Knowledge as Ecological *Cosmopoiesis*: From Euclidean Geometry to Geometrical Bioinspiration

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Abstract: The paper aims to outline a historical-epistemological trajectory that highlights the processes of *ecologization* of the mappings and geometric-mathematical models produced by Western civilization, thus developing a path in four stages. The first is marked by Euclidean geometry, whose metric rigor reduced the complexity of natural patterns to pure, ideal forms. However, the belief that Euclidean geometry constitutes the ontology of reality has been challenged by non-Euclidean geometries and by the reflections of the mathematician Imre Toth, according to whom geometry is not the ontological language of the world but, conversely, an activity of the human mind that implies a cosmopoiesis, the construction of infinite possible cognitive worlds. From this perspective, the fractal world is an exceptional case. Benoît Mandelbrot, for the first time in the history of Western mathematics, marks the end of the *a priori* application of models to reality, to observe the intrinsic patterns and forms of nature itself. Finally, we now witness a tendency, in biological avant-gardes, not only to observe the fractal forms of nature but also to relate natural geometry to the cognitive faculties of ecosystems, as shown by the studies of Stefano Mancuso. In this case, the biological geometry of nature becomes the reflection of the mind of ecosystems and, above all, can become a source of *Bioinspiration*: the possibility of rethinking social, urban, and digital systems looking at the organization of the natural world.

Keywords: *ecological civilization; cosmopoiesis; fractal geometry; bioinspiration; plant intelligence; ecological epistemology*

Ecological Civilization and Geometrical Models of Reality

The measure of an ecological civilization does not indicate exclusively the technical apparatuses through which it interacts with natural ecosystems; more properly, it refers, in the first place, to the scientific, philosophical, and religious ideas related to nature. Ideas that, inevitably, guide and influence economic and technical systems in the relationship between natural systems and social systems. In particular, the measure of a technological civilization depends, also and above all, on the ways in which natural ecosystems are represented, depicted, and mapped.

As Chilean neurophysiologists Maturana and Varela highlighted, every organism produces maps of reality: it does not interact with reality itself, but with its own systematizations of the world.[1] Indeed, an ecological civilization is also measured by the ecological quality of the maps it produces. We can affirm that a map of reality can be more or less ecological depending on its degree of reductionism.

I would like to examine the case of Western civilization, whose geometric-mathematical mappings of reality have undergone, over the years, profound transformations.

As is well known, Western scientific knowledge, developed with the rigor that characterizes it from the sixteenth century onward, is undoubtedly among the causes of the first and second industrial revolutions, whose well-known technical benefits are parallel to an ever more severe violation and plundering of natural ecosystems. According to Edgar Morin, the cosmological conception of classical science is characterized by four epistemological pillars: the pillar of order, the pillar of separability, the pillar of reduction, and the pillar of identity logic. In particular, the pillar of order postulated that

> the Universe is governed by imperative laws. Their absolute character derives from the origin of absolute monarchy, human and/or divine. Until Newton, it is divine perfection that guarantees the perfection of the Laws of Nature; subsequently, as God was reduced to technological unemployment by nineteenth-century science, Order is founded on itself, or rather it is the world conceived as a perfect machine that acquires the absoluteness torn from God. From the sovereignty of order thus derives a deterministic and mechanistic conception of the world. Every apparent disorder, every apparent chance, is considered as a deficiency of our knowledge or

[1] Humberto Maturana and Francisco Varela, *L'albero della conoscenza*, trans. Giulio Melone (Milan: Garzanti, 1992), 114.

> as an effect of our provisional ignorance. Behind this apparent disorder, there is a hidden order to be discovered.[2]

An order that, as testified by the reflections of Galileo Galilei and Johannes Kepler, is, ultimately, a Euclidean geometric-mathematical order. As is well known, indeed, for Kepler, "geometry, which before the origin of things was coeternal with the divine mind and is God himself...supplied God with patterns for the creation of the world, and passed over to Man along with the image of God".[3]

Similarly, the father of the experimental method, Galileo Galilei, stated that

> Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth.[4]

