# *Real or Ideal?*

## DNA Iconography in a New Fractal Era

*Rhonda Roland Shearer*



Like Charles Darwin's image of the march of progress, which shows evolution from a stooped monkey to an upright human, the double helix has become a standard-image scientific icon in Western culture *(fig. 1)*.

The new scanning tunneling microscope (STM) reveals a very different picture. Looking at DNA from images generated deep within an organism *(fig. 2)*, we are surprised to note that the same irregular textures and shapes experienced in our daily lives are also seen within nature at such a small scale. DNA is, in fact, highly irregular and lumpy. One cannot help but see a contrast between this new realistic visualization of DNA and the standard, idealized textbook illustration.

This visual conflict between the two DNA images can be described. In our traditional categories the STM image of DNA represents a direct "imitation" of nature, echoing nature's irregularities, while the textbook diagram can be seen as an "antagonist" of nature, an abstraction and idealization that throws out or transcends nature's imperfections.

These two categorizations of DNA fit into formalisms created by art historians of the early twentieth century—primarily such dualistic descriptions as abstract and real (figurative), or geometric and organic, that postmodern art historians now regard as "obsolete." Despite this postmodern conviction and the lack of recent papers addressing new or old categorization schemes (in stark contrast to a plethora of earlier twentieth-century art historical writings), recent textbooks for instructing museum curators or art students follow these earlier modernist categorizations.[1]

In spite of the postmodern claim for irrelevance of dualisms in art history, cognitive sciences—including linguistics and neuroscience—regard humans as "dichotomizing machines," whose dualisms are rudimentary forms of basic and inevitable categorization. Such scientists as Antonio Damasio and such linguistic scholars as George Lakoff believe that categories are fundamental to human cognition.[2] I write this paper within postmodern science, but with an open eye toward its complete relevance for art, and I let the art history experts, postmodern or not, judge the relevance of categories for themselves.

