Complexity Science, Living Systems, and Reflexing Interfaces:

New Models and Perspectives

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Chapter 2
Fractal Geometry as a Bridge between Realms

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ABSTRACT

This chapter describes fractal geometry as a bridge between the imaginary and the real, mind and matter, conscious and the unconscious. Fractals are multidimensional objects with self-similar detail across size and/or time scales. Jung conceived of number as the most primitive archetype of order, serving to link observers with the observed. Whereas Jung focused upon natural numbers as the foundation for order that is already conscious in the observer, I offer up the fractal geometry as the underpinnings for a dynamic unconscious destined never to become fully conscious. Throughout nature, fractals model the complex, recursively branching structures of self-organizing systems. When they serve at the edges of open systems, fractal boundaries articulate a paradoxical zone that simultaneously separates as it connects. When modeled by Spencer-Brown's mathematical notation, full interpenetration between inside and outside edges translates to a distinction that leads to no distinction. By occupying the infinitely deep "space between" dimensions and levels of existence, fractal boundaries contribute to the notion of intersubjectivity, where self and other become most entwined. They also exemplify reentry dynamics of Varela's autonomous systems, plus Hofstadter's ever-elusive "tangled hierarchy" between brain and mind.

INTRODUCTION

Any distinction is wholly eyemaginary, an act of creation, an act of the imagination. Each proof that convinces is a proof that uses imaginary values to reason to a true answer… Mathematics is about the consequence of making a distinction, as if there were such a thing as a distinction. It is all imaginary and only the imaginary is real!
— Louis Kauffman

The capacity to make distinctions between *this* and *that* lies at the base of human consciousness. Throughout the lifespan a key distinction involves discerning inner from outer processes. That is, we must distinguish products of imagination, memory

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and dreams from outside objects, people and events in the environment. British psychoanalyst Donald Winnicott (1974) introduces the significance of childhood play for creating/discovering inner versus outer realms of experience, by speculating that symbol, self and culture all emerge in the "transitional space" between mother and child. Likewise Australian psychiatrist Russell Meares (2006) details developmental processes by which young children shuttle back and forth between incorporating outside objects into imaginary play, and breaking away from play to attend to goings on in the immediate environment. Through this shuttling of attention an ever moving boundary is established between the interior dialogue of a personal self and the exterior dialogue of a social self. Figure 1 illustrates the play of imagination as it exists between inner and outer realms.

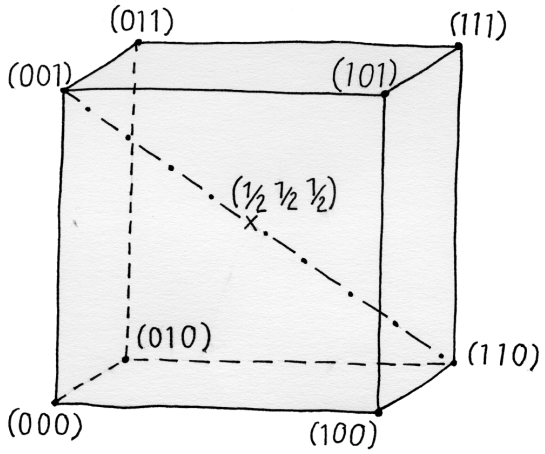
Whereas children's inner focus dictates the perspective of the observer, their outer focus illuminates objects and territory under observation. We might assume clear distinctions exist between observers and observed, but this is not necessarily the case. When a schizophrenic can't tell the difference between an object hallucinated and one that exists in reality, fuzzy boundaries between

Figure 1. The play of imagination as it exists between inner and outer realms (Courtesy of the author)

inner and outer realms become the stuff of psychosis. Yet similar fuzzy boundaries also characterize the mindsets of visionaries able to make their dreams come true. Clean boundaries between inner and outer realms, imply a Cartesian split as represented by the true/false, either/or distinctions of classic Aristotelian logic. According to this view, something *either* exists inside the observer *or* outside, but not in both places at once. By contrast, fuzzy boundaries offer more choices, with fuzzy logic permitting an infinite number of distinctions between true and false. This is illustrated by the fuzzy logic cube in Figure 2. If 1 and 0 represent true and false respectively, then the cube's corners are anchored by binary sets that characterize traditional logic. Inside the cube, a variety of fuzzy sets express degrees of truth, with the center point occupying the completely ambiguous, if not paradoxical, position of being just as true as it is false.

Writing about that magical, ambiguous zone between observer and observed, Lou Kauffman examines various systems of logic and mathematics. As the epigraph above indicates, Kauffman highlights paradox as he underscores the hidden action of the imaginary in bringing forth the "real" world of everyday distinctions. This chapter follows in the paradoxical spirit of Winnicott and Kauffman by investigating the play between imaginary/real, observer/observed as detectable within fractal geometry. I argue for the importance of fractal dynamics to model entangled relations between observer and observed, where each fully interpenetrates the other. By understanding the broad foundation of fractal geometry as it involves infinite recursion on the imaginary plane, we can enhance our understanding of reality as finitely perceived in nature. Conversely, by comprehending how fractals manifest ubiquitously at the joints in nature, we can expand our understanding of the infinitely extending, self-referential nature of mind. Of special interest here is the "deep relativity" that exists between observer and observed at all scales of observation, such that the closer we look, the more we can see. I introduce self-similarity as a newly discovered 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 main thesis is that fractal boundaries—whether between inside/outside, self/other, subjective/objective levels or conscious/unconscious underpinnings of experience—represent an imaginary/real foundation for the entangled co-creation of world and psyche.

Figure 2. Fuzzy logic cube (Courtesy of the author, from Marks-Tarlow, 2008)



Number as the Archetype for Conscious Order

If ... a group of objects is deprived of every single one of its properties or characteristics, there still remains, at the end, its number, which seems to indicate that number is something irreducible ... [something which] helps more than anything else to bring order into the chaos of appearances. — Carl Jung

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 *not as objectively conceived*, but rather *as subjectively perceived by an observer*. Here number links observers and observed, inner and outer worlds in a way parallel to second-order cybernetics. In the footsteps of Margaret Mead and Heinz von Foerster, this viewpoint is carried forth eloquently by the "Musings" of Ranulph Glanville, e.g., "the whole point of Second Order Cybernetics is that it asserts there is no observation without an observer. There is nothing spoken without a speaker, there is no action without an actor" (Glanville, 1998, p. 85).

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*. Jung intuited that the realm of mathematical abstraction is discovered, in so far as it uncovers quantitative "facts" about the workings of the external world. At the same time, it is invented as an abstraction in the mind, indicating something qualitative about the subjective realm of meaning. For Jung, number serves as the most fundamental structure of perceived reality, the place where observers and observed merge at the level of synchronicity, symbol and meaning. In building a bridge between mind and matter, Jung and his dedicated follower, Marie-Louise von Franz, 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.

