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I begin my final comments by expressing gratitude to Harris Friedman for his invitation to write on this special topic. Only at the point of starting to write did I realize how much I had to say. I also want to extend a heartfelt thanks to the broad range of colleagues who felt inspired to provide commentary. That such an esteemed group of physicists, biologists, mathematicians, psychiatrists, psychoanalysts, profes sors of religious studies, neuroresearchers, and other experimentalists were moved enough to weigh in, indicates to me the wide application of fractal mathematics across the spectrum of physical and social sciences. Whether as physical objects, temporal patterns, or mathematical attractors underlying surface chaos, fractal patterns appear to be ubiquitous in nature. Their presence on all sizes and scales of space, time, and the imagination is precisely what elevates their epistemological candidacy. Few other concepts or objects can match transpersonal psychology's scope across mind, matter, and spirit.

According to Harris (personal communication), the participation of contributors from the physical sciences in this journal is a welcome sign of the increasing acceptance of mathematics and the hard sciences within a maturing transpersonal field. I hope it is has proven refreshing to the readership to sample such a wide range of different perspectives. Most of the commentaries take for granted the legitimacy of my fractal claims by spring boarding off the target paper (Marks-Tarlow, 2020) within their respective fields. William Sulis fills in the history of mathematical precursors to fractal geometry. Jonathan Root gives a technical look at fractal dimensionality. Yakov Shapiro relates fractals to the complex topography of dynamical systems as applicable to psychology. William Coburn likens the complexity of fractals to situated perspectivism in psychoanalysis. Deborah Armstrong dons lenses as a clinician while resonating emotionally with fractals. Sally Wilcox and Leslie Combs equate far-from-equilibrium emergence to rare and unpredictable subjective transpersonal experiences. Katherine Kauffman Peil looks at fractals through evolutionary lenses related to emotion. William Jackson illustrates the widespread appearance of fractal images and concepts across world religions. Larry Liebovitch affirms the utility of fractals as an organic metaphor in contrast to the long history of mechanistic models of mind based on human technology. Fred Abraham examines the ontological significance of fractals as relates to the neurodynamics of mental processes. Herb Klitzner uses 4-dimensional quaternion fractals to model yoked polarities and perceptual switching in the brain. Larry Vandervert explores the interrelationship between form and function within the fractal neurophysiology of the cerebellum.

Harris Friedman presents himself as an "agnostic" with respect to fractals, while Elliot Benjamin expresses clear skepticism about their utility and uniqueness for modeling transpersonal phenomena. In my opinion, Benjamin has missed the central value of fractals for capturing fuzzy borders that are infinitely deep and filled with ambiguity, paradox, observer dependence, and interpenetrating elements. But in the pages to follow, I wish to address Benjamin's second concern—that fractals are not unique among mathematical objects for modeling psychological phenomena. Benjamin cites other mathematical objects that also possess psychological relevance, and by doing so, seems to believe this state of affairs renders my epistemological claims as irrelevant and arbitrary.

In putting forth a fractal epistemology, I do not wish to make a "one size fits all" claim. I am not asserting that fractal geometry is the only branch of mathematics worthy of providing metaphors and models for transpersonal phenomena. As a nonlinear science enthusiast and scholar, I do not endorse

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reductionism in any form and wholeheartedly agree that many facets of mathematics are useful to serve in this capacity.

Swiss psychiatrist Carl Jung came to view number as the most primitive quality of existence. By crafting an archetypal theory, his theory of number doubled over as a theory of mind. Jung attributed to number the power to bring order into the chaos of appearances, referring to material existence less as objectively conceived, and more as subjectively perceived by an observer. Jung viewed number as the realm where mind and matter meet, sometimes referred to as the psychoid level of existence and at other times the Unus Mundus (see Robertson, 1989).

As an example, Benjamin mentions the Möbius band as psychologically significant. To this I agree and wish to add the Klein bottle; both mathematical objects sport topological features that are literally mind-bending. Consider the Möbius band, which is made by cutting out a long strip of paper, giving it a half twist and then taping or gluing the ends together. The result is the topological oddity of a 2-dimensional object that occupies 3-dimensional space with only one side and one edge (Figure 1).