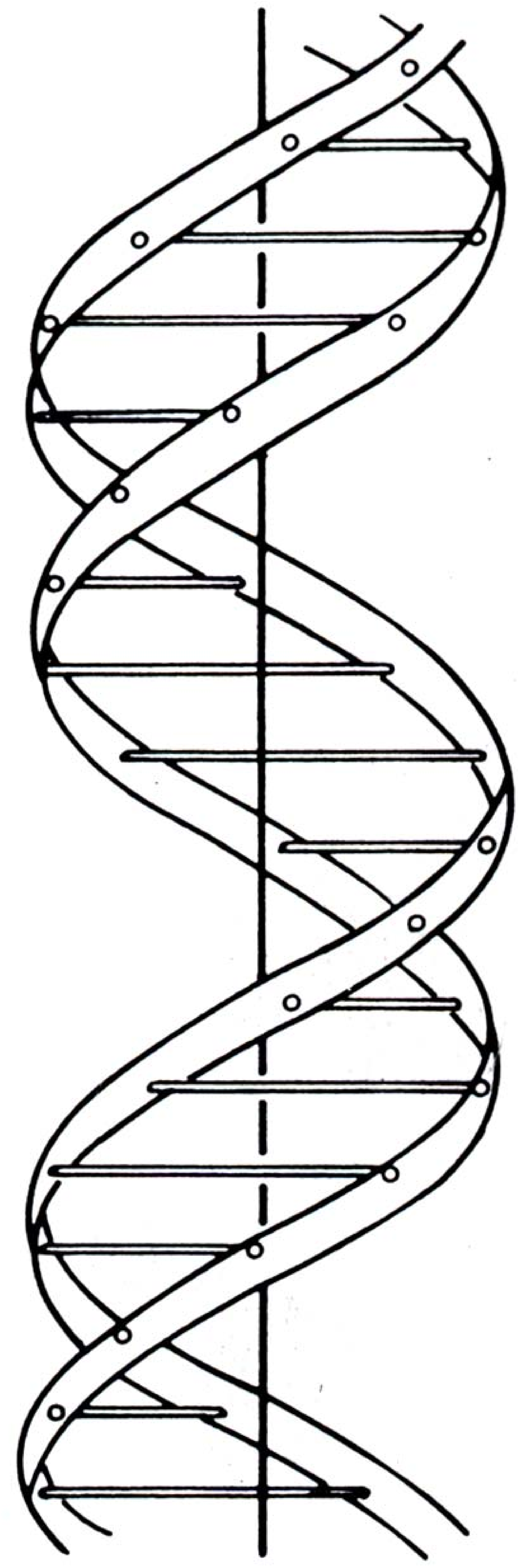

**FIG. 1** Standard textbook idealization of DNA.

In both art and science, much work in classifying images and concepts follows the conventional technique of reduction. The first step in conceptualizing complexity is, often, to carve it into dualities, or pairs of opposites. Dualisms are pervasive, in part because they can provide a logical, quick, and simple way to comprehend and organize our experiences.

Within the construction of familiar dualisms, like mind and body, and realism and abstraction, nature is typed as irregular and imperfect, whereas abstraction stands at the opposite pole. Abstraction, within this convention of Platonic tradition, is a complete withdrawal from