This radical form of Platonism and mathematical realism thus replaced the complex and processual multiplicity of reality with a fixed, immutable order corresponding to the metric space of the Euclidean plane; a space, therefore, of pure and eternal forms, which are thus hypostatized and made the ontological measure of the totality of reality. The operation of simplification is evident: the world described by modern philosophy is a complete and finished cosmos, only apparently chaotic and processual: the goal of science is, then, to identify the essential order of phenomena through a calculating and mathematizing Reason. The rationalization of the complexity and processuality of nature has led, over the years, to an evident plundering of natural resources: if, in the modern perspective, indeed, nature is a mechanism ordered according to a Euclidean space, which sees individual objects in linear and efficient interaction, the ecological consequence is that this nature, in fact inert matter, can be manipulated according to various necessities.[5]

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[2] Edgar Morin, *La sfida della complessità: La défi de la complexité*, ed. Annamaria Anselmo and Giuseppe Gembillo (Florence: Le Lettere, 2017), 32–33.

[3] Johannes Kepler, *Harmonice Mundi: The Harmony of the World*, trans. E. J. Aiton, A. M. Duncan, and J. V. Field (Philadelphia: American Philosophical Society Press, 1997), 304.

[4] Galileo Galilei, *Discoveries and Opinions of Galileo*, trans. Stillman Drake (New York: Doubleday Anchor Books, 1957), 237–238.

[5] Carolyn Merchant, *La morte della natura*, trans. Libero Sosio (Milan: Editrice Bibliografica, 2022), 297.

Yet, the history of geometry shows that far from being the transcendent and immanent language of reality, geometry, in its historical transformations, proves to be an interpretative language produced by human spiritual activity. The French Argentine epistemologist Miguel Benasayag, in fact, has distinguished Rationalism, that is, the dogmatic and scientistic faith in the cognitive power of a mathematizing Reason, from Rationality, that is, the attitude to pose foundational questions about reality. In this perspective, Rationality can only be historical. According to Miguel Benasayag, who reinterprets the history of geometric-mathematical sciences,

> rationality must be seen as a historically constructed system with variable geometry. Some elements that are at the heart of a certain system are suddenly set aside, only to reappear at the border of the irrational, or to be definitively expelled. The use of leeches applied to patients' bodies was long considered rational by doctors, before this practice became irrational. Other elements lose their universal character to become rational in a more localized way, as in the case of Newton's gravitational theory, which becomes regionalized and coexists with Albert Einstein's theory of general relativity.[6]

Reality, in this sense, is thus defined as processual, historical, entropic. The knowledge one has of reality qualifies, in the second place, reality itself: the world with which subjectivity interacts is always conceived starting from certain categories of meaning, which are inevitably interpretative and evaluative categories. Finally, the knowledge of the world, like the world itself, changes: it is a historical system as well.

Geometric space, then, in this perspective, does not reveal the essence of reality but, rather, is a map that can be applied to a processual, transformative territory. Already, Alfred Korzybski distinguished the territory from maps of the territory, stating that "a map is not the territory it represents, but, if correct, it has a similar structure to the territory, which accounts for its usefulness."[7] The territory is a metaphor, it refers to concrete, material reality. However, as physicist Werner Heisenberg also showed in his own 'Ordering of Reality', the knowledge one has of the world remains inevitably 'filtered' by mental and cognitive maps which can never perfectly correspond to the represented territories, as they

[6] Miguel Benasayag and Régis Meyran, *La tirannia dell'algoritmo*, trans. Eleonora Missana (Milan: Vita e Pensiero, 2020), 30.

[7] Alfred Korzybski, *Science and Sanity: An Introduction to Non-Aristotelian Systems and General Semantics* (New York: Institute of General Semantics, 1933), 58.

depend on biological, bodily, cognitive, ideological, cultural, social, theological factors, etc.[8] "The menu is not the meal", as probably stated by the American philosopher Alan Watts, whose theoretical commitment was to disseminate Eastern thought in the West, in particular Buddhist and Taoist philosophy.

If the map is not the territory, if an ordering of reality does not correspond to reality, thus surpassing the Thomistic and Cartesian dogma of Adaequatio rei et intellectus, since maps are free productions of the Spirit, it follows that the production of epistemic maps represents a moral challenge with evident ethical responsibilities.

This is the line of thought of the Romanian philosopher of mathematics Imre Toth, whose intellectual commitment has always aimed at a full understanding of geometric productions as free activities of the human Spirit, in relation to a reality that he attempts to understand through tools which, before being rigorous or exact, are above all creative.