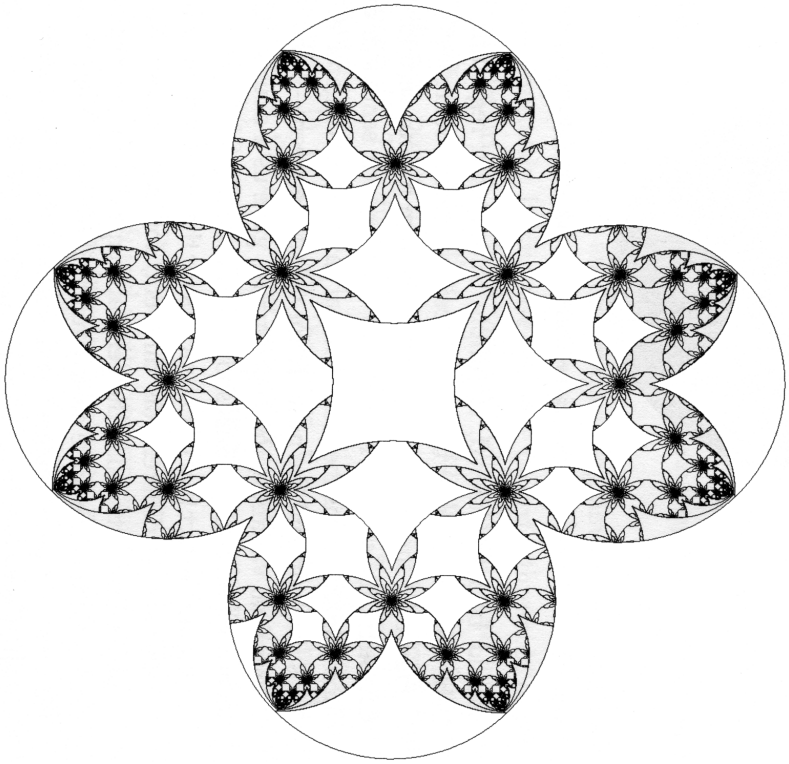
In this chapter I depart from the natural numbers that interested Jung to number as manifested *naturally* in what Benoit Mandelbrot (1977) calls the *fractal geometry of nature*. I argue for a link between imaginary numbers as iterated recursively on the complex plane and self-reflexive underpinnings of the dynamic unconscious. A precedent for my approach exists in the work of Jungian psychologist and mathematician Robin Robertson (1989). Robertson advances Jung's search for the archetype of order by tracing a history of the qualitative development of human consciousness based on the evolution of quantitative, mathematical discovery. Robertson identifies four stages of evolution, which I describe next, before placing fractal geometry into the context of the fourth.

The first stage involves knowledge of the counting numbers, as relates to primitive consciousness characteristic of many traditional tribes and young children. Here, the inner contents of the unconscious are unwittingly projected into outer, conscious experience. In cybernetic terms, observer and observed are unconsciously merged during the act of making/discovering distinctions in ongoing experience. Translated into the language of contemporary neuroscience, this stage depends upon procedural and implicit memory whose capacity is hard-wired into the primitive brain. This type of memory is *unconscious*, in the more contemporary meaning of the word, embraced by neuroscientists like Jaak Panksapp, Allan Schore, and Daniel Siegel. Whereas Freud's unconscious consists of repressed knowledge *dynamically* pushed beneath the surface of conscious awareness, contemporary neuroscientists view much of the brain's work as unconscious in a different sense. The self-organization of autonomic and limbic systems occurs subcortically, beneath the threshold of consciousness, operating on time scales too rapid *ever* to reach conscious awareness. This distinction between material pushed out of awareness and that which awareness can never reach becomes critical to my later assertion of fractal geometry as the abstract formalization for the ever-receding threshold between conscious and unconscious processes.

During stage two of collective human consciousness, zero emerges as a symbol around the dawn of the Christian era. Within Peircean semiotics, zero represents an important *portmanteau*, a sign that carries double meaning, in this case, by embodying paradox. Zero is a symbol form of *no-thing* that also means *some-thing*. In modern number notation zero serves as a placeholder that enables us endlessly to recycle the same ten digits. By eliminating the need for a different symbol to represent each new number, zero provides an invisible, underground unity to the number system. Here we see early glimmerings of Kauffman's virtual logic—the play of imagination that sharpens focus on "real" distinctions. Recycled digits brought the first formal sign of fractal dynamics within mathematics, albeit in inchoate form, because full arithmetic expression involves self-similar, nested structure on ever-grander scales of magnitude across the 10's, 100's, 1000's number columns. Whereas modern number notation represents a somewhat trivial example of self-similarity, in that it lacks the fractional dimensionality of true fractal form, SUNY philosophers Patrick Grim, Gary Mar, and Paul St. Denis (1998) assert significantly that all of mathematics and logic can be modelled on the computer as an infinitely expanding fractal system. Figure 3 illustrates one aspect of their system: how paradoxes of self-reference can be iterated on the computer.

The classic liar states, "This sentence is false." In the interpersonal version Socrates asserts, "Plato speaks falsely," while Plato counters, "Socrates speaks truly." Fuzzy logic allows infinite-valued variations, starting with the following two assertions:

Figure 3. Self-reference can be iterated on the computer (Courtesy of Patrick Grim, Group for Logic & Formal Semantics, Department of Philosophy, SUNY at Stony Brook)



x: x is as true as y,

y: y is as true as x is false

The assertions are translated mathematically as follows:

$$x_{n+1} = 1 - \mathrm{Abs}(y_n - x_n)$$

$$y_{n+1} = 1 - \mathrm{Abs}((1 - x_n) - y_n)$$

As these equations then are iterated on the computer, fractal images appear when escape time diagrams are colored according to how long it takes various pairs of points to cross certain thresholds.

Robertson's third stage in the evolution of modern consciousness emerged during the Renaissance with the formal introduction of infinity. Using zero as an anchor, humans flew to previously unseen heights of abstraction. The discovery/invention of calculus independently by Newton and Leibniz captured both symbols of zero and infinity concretely within the single concept of a *limit*. Calculus permits the human mind to delve ever more flexibly under the surface of moving and irregular processes into the chaos of imaginary waters, in order to resurface with a new perception of order. The simultaneous invention of perspective in art, plus René Descartes' method of analytic geometry, gave humankind an even sharper, downright 3-dimensional view of distinctions in the natural world.