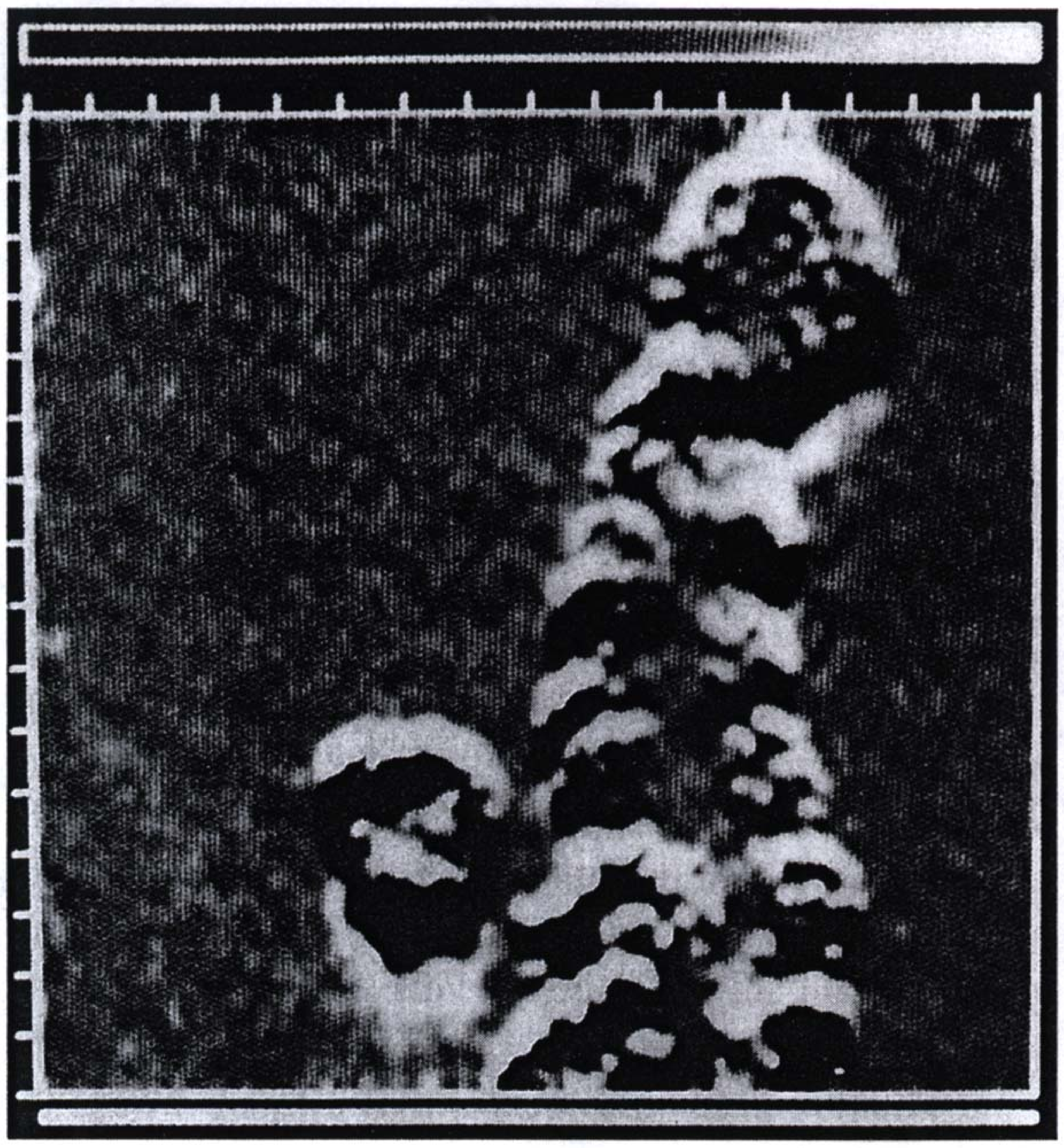

**FIG. 2** Scanning tunneling microscope image of "real" DNA.

nature, and is thereby assumed to be a more perfect, ideal version of the natural world. The circles, lines, and squares of Euclidean geometry provide an "ideal" vehicle for the traditional and Platonic visualization of abstraction because they are constructs or models removed or apart from nature. We rarely identify pure Euclidean shapes in nature because nature's forms are complex and indescribable within the taxonomy of Euclidean geometry. For example, in this Euclidean context, a real orange, with its irregular and lumpy surfaces and overall shape, is only a pale reflection of a Platonically ideal and perfect sphere.

Returning to figures 1 and 2, we can see that these two DNA images logically follow in this traditional dualistic, hierarchical, and Platonic interpretation of form. The traditional and idealized DNA double-helix icon is an abstract Euclidean geometric version of "reality"—a smoother, more regular, systematic, and standardized generalization. With the STM image of DNA, we reproduce the natural content directly. Its individual, irregular, and random shape is immediately identified and is experienced by the viewer as naturalism, not as an abstraction or some other formal level considered quite apart from nature.

I wish to argue here that the new fractal geometry and the related chaos theory, complexity and nonlinear sciences, force us to revisit and rethink these two fundamental categories, which we have traditionally used to organize our science, our art, and, more generally, our reality.[3] Fractal geometry, developed by Benoit Mandelbrot in 1975 is, for many, a revolutionary new kind of geometry that enables us to quantify and thus see order where we only observed disorder before. Based on the principle of "self-similarity," fractal structures exist throughout nature. Within the fractal theory, trees, clouds, fire, rivers, broccoli can be observed as mathematically structured by "similar" shapes that are repeated in different sizes or scales (like Russian stacking dolls from small to large).[4]

Major category change occurs episodically and with great effect throughout Western history, and constitutes a main feature of what many historians of science, like Thomas Kuhn and I. Bernard Cohen, call scientific revolutions.[5] Copernicus recategorized and thus demoted the earth from the all-dominant center of the universe to a mere planet revolving around a central sun. Darwin's theory of evolution recategorized and thus demoted humans from a separate, special form of creation to a genealogical relative of monkeys and apes.

As the cognitive linguist Lakoff and others have come to believe, categories are fundamental to understanding the way we order reality. When categories change, so does our way of looking at ourselves and the world. Scientific revolutions and their resulting changes in categorization do not happen overnight. Individual by individual, book by book, with time this "paradigm shift" (to use Kuhn's term) takes place. For Kuhn, new knowledge from scientific revolutions is assimilated by individuals who must then readjust their traditional beliefs to create "logical and factual congruence."