More radically, geometry is, for Imre Toth, a production of worlds, a true anthropological Cosmopoiesis of universes endowed with internal coherence. Indeed, the mathematician has told:

> The reflections I have been able to make have convinced me that mathematics is also an organic domain of the human spirit and the development of consciousness of freedom also takes place within this domain, apparently cold, and in it assumes very particular traits. In mathematics, we are dealing with a plurality of different worlds, and as the great mathematician Gerolamo Saccheri demonstrated, if a single triangle, even just one, of a geometric world is Euclidean, then all objects of the world are Euclidean. And if a triangle, a single triangle, is non-Euclidean, then all, absolutely all geometric objects of the world are non-Euclidean. In the first case, the world, the absolute totality of all that is, is Euclidean; in the second case, all that is, is non-Euclidean. Thus, we have two opposing "totalities" which, nonetheless, coexist simultaneously.[9]

Far, therefore, from being the Absolute Order characterizing the ontology of the Cosmos, mathematics and geometry are themselves producers of worlds.[10] According to Toth, mathematics and geometry are closer to artistic productions than to the rigor of physical sciences. In fact, he has stated:

[8] See Werner Heisenberg, *Ordinamento della realtà*, ed. Giuseppe Gembillo and Giuliana Gregorio (Messina: Armando Siciliano, 2020).
[9] Imre Toth, *Matematica ed emozioni* (Rome: Di Renzo, 2020), 46.
[10] See Morin, *La sfida della complessità*, 33.

> I realized that, from this point of view, mathematics can be compared rather to art, because there are only two forms of exact knowledge: Euclid's Elements and Flaubert's Madame Bovary. It might seem a jest, but it is not. When speaking of a triangle, of its properties, these must hold for all triangles, at all times, and are the properties indicated by Euclid; those that are not indicated, for example whether the triangle is red or blue, are not properties of the triangle, they simply do not exist. Thus, it is said that mathematics is an exact science, because it describes the triangle exactly. But the fact is that the triangle, as an object, imitates the text and it is not the text that describes the triangle. If we draw a triangle on the blackboard, the text does not describe this triangle of ours, whose lines will not be precisely straight, the vertices will not truly meet at a point, and so on. Conversely, our triangle, as an imaginary object, must imitate the text. But what about Madame Bovary? Madame Bovary is exactly as Flaubert described her in his book and no otherwise.[11]

However, there is a substantial difference between artistic productions and geometric-mathematical ones. The latter, in fact, are directly applied to nature and can, consequently, radically modify its internal balances. Toth himself clarified that "while a novel has no direct application to reality – at most, it can be used as a metaphor – mathematical theories can, sometimes, be applied to reality and profoundly modify it".[12]

It therefore seems appropriate to propose an epistemological reflection regarding the ethics of geometric-mathematical modeling and, more generally, the multiple systematizations of knowledge that cultures and societies can produce. The ontologization of Euclidean space has provided the image of an ordered and complete cosmos, built by a God-Demiurge like a clock: the movement of the individual part is the efficient cause of the movement of the other. The parts are not in transformative relations with each other but, rather, in static interaction. In short,

> God has created a perfect mechanism. Like a watchmaker, he has constructed a device made of interconnected pieces; the movement of each of them is determined by the piece that precedes it and determines the piece that follows. This movement obeys unchangeable rules; as a result, it follows a cyclical pattern in which everything repeats itself under any circumstance: place and time do not affect the

[11] Toth, *Matematica ed emozioni*, 41.
[12] Toth, *Matematica ed emozioni*, 42.

> events. Everything is reversible, and from any point, one can go forward as well as backward with perfect coherence: the great chain of Being, whose links are connected according to a cause-effect relationship, can be reversed and retraced in the "negative" effect-cause direction.[13]

If modern philosophy of nature was certainly revolutionary, as Miguel Benasayag showed, the scientific revolution of the twentieth century demonstrated the limits of rationalist knowledge.[14] Euclidean models were proved insufficient to grasp the abundance and complexity of reality, which was reduced to abstract geometric forms whose techno-scientific application did not capture the emergent properties of ecosystems, which today are radically modified by the rationalizing activity of humans.

