.org/pdf/2202.00594

Sorenson, E. Richard. (1998). Preconquest consciousness. In H. Wautischer (Ed.), *Tribal Epistemologies* (pp. 79–115). Aldershot, England: Ashgate.

Spiegelberg, Herbert. (1984). *The Phenomenological Movement*. The Hague: Martinus Nijhoff Publishers.

Spivak, Gayatri C. (1976). Preface to *Of grammatology*, by Jacques Derrida (Gayatri C. Spivak, Trans.). Baltimore: The Johns Hopkins University Press.

Stiskin, Nahum. (1972). *The looking-glass god*. New York: Autumn Press.

Sugerman, Shirley. (Ed). (2008). *Evolution of consciousness: Studies in polarity*. San Rafael, California: Barfield Press.

Syz, Hans. (1961). A summary note on the work of Trigant Burrow. *The International Journal of Social Psychiatry*, *VII*(4), 283–291.

Timpson, Christopher G. (2010). Information, immaterialism, instrumentalism: Old and new in quantum information. In A. Bokulich and G. Jaeger (Eds.), *Philosophy of quantum information and entanglement* (pp. 208–227). Cambridge: Cambridge University Press.

Tinsley, Johnathan N., Maxim I. Molodtsov, Robert Prevedel, David Wartmann, Jofre Espigulé-Pons, Mattias Lauwers and Alipasha Vaziri. (2016). Direct detection of a single photon by humans. *Nature Communications*, 7, 12172.

Von Neumann, John. (1932). *Mathematische grundlagen der quantnmechanik.* Berlin: Springer.

Weber, Renee. (1978a). Field consciousness and field Ethics. *Re-Vision*, *1*(3–4), 19–23.

———. (1978b). The enfolding–unfolding universe: A conversation with David Bohm. *Re-Vision*, *1*(3–4), 24–51.

Wehner, Stephanie, David Elkouss and Ronald Hanson. (2018). Quantum internet: A vision for the road ahead. *Science*, 362, 6412.

Wheeler, John A. (1990). Information, physics, quantum: The search for links. In W. H. Zurek (Ed.), *Complexity, entropy and the physics of information* (pp. 309–336). Redwood City, California: Addison-Wesley.

Wigner, Eugene. (1961). Remarks on the mind-body question. In I. J. Good (Ed.), *The scientist speculates: An anthology of partly-baked ideas* (pp. 284–302). London: Heinemann.

———. (1963) Problem of measurement. *American Journal of Physics, 31,* 6–15.

———. (1967). *Symmetries and reflections*. Bloomington, Indiana: Indiana University Press.

Wikse, Jack. (2003, November 8). *Slowing things down*: Gelassenheit *and the somatics of dialogue* [Paper presentation]. 2003 Conference of the Society for Phenomenology and the Human Sciences, Boston, Massachusetts. Retrieved from http://towardsocialsanity.net/slow.htm.

Wolf, Fred Alan. (1981). *Taking the quantum leap*. San Francisco: Harper & Row.

Young, Arthur. (1976). *The reflexive universe*. New York: Delacorte.