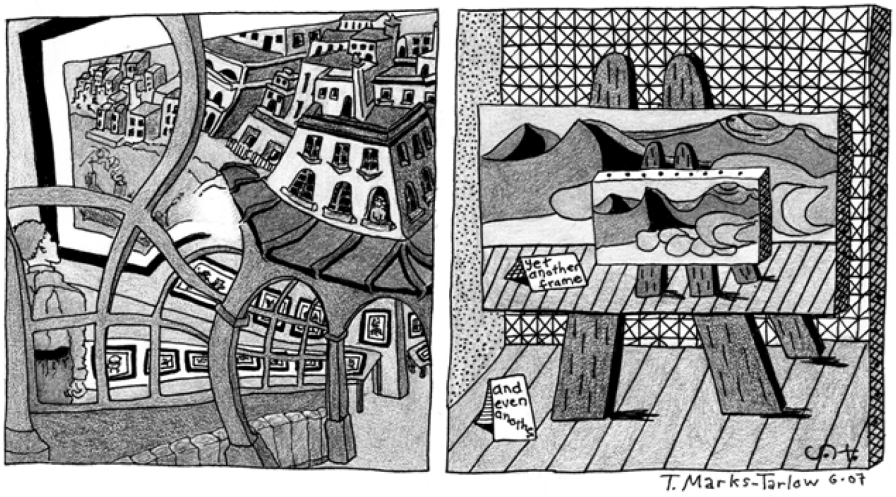
During this third stage, human beings stopped projecting the contents of inner processes into the outer world. Or at least, this is what they believed they were doing. Beginning with the Renaissance, all attention became fixated on how to categorize perceptible objects. The world of appearances became privileged over that of the imagination, and tools of science and math aided in this mission of *objectifying* perception. With everyone acting as if observers could be separated from processes of their observation, this period of collective consciousness accompanied the development of classical science, while anticipating the emergence of first-order cybernetics.

The fourth and current stage of self-reflexive consciousness arose during the nineteenth century, when previous seeds of recursion became concretely embedded into mathematical technique. Georg Cantor's introduction of the "pigeon-hole technique," by which numbers are paired one-to-one with subsets of themselves, brought recognition of multiple sizes of infinity. Eventually, the number of infinities proliferated until an infinite variety was unveiled.

At the same time that conscious understanding of recursion became ever-more deeply embedded in abstract systems of symbolization, human consciousness was beginning to circle back around to conceptualize imaginative bases for its own unconscious processing. This is evident in the work of South American psychologist, Ignacio Matte Blanco, who uses the seeming *illogic* of infinite sets to characterize the nature of unconscious thinking (e.g., Matte Blanco & Raynor, 1998). The hallmark of infinite sets—that their subsets equate to the whole—is apparent psychologically whenever we generalize a single encounter to every case. This occurs, for example, in the immature psyche of young children fond of calling all women "mommy." It also occurs in the immature psyche of adults guilty of stereotyping, racial bias or misogyny. By contrast, Matte Blanco claims that consciousness of everyday distinctions rests on the mathematics of finite sets. Here, thinking is tethered to deductive methods of concrete discovery. Objects either exist or do not, as deduced by minute-to-minute experience, and guided by Boolean and Aristotelian logic devoid of wild inductive leaps.

Matte Blanco's brand of virtual logic, inspired by properties of infinite sets, anticipates this author's intrapsychic interpretation of fractal dynamics (Marks-Tarlow, 1995; 1999; 2002; 2008). As mathematically defined, fractals are partially infinite and partially finite. While their Euclidean dimension anchors and bounds them in the real world, they also partake of the infinite, which is necessary to calculate fractional dimensionality. As elaborated upon shortly, fractals occupy a

Figure 4. a)Escher's drawing, The Art Gallery, and b) a portrays self-reference as a canvas within a canvas (Courtesy of the author, from Marks-Tarlow (2008))



a) b)

twilight existence *between* "real" and idealized dimensions. Here the symmetry of identity—self-similarity —paradoxically exhibits parts as complex and infinitely detailed as their whole.

Observers Observing Themselves: Imaginary Numbers and Hidden Dimensions

The shortest path between two truths in the real domain passes through the complex domain. — Jacques Hadamard

By self-reflexively using numbers to code and reflect upon other numbers, Austrian mathematician Gödel brought this fourth stage of human self-reflexive consciousness to full fruition in the mid-twentieth century. Enter second-order cybernetics plus symbol makers using symbols to symbolize the symbolizing process itself plus inherent limitations therein. Like an eyeball attempting to twist around to view its own mechanism, Gödel's mathematics plus the cybernetics of cybernetics make obvious that no observer can ever hope to observe the observation process fully, without either receiving an incomplete view or becoming mired in paradox.

Figure 4 illustrates how paradoxes of self-reference appear in the work of two different artists. The left frame portrays the author's rendition of Maurice Escher's famous drawing, *The Art Gallery.* An observer looks at a picture of a gallery that includes the observer himself. The perspective is continuous, as it wraps from outside towards inside the observer. Yet a point of discontinuity remains in the form of a blank spot in the center. The blank spot indicates a singularity forming where all order breaks down and the image dissolves recursively into internal contradiction. The right-hand frame, inspired by a David Hockney drawing, portrays self-reference as a canvas within a canvas, implying a discontinuous relationship between external observation and the embedded nature of the self as observer. Just as a different "picture" on the lens can emerge with the next blink of an eye, this form of discrete representation displays crisp edges between embedded levels.