It is therefore necessary to think of new maps, new orderings of reality capable of understanding and respecting the complex processual dynamics of reality. Given that every map is produced by a subject, the challenge posed by the current environmental crisis is, before being political or technological, cognitive: in what ways can sciences produce epistemological systematizations that do not separate humans from nature but, on the contrary, contribute to enhancing its intrinsic interdependent relations? Above all, in what ways can geometry respect the reality it intends to understand? If, indeed, an ecological civilization requires a rethinking of the way we inhabit the world, it is urgent to consciously and ethically reconsider how we design, depict, and map our environments. In this sense, geometry can become a relational gesture, a practice of signification and understanding of reality.

Geometry of Nature as an Ecological Relation

It appears that it is in this direction that the studies of the new world of fractal geometry proceed, thematized from the 1960s and 1970s by the French mathematician of Lithuanian origin Benoît Mandelbrot. Mathematical knowledge ceases, in fact, with Mandelbrot, finally, to claim to rectify reality based on approximations referring to 'pure' geometric forms, in order to grasp, on the contrary, nature in its irregularity, fragmentariness, and fractality.

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[13] Giuseppe Gembillo, Annamaria Anselmo, and Giuseppe Giordano, *Complessità e formazione* (Rome: ENEA, 2008), 20–21.

[14] See Benasayag and Meyran, *La tirannia dell'algoritmo*, 34–35.

Referring to the mathematical revolution he triggered, Mandelbrot thus comments on the discontinuity between Euclidean geometry, a geometry of pure and ideal forms, and fractal geometry, which looks at the patterns of irregularity of natural forms:

> To appreciate the nature of fractals, it is useful to recall the splendid Galilean manifesto of 1632: "Philosophy is written…in the language of mathematics, and its characters are triangles, circles, and other geometric figures, without which means…it is to wander in vain through a dark labyrinth". Note that circles, ellipses, and parabolas are almost perfectly smooth forms and that a triangle has very few points where it is irregular. Such forms were my youthful passion, but in nature, they are the exception. When he stated that they are indispensable to science, Galileo was absolutely right. Then, however, they proved insufficient, for the "simple" reason that the world is decidedly rough and very complicated. Nevertheless, the infinite sea of complexity includes two islands of simplicity: one is Euclidean simplicity; the other is relative simplicity in which roughness exists, but it is the same at all scales. The cauliflower is a typical example of a form that does not change if shrunk or enlarged. A glance is enough to notice that it is made of many florets. Now, if we remove one and examine it by itself, we notice that it looks like a small cauliflower. Repeating the operation (soon a magnifying glass will be needed) we find ourselves with an ever smaller cauliflower but identical to the original, aside from size. The cauliflower is an excellent example of an object made of many parts, each of which is the object itself in miniature. Another example of repeated roughness is the cloud. A cloud is made of protrusions upon protrusions upon protrusions similar to miniature clouds. Approaching a cloud, one does not arrive at seeing something smooth, but always the same irregularities at a smaller scale.[15]

It is evident, in short, that nature presents itself in a far from ordered, smooth, or 'straight' shape: on the contrary, the patterns and structuring forms of nature are rough, irregular, characterized by jaggedness and interruptions that reappear, almost identically, across various levels of size of the individual system, thus revealing the characteristic of self-similarity and homothety of nature. Mandelbrot wrote:

[15] Benoît Mandelbrot, *Gli oggetti frattali: Forma, caso e dimensione*, trans. Roberto Pignoni (Turin: Einaudi, 1987), 277.

> In this essay, very diverse natural objects are studied—many of which are quite familiar, such as the Earth, the sky, and the ocean—making use of a wide family of geometric objects considered until now esoteric and unusable, and which I instead propose to demonstrate deserve to be soon integrated into elementary geometry because of the simplicity, diversity, and truly extraordinary scope of their new applications. Although their study pertains to various scientific disciplines, including geomorphology, astronomy, and turbulence theory, the natural objects in question share the characteristic of being of extremely irregular or interrupted form; to study them, I conceived, developed, and widely used a new geometry of nature. The notion guiding them will be designated with one of the two synonymous neologisms "fractal object" and "fractal", terms I conceived for the needs of this book, referring to the Latin adjective fractus, which means "interrupted" or "irregular."[16]