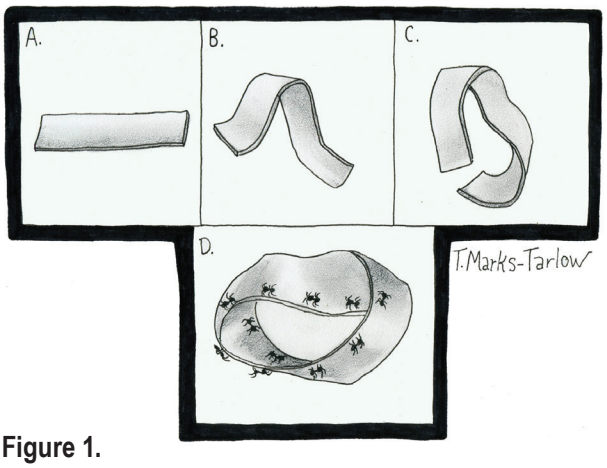

Figure 1.
Möbius Band, from *Psyche's Veil* (Marks-Tarlow, 2008)

As I have written previously (Marks-Tarlow, 2008; Marks-Tarlow, Robertson & Combs, 2002), the Möbius band functions like an Uroboros, or snake eating its own tail, prototypical symbol of self-creation (Neumann, 1954), based on the workings of recursive feedback loops, where each cycle ending becomes a new beginning.

In order to make a Klein bottle, one simply starts with a Möbius band and move it up a dimension by enclosing all the edges and stretching out certain aspects. What was the half twist at lower dimensions becomes a self-intersecting feature in higher dimensions (Figue 2).

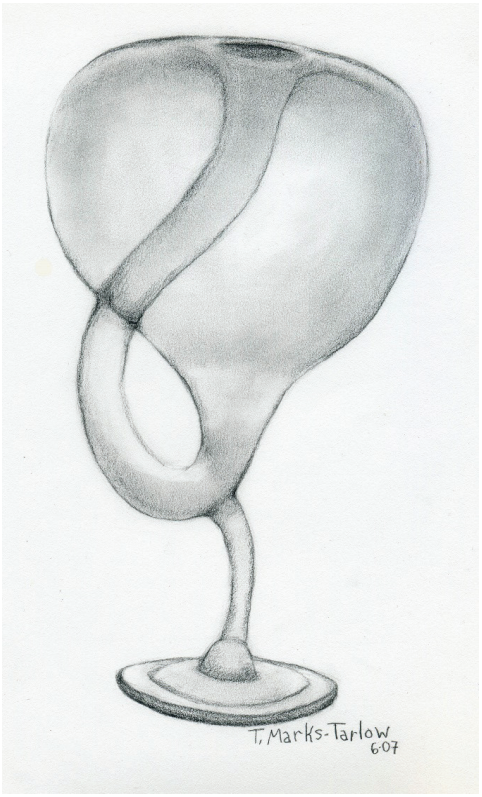

Figure 2.
Klein Bottle, from *Psyche's Veil* (Marks-Tarlow, 2008)

From our limited human perspective that is restricted visually to 3-dimensional space, the Klein bottle appears to contain both an inside and an outside. Yet, it is actually a 4-dimensional object, where much like the psyche, this self-intersecting object has porous boundaries, mercilessly leaking its insides into its outsides, and vice versa, forever.

Both the Möbius band and the Klein bottle relate to fractals, in that all share the quality of being *interdimensional*. From my perspective, it is precisely this quality of *betweenness* or *interdimensionality* that is so relevant to transpersonalists who love to explore interdimensional phenomena, such as mind travel through physical space or the mind's capacity to influence matter. The psychologist Steven Rosen (1994) has written a fascinating book, *Science,*

paradox and the moebius principle: The evolution of a "transcultural" approach to wholeness, which launches off these topological oddities to explore boundary crossings and paradoxes, such as "the two as one" within a philosophical position he dubs "nondualist dualism."

As I see it, both the Möbius band and Klein bottle are precursors to fractal geometry. They are paradoxical, interdimensional objects, with the concept of infinity implicitly tucked into their infinitely stretchable topological space. By contrast, fractal geometry utilizes infinity more explicitly within the new concept of fractal dimensionality. Their infinite stretch *between* ordinary dimension is what renders fractal objects ideal for incorporation into religious architecture and art, as Jackson so elegantly describes. To behold a progression of self-similar steeples as it unfolds upwards from a Buddhist temple is to get an embodied feel for fractals as grounded in the finite realm of matter, while stretching towards the infinite realm of spirit (Figure 3).