Like the category shift from premodern science, which included the "knowledge" that rocks were alive, to the conviction of modern science that rocks are dead matter, we now are facing a similar radical change. But this time, as a result of fractal geometry, we are forced to place our focus on reassessing and changing fundamental categories themselves—and this shift will radically affect our perception and cognition.

Before looking again at the two DNA images, consider a computer-generated fractal geometric structure *(fig. 3)*. The mountain is not real in the traditional sense of opposite from abstract, where abstract is defined as "withdrawal" or "removal from nature." Within our conventional

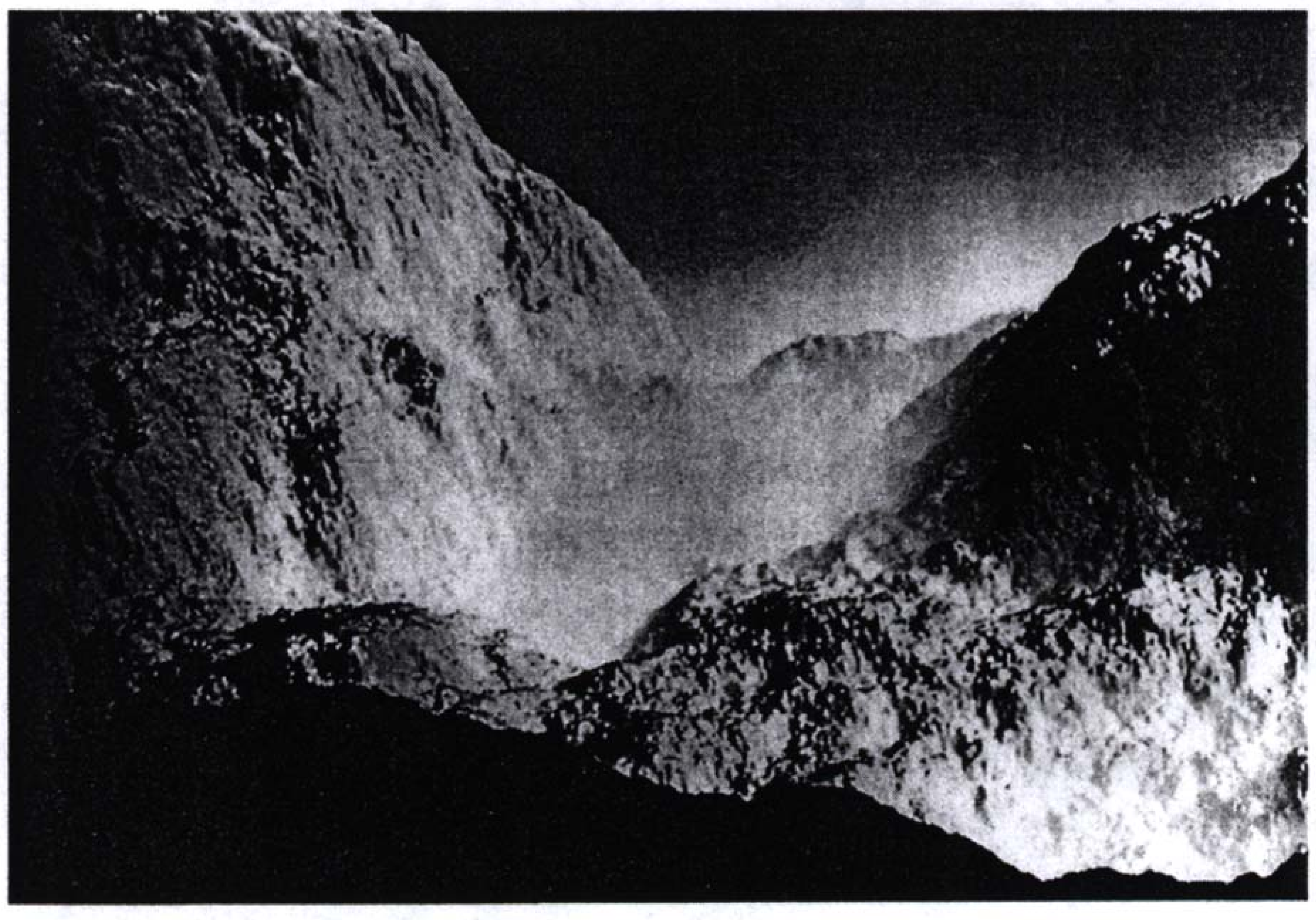

**FIG. 3** Richard Voss, fractal mountain, computer-generated image.

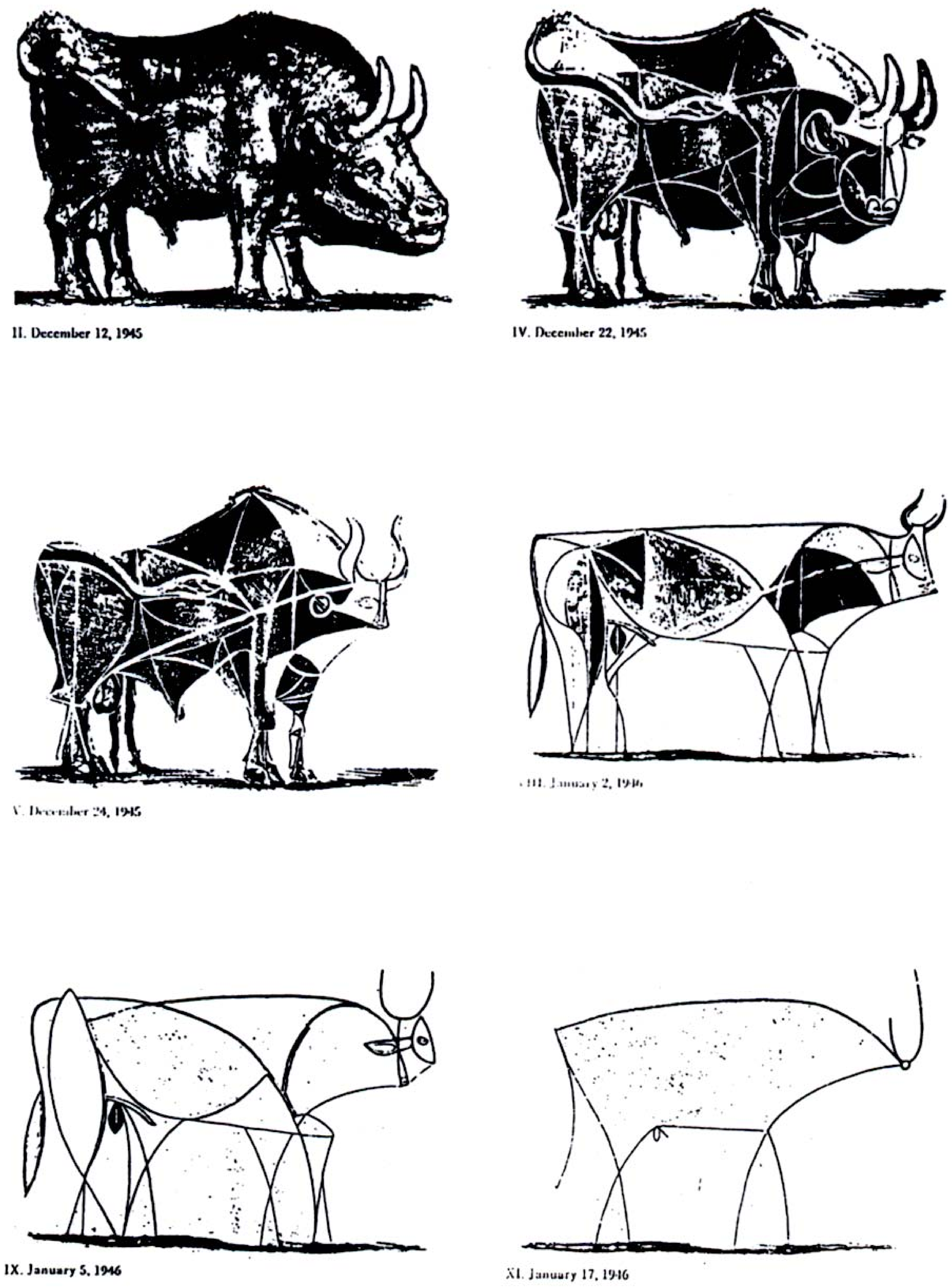


**FIG. 4** Pablo Picasso, *Bull*, 1945–46, progressive states in a lithograph series (II, IV, V, VIII, IX, XI), 11³⁄₈ × 16¹⁄₈ inches. Collection of Bernard Picasso, Paris.



conception of the world, based on traditional categories, one has to ask, in view of such fractal images, how can the mountain be accurately categorized as both real and abstract, or organic and geometric, all at the same time? Fractals literally and formally break down the traditional separation between abstract (ideal) and real because fractal-generated images, as figure 3 shows, can look so much like the complexity of a real object—a fern or mountain, for example—yet such fractal figures are only a mathematical abstraction generated by simple numbers (or an algorithm) on a computer.