The merit of Benoit Mandelbrot is, therefore, certainly that of not attempting to reduce the natural and complex shapes of natural reality to pure and abstract forms, ideally underlying a pre-constituted order belonging not to reality as such but to a rationalizing tendency of Western culture. Overcoming the attempt of *reductio ad unum,*[17] Mandelbrot, with a holistic and systemic, rather than analytic spirit, observed that there exist continuities of patterns and shapes identifiable in nature. The most famous example provided by Mandelbrot is the jaggedness of the coasts of Great Britain, whose length cannot be measured through attempts at Euclidean rectification. In fact:

> Taking a stretch of coastline in a rugged region, we will try to measure its actual length. It is evident that this length is at least equal to the straight-line distance between the ends of our curve section; if the coast were straight, the problem would already be solved; finally, a truly wild coast is extremely sinuous and, consequently, longer than the aforementioned straight-line distance. It can be accounted for in various ways, but in any case, the final length will be so large that it can, without practical inconvenience, be considered infinite. When, later, we want to compare the "contents" of different coasts, we will have no choice but to introduce different forms of a mathematical concept that everyone thought had no concrete applications: the concept of fractal dimension.[18]

[16] Mandelbrot, *Gli oggetti frattali*, 7.
[17] See Morin, *La sfida della complessità*, 3.
[18] Mandelbrot, *Gli oggetti frattali*, 21.

And Mandelbrot continues:

> The fact is that if the coasts are very irregular, the degrees of irregularity corresponding to the different scales are roughly the same. It is impressive, in fact, to note that if one considers a bay or a peninsula, represented on a map at a scale of 1:100,000, and examines it on a map at a scale of 1:10,000, countless sub-bays and sub-peninsulas are distinguished on their outline. On a map at a scale of 1:1,000, sub-sub-bays and sub-sub-peninsulas appear, and so on. One cannot go on infinitely, but one can go very far, and it will be found that, although the various maps corresponding to successive levels of analysis are very different in their specifics, they nevertheless present the same global character, the same generic features. In other words, one is led to believe that, apart from scale, the same mechanism may have generated both the minute details and the global characteristics of the coasts. This mechanism can be seen as a kind of cascade, or rather as a multi-stage firework, in which each stage generates smaller details than the stage that preceded it. In the case where each piece of coast is, statistically speaking, homothetic to the whole – aside from certain particulars we choose to ignore – it will be said that the coast possesses an internal homothety.[19]

If Mandelbrot's formulation remains, in any case, a map suitable to represent the territory, it remains a fact that it is a map, a cognitive and instrumental apparatus, which does not intend to rectify reality in order to grasp it, but rather observes it in its concrete dialectical dimension, which sees a constant movement between order and disorder, negentropy and organization, regularity and irregularity of forms.[20]

Fractal maps are evidently ecological mappings. The *cosmopoietic* action of Mandelbrot results from a direct interrogation of Nature, and not from the *a priori* application of ideal forms and structures. It represents a science in direct dialogue with the Nature it observes.

Moreover, Mandelbrot's *cosmopoietic-geometric* models were immediately, and successfully, applied to a wide range of natural systems that Euclidean geometry could not capture in their complex characteristics and which, for this reason, ended up reducing and mutilating. From clouds to the plant kingdom to human organic physiology, Mandelbrot's geometric universe revealed, on a mathematical level, a reality that is rich, abundant, and above all concrete. James Gleick revealed in this regard that

[19] Mandelbrot, *Gli oggetti frattali*, 26–27.

[20] Giuseppe Giordano, *Complessità: Interazioni e diramazioni* (Messina: Armando Siciliano, 2021), 263.