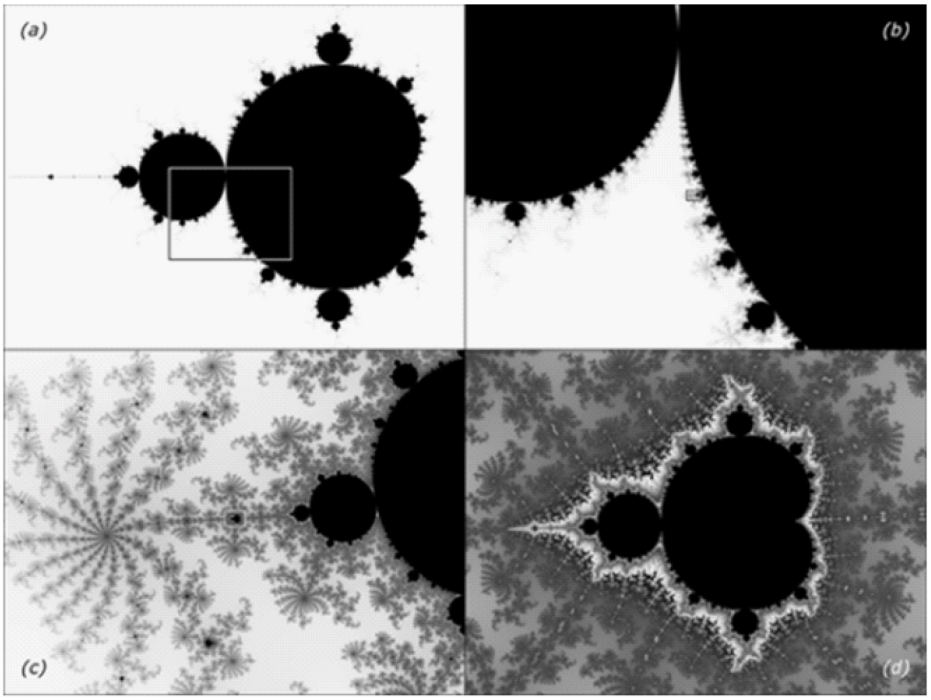
While I won't claim that fractals represent a symbol at the same level that zero and infinity do, I will assert that the system of notation ushered in by fractal geometry represents a portmanteau embodying infinite/finite, continuous/discontinuous methods of symbolization. Here, recursive iteration on the imaginary plane reveals yet another level of complexity both in nature and collective consciousness. Here, observers are even more complexly, self-reflexively and consciously entangled in the observed. This fleshes out further Jung's intuition that number brings "order into the chaos of appearances." Within fractals, not only does what you see depend upon the scale of observation, but also the closer you look, the more there is to see.

As a prelude to fractals, let's consider imaginary numbers, which appear as a vital link between complicated order manifest in nature and in the human mind. Discovered in the seventeenth century by Italian mathematician Jerome Cardano, imaginary numbers involve two independent, or orthogonal, axes, one real and one imaginary, and the seemingly impossible square root of –1. As their name suggests, these numbers originally were considered entirely fanciful, even though they kept cropping up in equations of the form, $X^2 = -1$. As often occurs with even the most far-out seeming mathematical abstractions, unexpected practical uses are eventually found, sometimes in the strangest, most apparently magical places. For example, although non-Euclidean geometry was originally thought impractical and contradictory to everyday perception, its rather strange geometry perfectly models Einstein's four-dimensional curvature of spacetime. Generally within mathematical equations, the square root of –1 represents invisible, extra, or hidden dimensionality. In electrical engineering it models reversed polarities of alternating currents. In Einstein's famous equation, $E = mc^2$, the square root of -1 represents the fourth dimension of time, added to the three customary dimensions of space: length, width, and depth. As modeled geometrically by Kauffman (2001), imaginary numbers also crop up in quantum mechanics, another field spawned by Einstein's discoveries, where they capture (or fail to capture) immeasurable, non-local aspects of electron behavior known as *wave functions*.

Jung and his followers play with the idea that imaginary numbers serve to unify inner and outer worlds. As Robertson (2000) notes, Jung mistakenly calls them "transcendent numbers," and names a corresponding psychological function – the *transcendent function* – after them. Jung interprets real and imaginary aspects of the complex plane in terms of the union of conscious and unconscious contents of the psyche. This union for Jung constitutes the essence of individuation, the process by which we come most fully into ourselves. During individuation, the "little self" of the conscious ego aligns and balances with the "big Self" of the unconscious whole: The part of the known coincides with the whole of the unknown.

Physicist and psychologist Arnold Mindell (2000) believes that all mathematics is a code for linking observers with the observed. Mindell upholds imaginary numbers to represent qualitative, subjective aspects of experience, or what he calls "nonconsensual reality," his thinking influenced by Wolfgang Pauli, a physicist whose psychoanalysis also inspired Jung. Pauli's most famous dream involved an inner music teacher who conceptualized imaginary numbers as the key to unifying physics and psychology (see Wolf, 1994). Geometrically, by signifying a phase shift of 90 degrees in the complex plane to represent orthogonal dimensions, Kauffman (2001) characterizes *i* as the most primal distinction in the observer. Generally, it appears that those artificially constructed *fictions* called complex numbers, which possess both a real and an imaginary component, tend to emerge in the very same, self-reflexive places where the observer is increasingly detectable within the observed.

Figure 5. A Mandelbrot set and its zoom levels (Courtesy of Nicolas Desprez, from Marks-Tarlow, 2008)