Geometric and organic, or abstract and real, are descriptions of dualistic and hierarchical opposites. The abstract is traditionally considered, in Western culture, going back to ancient Greece, not only as opposite but also as superior to the real. Our preference for the abstract over the real has dominated Western history, whether in art, science, religion, or philosophy.[6] Our geometries have now evolved from reductionistic abstractions to include fractals, which can be defined as reductionistic and holistic, abstract and real.

The two DNA images *(figs. 1 and 2)* are now significant because they map and therefore bridge a visual, historical transition from the past (where abstract is opposite and superior to the real and is described in classical Euclidean and non-Euclidean geometries) to the future (where the abstract and the real are nonhierarchical and nondualistic and described in both classical and fractal geometries).[7]

I believe that changes or revisualization of the geometries of ideas (such as we observe from the two DNA images) are historically fundamental to revolutions in both art and science.[8] In science, for example, Einstein's general theory of relativity can be seen as a new geometric revisualization of Newton's universe. Our Newtonian concept of space went from fixed and absolute to curved and relative in its shape, as in Einstein's idea. In art, two large-scale developments legitimately viewed as analogous to scientific revolutions are Renaissance perspective and the birth of modern art at the beginning of this century. As in scientific revolutions these two artistic revolutions can be visualized not only as changing images and ideas but also as changing geometries.[9]

The two dimensions of medieval art gave way to the artistic and scientific development of Renaissance three-dimensional perspective, and the birth of modern art defeated the stranglehold of three-dimensional perspective, offering other geometric possibilities of two and even four dimensions.