> blood vessels, from aorta to capillaries, form another kind of continuum. They branch and divide and branch again until they become so narrow that blood cells are forced to slide through single file. The nature of their branching is fractal. Their structure resembles one of the monstrous imaginary objects conceived by Mandelbrot's turn-of-the-century mathematicians. As a matter of physiological necessity, blood vessels must perform a bit of dimensional magic. Just as the Koch curve, for example, squeezes a line of infinite length into a small area, the circulatory system must squeeze a huge surface area into a limited volume. In terms of the body's resources, blood is expensive and space is at a premium. The fractal structure nature has devised works so efficiently that, in most tissue, no cell is ever more than three or four cells away from a blood vessel. Yet the vessels and blood take up little space, no more than about five percent of the body.[21]

From Biological and Ecosystemic Geometry to Bioinspiration

Moving towards an ecological civilization requires, even before political and economic maneuvers, an authentic epistemological reflection on the production of models and the organization of knowledge. An authentically ecological civilization, in fact, cannot base its hopes exclusively on technical tools and economic models. Rather, it implies, first and foremost, the awareness that producing models of reality entails, more or less indirectly, intervening in reality and transforming it.

If, as Imre Toth asserts, geometric modeling constitutes the production of internally coherent universes, and if, as Mandelbrot has done, such *cosmopoiesis* can occur within a relationship of observation of natural patterns, contemporary biological sciences are increasingly interested in identifying the specific configurations of forms in nature and living beings.

Noteworthy from this perspective is the work of the Italian plant neurobiologist Stefano Mancuso, whose decades-long research has largely focused on studying the forms through which plant organisms structure their organization. The ideas of plant neurobiology and plant psychology, whose most prominent exponents, in addition to Stefano Mancuso, include Monica Gagliano and Paco Calvo, contribute to overcoming the Aristotelian idea of the vegetative soul, hierarchically inferior to sensitive and intellectual faculties, and connect, to a certain extent, to the avant-garde Goethean botany.

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[21] James Gleick, *Chaos: Making a New Science* (New York: Viking, 1987), 108.

Specifically, what Mancuso has shown is that the internal geometry of the plant world is configured as a modular and reticular architecture, which helps to distribute cognitive faculties throughout the entire plant body. According to Mancuso the plant's

> bodies are constructed on a modular design, in which each part is important but none is truly indispensable. This structure represents a fundamental advantage vis-à-vis the animal kingdom, especially considering the number of herbivores on the planet and the impossibility of escaping their voracious appetites.[22]

Plant forms, in short, repeat themselves, revealing a certain internal homothety and fractality:

> It's no accident that we continually refer to ourselves as individuals: the term comes from the Latin *in* (which here means "not") and *dividuus* ("divisible"). Our body really is indivisible: if we're cut in half, the two halves can't live separately; they die. But if we cut a plant in half, the two parts can still live independently, for the simple reason that a plant isn't an individual. In fact, the right way to think about a tree, a cactus, or a shrub is not to compare it to a human being or any other animal, but to picture it as a colony. A tree is much more like a colony of bees or ants than an individual animal.[23]

The revolutionary element in Mancuso's research is undoubtedly the correlation between the geometric shapes that structure the plant world and the cognitive and mental faculties of plants. Observing the internal geometry of plants reveals, in this sense, their cognitive capacities, which exhibit an intelligence profoundly different from that of animals and humans:

> A plant doesn't have individual organs such as a brain, a heart, lungs, one or more stomachs because, if it did, their injury or removal…would jeopardize the entire organism's survival. In plants, no single part is essential; and, in fact, the structure is mostly redundant, made up of repeated modules that interact with one another and that in certain conditions can even survive autonomously.[24]

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[22] Stefano Mancuso and Alessandro Viola, *Brilliant Green: The Surprising History and Science of Plant Intelligence*, trans. Joan Benham (Washington, DC: Island Press, 2015), 34.
[23] Mancuso and Viola, *Brilliant Green*, 36.
[24] Mancuso and Viola, *Brilliant Green*, 125.

What Stefano Mancuso proposes is an internal geometry of nature: the plant organism, in this sense, articulates itself through the development of forms and patterns that the scientist observes in their characteristics. Observing these geometric forms, then, allows the study of plant cognitive systems. Geometry, in its etymological sense as the study and measurement of earth, also enables the study of the mind itself. The epistemological and cosmopoietic act of world creation is here profoundly innovative: in a direct and continuous dialogue with nature, the scientist attempts to bring organization to knowledge. This order, however, is not Cartesian-fixed but processual, dialogical, and evolving as the Reality it represents.

Thus, an ecological civilization capable of observing the relational and processual shapes of nature can allow itself to be inspired by organic nature to reorganize its knowledge systems, as well as economic and social structures.