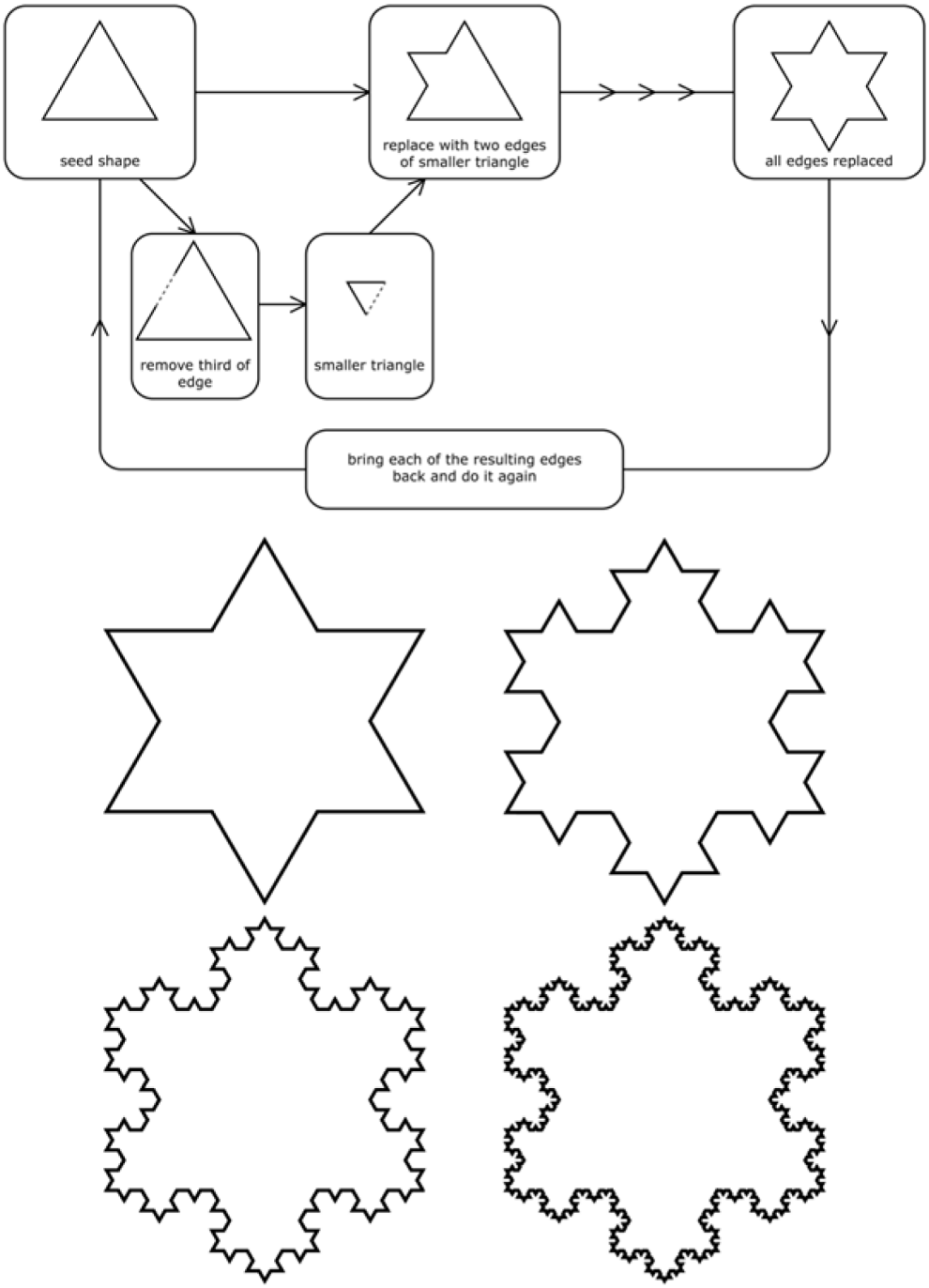
Fractal Geometry

If you like fractals, it is because you are made of them. If you can't stand fractals, it's because you can't stand yourself. It happens. — Homer Smith, Computer Engineer, Art Matrix

Fractal geometry represents the full mathematical fruition of the fourth stage of self-reflexive consciousness, where imaginary numbers are concretized in nature simultaneously to co-create world and self. Computer-generated fractals provide one of the most successful tools ever discovered/invented for simulating highly complex forms in nature. With fractals comes the cyber-semiotic recognition of how the infinite becomes finitely embodied in nature. When the computer is used as a microscope on the complex plane to zoom in on ever-smaller scales of the nonlinear Mandelbrot set ($z \rightarrow x^2 + c$), iteration exhibits unceasing complexity, shifting dynamically with the perspective of the observer. This is illustrated in the Mandelbrot zoom within Figure 5, where each box represents a magnification of a small area within the previous box.

The benchmark of fractals is self-similarity, a newly discovered, self-reflexive symmetry in which parts of a fractal object resemble the whole. Sometimes this resemblance is approximate and statistical, as is the case with the nonlinear Mandelbrot set. Other times self-similarity is exact, such as with linear fractals. Figure 6 illustrates a linear fractal called the Koch snowflake. In this figure, we easily see how each iteration brings greater complexity. While the area within the snowflake remains finitely bounded, the edges of the Koch curve grow infinitely complex. Whether we consider the linear or nonlinear variety of fractal, not only is the whole greater than the sum of its parts—the hallmark of organic as compared to purely mechanistic systems—but the whole is also paradoxically embodied within the very parts themselves.

Figure 6. Koch's snowflake (Courtesy of Nicolas Desprez, from Marks-Tarlow, 2008)



Everywhere they arise, fractals occupy the *boundary zone between dynamic, open processes in nature*. This quality of *betweenness* is illuminated by a technical understanding of fractal dimensionality. Since imaginary numbers model hidden dimensionality, in the case of fractals, this consists of infinite expanses, or imaginary frontiers that lurk *in the spaces between* ordinary, Euclidean dimensions.

Clouds can be conceived as 0-dimensional points that occupy 3-dimensional space. Coastlines are 1-dimensional lines that occupy 2-dimensional planes. Mountains are 2-dimensional surfaces draping a 3-dimensional world. Quaternions are products of the hypercomplex plane consisting of one real and three imaginary axes, as is illustrated in Figure 7. If imaginary numbers do relate to abstract processes in consciousness, and more specifically to the fuzzy zone between mind and body, inner and outer processes, then because they are 3-dimensional shadows of 4-dimensional space, quaternions may provide some clues as to the internal landscape of higher dimensional thought. To understand this, imagine a pink elephant dancing, and you will be manipulating a 3-dimensional image through the 4th dimension of time.

To calculate fractal or Hausdorf dimension (one of a number of ways to measure fractal dimensionality) a log/log relationship estimates the rate at which more information becomes available as we shrink the size of our measuring device. Here a kind of magic becomes evident in the unexpected relationship that emerges between the observer and observed, that is, between measuring stick and that which is measured. Unlike finite objects, where resolution of measurement is possible, because fractal objects partake of the infinite, they exhibit a paradoxical quality: the smaller the measuring stick, the larger the measurement, as illustrated in Figure 8. Because the quantity of measure continually alters relative to the size of the yardstick, fractal dimension is *not only a measurement of quantity* as we usually conceive it. Instead, fractal dimension represents a portmanteau that also indicates the *quality of relations between observer and observed*. Since fractal dimensionality signals what remains constant as we change scales, another paradox soon becomes evident. Fractal pattern simultaneously appears on *all* scales, at the same time that it demonstrates no characteristic scale – a quality called *scale invariance* (Figure 9).

Paradoxical Boundaries

The imaginary numbers are a wonderful flight of God's spirit; they are almost an amphibian between being and not being. — Gottfried Wilhelm Leibniz

Figure 7. A 3D fractal (Courtesy of Nicolas Desprez, from Marks-Tarlow, 2008)

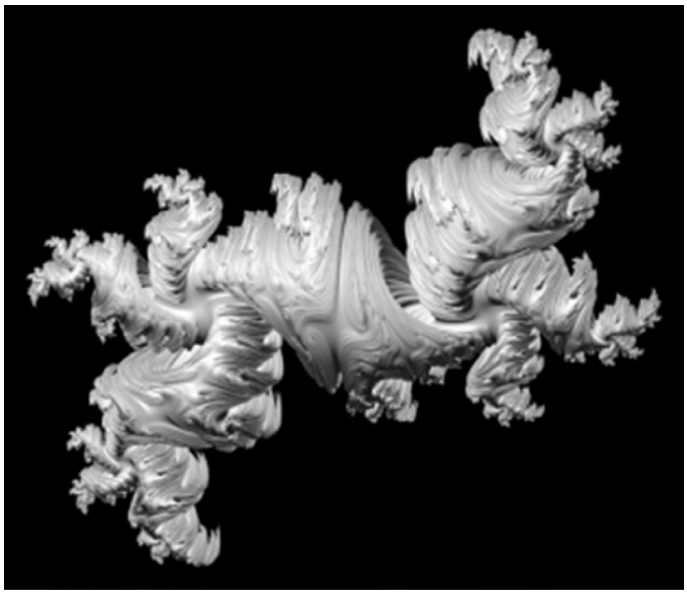


Figure 8. Compass rule to determine the fractal dimension of a Koch's curve (Adapted from Eglash, 1999, from Marks-Tarlow, 2008)