It is interesting to note, but not commonly known, that many artists, like Marcel Duchamp and Naum Gabo, at the beginning of modern art, were familiar with the new geometries then being popularized during the late nineteenth and early twentieth centuries, namely non-Euclidean (space as curved) and n-dimensional geometries (the fourth dimension).[10]

The same "new" non-Euclidean geometries that were inspirational in art and popular culture in the late nineteenth and early twentieth century also inspired Einstein. Cubism, which began in 1907 with Georges Braque and Pablo Picasso, was quickly joined in the 1910s by a plethora of various movements, including Constructivism, De Stijl, and Futurism. Einstein published general relativity in 1915. This theory was based on the same kind of revisualized geometry (imagining curved spaces) that some early modern artists gained from non-Euclidean concepts. In Einstein's case the input was specific and on a more technical basis: Riemanian geometry.[11]

The conceptual shift that I am describing with the two DNA images does not involve a geometric revisualization, as happened between Newton's and Einstein's views of space. In this case the geometric change between the two DNA images reflects the larger revolution of concepts now taking place and affecting both art and science, specifically, nonlinear sciences, which include fractal geometry, complexity, and chaos theory. These two images do not conflict in this new fractal era. They are a map for present developments in understanding more about the direct relationship between order and disorder. This creates a necessity for reorganizing our conventional knowledge, assumptions, and categories.