Figure 3. Rajbana Vihara, Rangamati, Chittagong (PD)

That the concept of infinity bridges mind, matter and spirit also arises in the work of Ignacio Matte Blanco (1980), a Chilean psychiatrist and psychoanalyst. Matte Blanco developed a rule-based structure using the mathematics of infinite sets in order to make sense of non-logical aspects of thought typical of the unconscious. According to Matte Blanco, the ordinary logic of the conscious mind conforms to additive, reductionist, asymmetrical properties of finite sets. For example, the conscious mind follows stepwise, Aristotelean, tautological, if/then logic: "*If* I do not do my laundry, *then* my clothes will not be clean." By contrast, the a-rational logic of the unconscious conforms to the symmetrical equivalence of wholes with their parts that is found within the mathematics of transfinite numbers, where for example, the set of infinite whole numbers is equivalent in size to any subsets, such as the set of all even numbers. Psychologically, Matte Blanco equates this property to children who generalize from parts to whole by calling all dogs "Fido," or adults who are racist by equating each individual member of a group to properties attributed to the group as a whole.

For Jung (1973), number serves as the most fundamental foundation of perceived reality, the place where observers and observed merge at the level of synchronicity, symbol and meaning. Similarly, Spencer-Brown (1969) developed a system of mathematics based on *first distinctions* of *something from nothing*. Spencer-Brown invented his own notation as the *cradle of creation*, both abstractly in domains of mind, and concretely in domains of matter, from which he then re-invented all of mathematics. While his followers love his work, his critics dismiss it as redundant. Within the unified cradle of creation, we might say the realm of mathematical abstraction is *discovered*, in so far as it is rule-bound and capable of uncovering quantitative facts about the workings of the external world. At the same time, it is *invented* as an abstraction, indicating something qualitative about the subjective realm of mind and meaning. In building a bridge between mind and matter, Jung and his dedicated follower, Marie-Louise von Franz (von Franz & Verlag, 1986), were interested primarily in the counting numbers as symbols and founts of inexhaustible metaphor during the production of conscious experience. Whether in dream, mythology or art, the number one tends to symbolize undifferentiated unity; two signifies the first distinction or duality; three indicates dynamic change and movement away from the static opposition, and four suggests stable manifestation.

A seminal paper by Robin Robertson (1989), Jungian psychologist and mathematician, advances Jung's search for number as the archetype of order. Robertson traces a history of the qualitative development of human consciousness based on the

evolution of quantitative, mathematical discovery. He describes four major stages of human conscious awareness. The first, most primitive stage begins with the counting numbers. Here, products of mind and products of matter are magically merged. The second stage involves the purely abstract discovery of zero, an absence that becomes a presence, allowing for the modern number system plus the discovery of negative numbers, as necessary for the debt/credit system of social exchange of goods and services. The third stage involves the discovery of infinity, which made possible calculus through the discovery/invention of limits. This enabled measurement of complex and moving objects that formed the foundation of the modern scientific/technological mind. Robertson's fourth stage is timed with the recursive mathematics of Gödel, who proved that no system of logic can be fully complete and consistent simultaneously. Meanwhile, Gödel's recursive method of correspondences modeled recursive loops of consciousness necessary for self-reflection as well as the nascent study of psychology (which uses the mind recursively to study the mind).

In a paper entitled, "Semiotic seems: Fractal dynamics of reentry" (Marks-Tarlow, 2004,) I extended Robertson's history of human conscious beyond the mathematics of Gödel as follows:

> I argue for the importance of fractal dynamics to model entangled relations between observer and observed. To recognize the broad foundation of fractal geometry within infinite recursion on the imaginary plane can enhance our understanding of reality as finitely perceived in nature. Conversely, to comprehend how fractals manifest ubiquitously at the joints in nature, in turn, self-referentially expands our understanding of mind, especially the deep relativity that exists between observer and observed at all scales of observation. I introduce self-similarity as a new symmetry in nature that represents the sign of identity. Explored semiotically, self-similarity can be seen as a distinction that leads to no distinction. I relate this paradoxical equivalence of change and no-change to the operation of cancellation within Spencer-Brown's arithmetic of first distinctions, as well as to Varela's reentry dynamics characteristic of autonomous systems. My thesis is that fractal separatrices between inside/outside, self/other, subjective/objective levels, as well as conscious/unconscious underpinnings of experience, represent an imaginary/real foundation for the entangled co-creation of world and psyche. (pp. 49–50)

In sum, I do not privilege the mathematics of fractals for modeling psychological phenomena. There is a place for all of mathematics to model and mirror human collective consciousness. At the same time, I do believe that only the mathematics of fractals is rich and robust enough to model the *most complex* psychological phenomena, which corresponds to the Mandelbrot set as the most complicated mathematical object known to humankind. I sincerely hope that by employing a fractal epistemology, some of the ideas expressed in these pages can be extended into new transpersonal horizons, currently invisible to us all.

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About the Journal

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