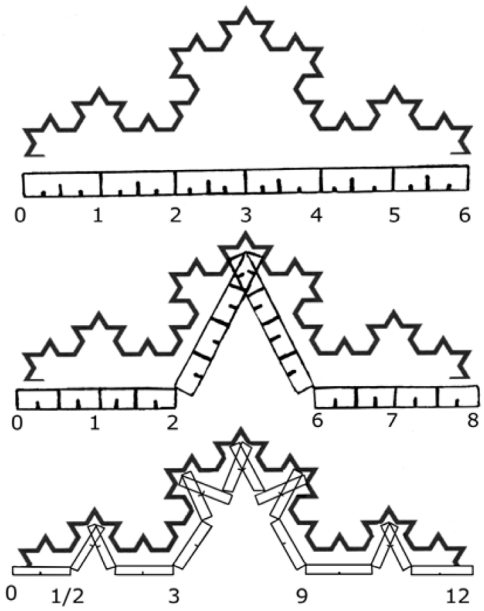
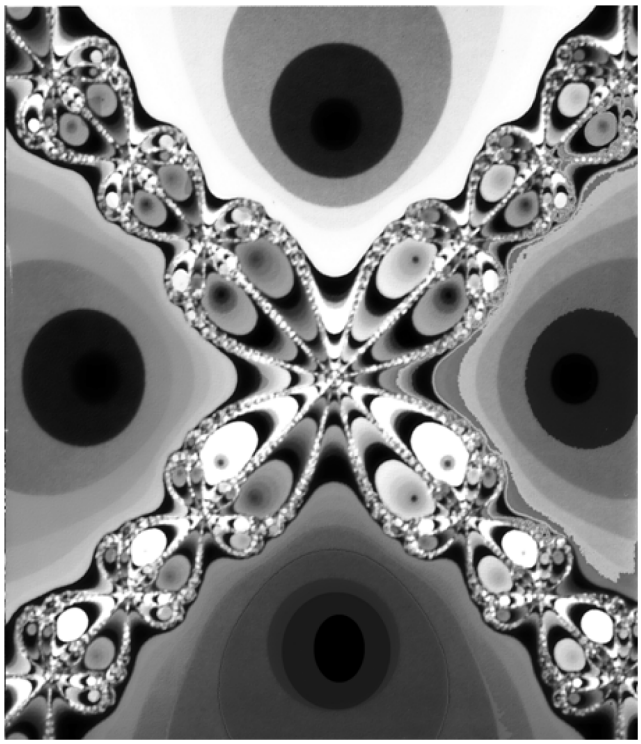


Figure 9. A fractal set (Adapted from Gleick, 1987, from Marks-Tarlow, 2008)



Although mountains and rivers appear to be stable *things* to our Western minds, they are actually continually moving processes that evolve dynamically on various time scales. The fiction of stability and *thingness* is reified by the English language with its predominance of nouns acting on and acted upon by verbs. The dynamism of fractals as processes-in-nature seems much more consistent with American Indian languages, where features such as lightning and coastlines are described using verbs.

As embodied in nature, fractals occupy the complex interface between chaotic forces, such as wind, water and heat comprising the weather. They represent the place where time gets etched into structure through process (see Kauffman, 1980). Fractal dynamics pervade our bodies (e.g., Iannaccone & Khokha, 1996), occupying zones of openness, communication and transportation between various subsystems of the body, as well as between the body and the outside world (Marks- Tarlow, 2002). Blood circulates throughout the body in the fractal branching of arteries and veins. The lungs cycle oxygen in and carbon dioxide out through fractal bronchioles. Even the ion channels in our cells and the neural pathways in the brain, our main organ for perception and communication, are fractal. Self-similar dynamics also pervade psychophysics, in that physical stimuli outside our bodies often follow power laws, which transmute into "just noticeable differences" in sensation and perception.

In human physiology generally, as in nature broadly, fractals function in open systems as boundary keepers, both by separating and connecting various subsystems and levels of being. Skin pores, wrinkles and other markings on the *sacks* in which humans and other animals are enclosed are usually fractally distributed. Facial wrinkles are a good example of how time can get etched into space through fractal form at the outer edge of our bodies. Whereas babies all have smooth faces, older people get uniquely lined. Brows furrowed with worry and mouths framed by laugh lines allow us to "read" the social history of a person. In this way, self-similar wrinkles engrave characteristic muscle patterns related to emotional response and expression throughout life.

Wrinkles reveal fractals at the interface between mind and body, psychological and physical levels. Likewise, fractals in the brain's neuronal branches and recursively embedded circuits mediate similar *space between* subjective and objective processes. Mathematician Manford Schroeder (1991) opened a door for analyzing fractals symbolically, through which cyberneticist Ron Eglash, among others, now walks. Eglash describes self-similar patterns in Dogon culture, based upon the human form as the unit of meaning (1989), as well as illustrates fractals in African settlement patterns (1999). Physicist-cyberneticist Nicoletta Sala demonstrates that fractal geometry, in particular the self-similarity, is present as an aesthetic property in all cultures, for example in African, Mesoamerican, Western, Japanese, Chinese, Hindu and Islamic cultures (Sala, 2004). She also analyzed the fractal components in different architectural styles as unconscious or conscious acts of design (Sala, 2002). This kind of geometry finds application for generating virtual worlds (Sala, 2010).

Elsewhere (Marks-Tarlow, 1999, 2002) I have detailed the existence of fractals at a more abstract, symbolic level within the human psyche. In the paradoxical, intersubjective space between self and other, fractal dynamics become evident in human behavior, as personality traits manifest in self-similar patterns at multiple scales of social observation. An aggressive person may push others aside verbally with overtalk, push ahead of others physically in bank and other lines, while pushing self-oriented needs ahead of others' in significant relationships. In the clinical sphere, fractals are evident in the frequent mirroring of content in process, as well as within common therapist lore that the entirety of a patient session or even psychoanalysis can be gleaned from a first utterance or dream (e.g., Levenson, 1983;

Marks-Tarlow, 2008). The fractal self is multiply embedded within different scales of social observation (Marks-Tarlow, 1999). Each of us has a proto-self that is biologically driven and precedes consciousness. We have an intrapsychic self, revealed by dreams and unique patterns within our intrapsychic landscape. We possess an interpersonal self, brought into social existence through interaction with others. We have a cultural identity that enables us to share the language and customs of like others. And we possess a national identity that contrasts with people from other countries. Possibly, we possess a global identity opened up by high-tech communication that allows instant access the world over.