When we look at the two DNA images with classical geometries in mind, we can rank figure 1 as abstract or idealized and figure 2 as "real." When we look at the two DNA images with both classical and fractal geometries in mind, what we see and categorize is quite different. In the new fractal era, we see that figure 1 is a Euclidean geometric expression of DNA—representing a traditional concept of abstraction—whereas figure 2, with its irregularity and lumpy, self-similar surfaces, is identifiable as being fractal and representing a new order of abstraction.

From early schooling we all become familiar with Euclidean structures and the concept of abstraction. Dimensions (zero to three) and shapes (point, line, plane, and solid in sequence ranging from the simple [point] to the complex [solid]) embody the process of reduction of nature with abstraction. In both science and art, abstraction has been a process of reducing nature (the complex) to "progressively" lower dimensions (the simple). As pointed out earlier, this geometric abstraction—the complex reduced to the simple, the real to the abstract—is a geometry not of objective science and art, but of convention and social value. The abstract is preferred and valued hierarchically above the real. The abstract, or the reduced dimension, is considered perfect and ideal, especially in comparison to sensuous, irrational, and irregular reality.

In this traditional view of abstraction, the DNA image in figure 1 is Plato's "eidos" and in figure 2 is Aristotle's "entelechy." Eidos is pure form, which exists a priori—timeless, uncreated, and eternal. Entelechy is an active generalization based on generation, time, and chains of relationships within nature—Aristotle's "man begets man." Classical geometries—Euclidean and non-Euclidean—are based on "eidos" and not "entelechy." Eidos and entelechy are traditionally at philosophical odds and in conflict at opposite poles, just like abstract and real. The fact that we had a geometry for visualizing eidos, but no geometry or formal order for entelechy, reinforced the notion of eidos' abstract superiority. We had no language to identify or organize an order within nature's entelechy or complexity, so we assumed that no such order existed. As based on the only structures we knew, we assumed that abstraction or generalization could only be of a single kind—hierarchical reduction from the complex to the simple.

This classical geometric concept and specific order of abstraction is mapped throughout modern art starting right at its beginnings: Piet Mondrian's dematerializing tree series—his impressionistic *The Red Tree* through the gridded *Composition (tree)*—or Theo Van Doesburg's abstract cow series (a real cow tranformed into rectangles and squares) or Picasso's *Bull* lithograph series *(fig. 4)*. Fractals provide a new mode of abstraction, but also show