Stefano Mancuso himself has frequently spoken of *Bioinspiration*: that is, of taking inspiration from the reticular geometry of plants to reorganize even our digital and urban ecosystems.

As Mancuso has clarified,

> the plant kingdom may offer numerous innovative solutions to many of our most common technological problems. *Bioinspiration*, or finding impetus in the living world for devising new technological applications, originated centuries ago (think, for example, of Leonardo's studies of flying machines, inspired by bird flight). Our eyes have long been fixed on the animal kingdom (the realm closest to us) and have only recently begun to discern the treasure hidden in the plant realm, where one day we may find—among other things—the cure for many of humanity's most serious illnesses, new forms of clean energy, opportunities for innovation in man-made materials, and incalculable unexplored possibilities in the chemical and biological world.[25]

Indeed, plant organisms, due to their repeated and fractal constitution, are in constant communication, operating within networks that allow the passage of chemical signals affecting the entire network, mostly for homeostatic purposes.

A detailed description of plant communication networks by Mancuso reads:

[25] Mancuso and Viola, *Brilliant Green*, 157–168.

> Millions of root tips working in a network so that the destruction or predation even of an important part doesn't compromise the network's survival. By itself, one root tip doesn't have great calculating capacity, but together with the other root tips it is capable of extraordinary feats, just like an ant, which cannot map out strategies on its own, but by working with other ants creates a society that's among the most complex and structured in nature....The root system is first of all a physical network in which the roots are connected to each other anatomically. And yet, this connection doesn't seem at all to be the most important. In fact, the signals enabling each root to communicate with the others probably don't travel inside the plant.[26]

It is no coincidence that Mancuso, in reference to the communicative organizations of plants, has discussed the idea of *green democracy*. The expression 'green democracy' denotes the configuration, observable in every plant ecosystem, of relational models closer to a network, where each part contributes to the development of the whole, rather than a hierarchical-pyramidal structure, which implies a command center and one or more peripheries that execute orders. Indeed, in a technological context in which the Internet often becomes an instrument of control and influence, plant communication networks can provide a model from which to rethink intersubjective and intercultural communication networks, which should facilitate, among other things, the possibility of knowledge dissemination across continents, democratically available to all, supporting a constant circulation of ideas and projects beyond national and geographic borders, and, as even American economist Jeremy Rifkin has argued, facilitating empathy and solidarity among cultures.[27]

The challenge, therefore, is to imagine digital ecosystems that are free, genuinely reticular, and interconnected, capable of promoting an authentic democratic practice that can lead to the reformulation of political and social management of the Internet, which is currently often expressed in terms of control, surveillance, and mass manipulation. By contrast, as the outcome of a truly ecosystemic practice applied to digital spaces, a green network originates from ecological awareness, according to which the free activity of each living and social singularity contributes to the richness and complexity of the environments in which it develops and from which it is recursively produced, within a

[26] Mancuso and Viola, *Brilliant Green*, 142–143.

[27] See Jeremy Rifkin, *The Empathetic Civilization: The Race to Global Consciousness in a World in Crisis* (New York: TarcherPerigee, 2009).

systemic-reticular relationship that values both the individual and communities—in the broadest sense of the term.

We have thus outlined a four-step pathway. After clarifying how the maps and representations of the world constructed by a civilization can be more or less ecological, it was shown that Western civilization is gradually making its geometric mappings of the world increasingly ecological. First, from Euclidean geometry, which reduced the complex and abundant forms of nature to pure ideal forms, there has been a transition to non-Euclidean geometries and Imre Toth's reflections. Geometry is not the ontological language of the world but, conversely, an activity of the human mind that implies cosmopoiesis, the construction of infinite possible worlds. From this perspective, the fractal world is an exceptional case. Mandelbrot, for the first time in the history of Western mathematics, marks the end of the a priori application of models to reality, in order to observe the intrinsic patterns and forms of nature itself. Finally, following this line, we now witness a tendency, in biological avant-gardes, not only to observe the fractal forms of nature but also to relate natural geometry to the cognitive faculties of ecosystems, as shown by the studies of Stefano Mancuso. In this case, the geometry of nature becomes the reflection of the mind of ecosystems and, above all, can become a source of bio-inspiration: the possibility of rethinking social, urban, and digital systems in light of the organization of natural ecosystems.

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