Generally speaking, self-similar dynamics appear in the joints, in the space between levels. Not only does identity in nature appear fundamentally fractal, where self-similarity captures scale-invariant patterns as well as scale-variant irregularities and discontinuities, but also, fractals are prevalent in the psyche, where identity is constituted intersubjectively by endless feedback loops in the space between self and other, inside and outside. Within the psyche, scale invariance allows us to operate psychologically on all size and time scales, while self-similarity carries our characteristic stamp of uniqueness and wholeness to each facet of symbolic and social operations.

Seeking Semiotic Seams

It appears as if different, successively larger levels are connected and intercross at the point where the constituents of the new lower level refer to themselves, where antinomic [contradictory] forms appear, and time sets in. We recognize this fact in ordinary speech. When trying to convey a description of a new domain we often construct an apparent antinomy to induce the listener's cognition in a way such as to compel his imagination towards the construction of a larger domain where the apparent opposites can exist in unity. (A moral example: once you lose everything, you have everything; a philosophical one: a being is when it ceases to be). — Francisco Varela

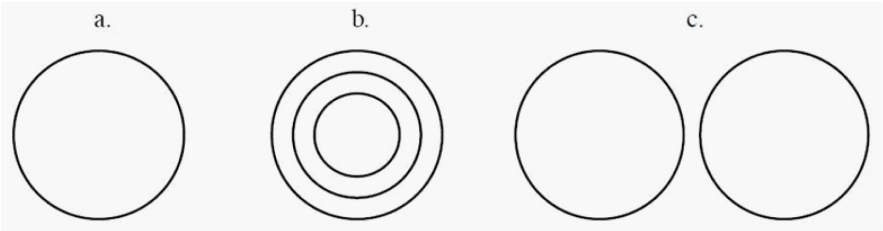
I have argued that self-similarity spans the full range of existence, from the most concrete, material levels to the most highly abstract and psychological ones. Viewed semiotically, I believe this newly discovered symmetry represents the sign for identity in nature, *the pattern of patterning,* by which essences actually precede evolution and biological reproduction. Due to self-similarity, wholes in nature can dynamically inform the shaping of self-similar parts.

Consider symmetry semiotically as a distinction that leads to no distinction. Within the search for universal scientific laws, this makes sense, because symmetry functions as a formal transformation that results in invariant operations. The idea of a distinction leading to no distinction also links back to the operation of *cancellation* within Spencer-Brown's primitive arithmetic (1969, 1979). Here, at the level of first distinctions, before space and time become established as clear dimensions, symmetry can be viewed as a double-crossing that annihilates the original distinction. An everyday example would be to rotate an object through a mirror axis of symmetry and then back, without any detectable difference.

At the level of first distinctions, where the act of marking is inseparable from the mark itself, a paradox appears: We can't tell the difference between a second crossing that, at less primitive levels, brings us deeper into marked space, over into unmarked territory, or right back to where we started. Formally, all three possibilities are equivalent (as shown in Figure 10).

This is easily visualized with the help of nested versus adjacent circles. Begin with the first distinction indicated by a circle that brackets off insides as *marked* from outsides as *unmarked* (a.). Now consider three recursively-nested circles, each inside the next (b.). Here, to cross twice represents penetration into a deeper level of marked space. In the case of two adjacent circles

Figure 10. Courtesy of the author, from Marks-Tarlow, 2005



(c.), to cross twice represents entry into an entirely different marked space. Finally in the case of only a single circle (again, a.), to cross twice is to leave and reenter the original marked area. The single circle (a.) represents the basic inner/outer distinction of the self; the three nested circles (b.) represent degrees of interiority of the self; while two adjacent circles (c.) represent the two subjectivities of self and other. The impossibility of formally distinguishing between these three conditions establishes their imaginal, paradoxical foundations at the level of first distinctions. This inability definitively to distinguish between realms of self, world and other carries far-reaching implications.

In the *Laws of Form*, logician Spencer-Brown moved from the duality implied by first distinctions, to paradox that sometimes stems from the self-referential capacity of a system to reenter itself. Varela (1975) notes the brilliance of Spencer-Brown's interpretation of the paradox of reentry as an oscillation, or "an *imaginary* state in the form seen in *time* as an alteration of the two states of the form" (p. 20, emphasis in original). Spencer-Brown's "discovery" of time implicitly links paradoxical form to imaginary numbers on the complex number plane. By asserting reentry as a third value in its own right, Varela agrees with Spencer-Brown that self-referential dynamics establish the presence of time. With Kauffman, Varela went further to assert that paradox becomes embodied at the most basic level, *in the very process dynamics of form itself* (Kauffman & Varela, 1980).

Perhaps the primal confusion surrounding first distinctions, where a double-crossing sometimes leads back to the original marked area and at other times does not, helps explain why Varela's reentry dynamics sometimes lead to paradox and at other times do not. This primal confusion between inside/outside, self/other, organism/world becomes even clearer where second-order cybernetics dovetails with clinical psychology. In this territory, we find a persistent, fundamental inability to distinguish between the deepest recesses of our own subjectivity, versus the intersubjectivity of others, versus the "objectivity" of a world that exists outside of the organism. The notion of primal confusion helps explain the *felt-reality* of dreams and psychoses, and legitimates the controversy surrounding psychoanalytic concepts, such as introjection (the subjective reality of an idealized other as "swallowed whole"), or projective identification (an aspect of the therapist's experience considered as a *disowned* piece of the patient's psyche). Finally, it lends a kind of *imaginative reality* to the apparent *out-there-ness* of everyday experience as well as to the "objective stance" of classical science.

In a previous article for *Cybernetics & Human Knowing* (Marks-Tarlow, Robertson & Combs, 2002), I, with colleagues, speculate on the psychological significance of Varela's recursive dynamics, by examining the individuation process as lifelong, self-reflexive cycles of reentry. Psychological birth is preceded by the paradoxical union of opposites within the unconscious, as we begin our mental life with good/bad, you/me, inside/outside melded together. In order to

make first distinctions, nascent consciousness must separate each pole from its opposite. Yet, complete psychological evolution requires that we bring together, blend and balance all opposites. Inner development requires that we leave ourselves in order to get deeper inside. In fact, spiritual advancement can be characterized as the use of self-reflection to achieve increasing objectivity. Yet most spiritual paths aimed towards objectivity move in the opposite direction, e.g., using methods of meditation, to delve yet further *inside* one's inner life. To reframe this primal confusion in terms of fractal boundaries between mind and body, conscious and unconscious elements of experience, provides a new reading of Douglas Hofstadter's (1979) seminal book, *Gödel, Bach and Escher*. Within his proposed *tangled hierarchy*, the "software tangle" of symbols as supported by the brain's "hardware tangle" is easily re-conceptualized in terms of fractal boundaries. Such thinking receives empirical support from the research of Carl Anderson (e.g., Anderson et al., 1998) on the role of rapid eye movement (REM) sleep in fetal and neonatal brain development. Periods of *nuchal atonia* (loss of neck muscle tone) during REM sleep appear organized into self-similar patterns of phasic EMG bursts. From this and related studies, Anderson theorizes that the foundations of consciousness are based on the vertical convergence of 1/f power law dynamics, from ion channels to behavioral states (Anderson & Mandell, 1996).

More broadly, I propose that fractals comprise reentry dynamics within Varela's (1979) realm of *autonomous functioning*, typified by borders that are functionally closed yet structurally open. Whether in organic or inorganic forms, autonomous systems appear supported by inherently contradictory underpinnings, which allow recursive cycles of reentry to etch temporal dynamics into spatial form. In the epigraph at the beginning of this section, Francisco Varela (1975) offers self-reference as "the hinge upon which levels of serial inclusiveness intercross" (p. 12). It is easy to view the universe in terms of successively larger levels of serial inclusiveness. As a crude example, from a semiotic perspective, we might say that physics is embedded within chemistry, which is embedded within biology, which is embedded within psychology. Fractal boundaries help us to conceptualize how Varela's levels of serial inclusiveness connect and intercross. The primal confusion that arises when discontinuous, finite distinctions are made in systems that are embedded in infinite, continuous dynamics suggests why paradox so often arises at the seams in nature.

Whether existing in symbolic or physical form or comprising ordered attractors beneath chaotic forces in nature, fractals negotiate the boundary zone, a place where levels contain the antinomy of opposites both unified and separated. Because fractals span all scales of observation, both to divide and connect them at boundary points, these dynamics might help to bridge traditional levels of analysis, from the purely physical level of Prigogine's far-from-equilibrium thermodynamics, through biological levels of reentry in Maturana and Varela's autopoietic systems, to higher order social and cultural levels implied by Peirce's concept of historical drift and praxis.

CONCLUSION: A FINAL WORD ABOUT CYBERSEMIOTICS

This chapter suggests fractal geometry as an important archetype of order, the pattern of nature's patterning, as a bridge between finite and infinite dimensions, real and imaginary processes, as well as material and psychological levels of existence. One irony is this: While we use *unnatural* or mechanical means, such as computers, to discover and illuminate the workings of fractals, what we illuminate extends beyond and beneath the postmodern mirrors that reflect infinite regression in forms of human production and reproduction. Ranulph Glanville rails against the cybernetic nightmare of machines controlling human beings, presenting

instead the second-order cybernetic alternative of the controller controlled by the controllee. Fractal geometry helps us move away from the paradigm of control entirely. By illuminating fractals, we self-reflexively illuminate wholes in nature where the observer appears in the observed during the co-creation of both.

That we need the computer to help us visualize fractals suggests the importance of cybersemiotics to psychological development. While it takes a community to raise a child, by providing multiple subjectivities necessary for full cultural and social awareness, ironically it takes the mechanism of a computer to develop the potential for greater self-awareness and connectivity back to nature. Because the mathematics of fractals depends upon infinite, recursive iteration, humankind had but a glimpse of this geometry during the nineteenth century, in the form of *monster curves* and Julia sets.The ability to represent the granddaddy of all Julia sets – the full Mandelbrot set – plus higher dimensional offshoots – like quaternions – required the speed and tremendous parallel processing capabilities of the computer, which was not possible until the end of the twentieth century.

Whereas first-order cybernetics purports to represent reality as it exists outside of observers, second-order cybernetics twists around recursively to represent the observers themselves, using the computer as metaphor and mind modeled as mechanism. With fractal geometry, the metaphor comes full circle back to its organic bases. A unity between mind, machine, and nature becomes apparent when self-similarity is regarded as nature's sign of identity. This insight dovetails with the frequent spiritual vision of all of creation as a self-reflexive expression of self into form in order to know, share and lovingly reunite with Self. Indeed fractals are evident in religious images and architecture throughout the world (see Jackson, 2004). The notion of fractals unifying mind, machine and nature also dovetails with the position of neurological positivism espoused by philosopher and psychologist Larry Vandervert (1990). Vandervert claims that evolution itself proceeds self-reflexively, culminating in the most complex object in the known universe, the human brain. As we use our brains self-reflexively to examine ourselves, our models grow more sophisticated and ever closer to the fractal stuff of which our minds, brains and nature at large is composed.

Semiotically, the ubiquitous presence of fractals and self-similar dynamics in mind, body, and nature as revealed by modern computing, offer exciting possibilities for new metaphors of unity between mind, machine and nature. By allowing us to see deeper into the unconscious bases of our own experience, fractals point the way to the invisible, interconnected ground of all being, giving rise to observer and observed, mind and body, inside and outside, subjective and objective experience alike. Here we glimpse the fabric of the infinite whole as it is sewn into each finite part.

In sum, whereas Jung speculated about the archetypal significance of the *natural* numbers, in this essay I explore number as manifested *naturally* in the fractal geometry of nature. Whereas Jung speaks of number as an archetype of order *which has become conscious*, I present fractal geometry as deep order under chaos, *which is yet to become conscious and impossible ever fully to do so*. With fractals as a new metaphor of mind, we no longer need to deify or defile mechanism as metaphor.

Instead we can use mechanism as a tool. As we continue to use the recursive formulas of chaos, complexity, fractal geometry and cellular automata to simulate the natural world, we see across multiple, nested levels of serial inclusiveness, how self-similar fractal dynamics recur as a meta-pattern.

Cycles of reentry continually oscillate between creating and erasing the seam where observer and observed, perceiver and perceived, inner and outer, self and other, intersect and self-cross paradoxically. At these semiotic seams, self and world appear mutually co-determining. Meanwhile, fractals represent another level of abstraction in human consciousness, suggestive of the dynamic

underpinnings of the unconscious. In this elusive seam where the unconscious and conscious minds touch, we forever seek the means by which brains cobble minds that study brains. Here, the physiological act of making a distinction creates the world as we perceive it, while the world brings distinction to the consciousness of the perceiver.

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