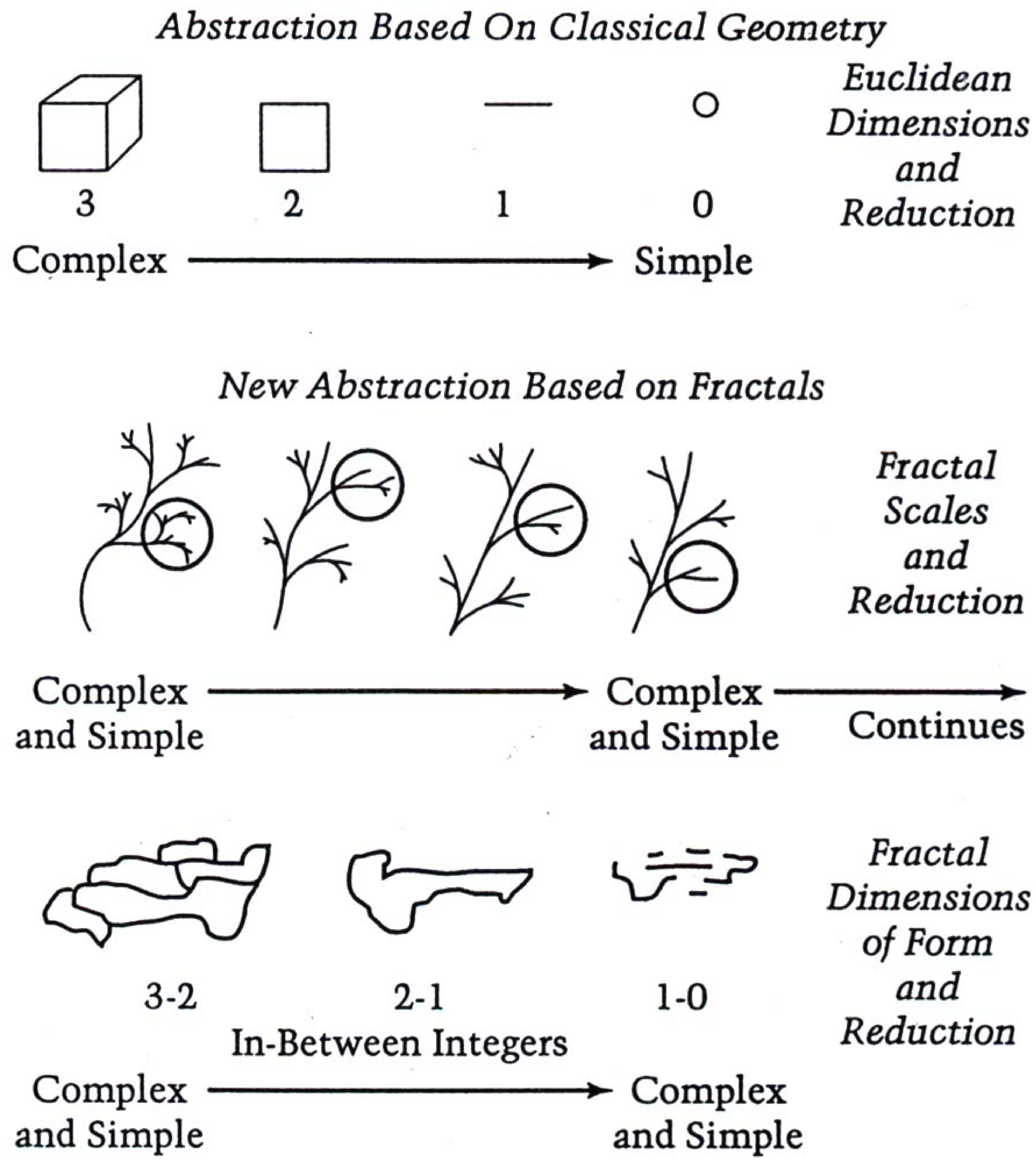


**FIG. 5** Chart comparing fractal and classical geometries.



that our Platonic notion of abstraction and form was restrictive and false. Look at figure 5 for comparison.

With its two characteristics—fractal scaling (or self-similarity) and fractal dimension—fractals provide a new form of abstraction and a different kind of "order" than we have known before. Instead of point, line, plane, solid, moving from the simple to the complex, we now have self-similar shapes. The twig has a similar shape to the larger branch, which is similar to the trunk, etc. With fractal structures the shape stays basically the same. The only change between twigs and branches or any level in a naturalistic fractal series is a slight variation by minor individualization of branches (no two would ever be exactly alike), and the size or scale. Rivers, fire, clouds, even our own vascular system, have this fractal scaling property.

Look at the veins protruding from the back of your own hand. Traditional geometric circles, lines, or squares are poor abstractions or generalizations of the dynamic and generative forms of nature. Fractals are not real, but certain types of fractals can appear "real." Such fractals as figure 3 are abstract, geometric generalizations that appear very real to our eye and brain. This sense of reality may reflect the way the brain processes information: the fractal structure may be what we see; therefore, fractals generated on a computer screen as abstract structures will appear to us as real. But if one looks closely, however, for what is visually "true," one can see that these are not "photographic reproductions" of a fern or a mountain (especially glaring for a botanist or geologist), but geometric represen-

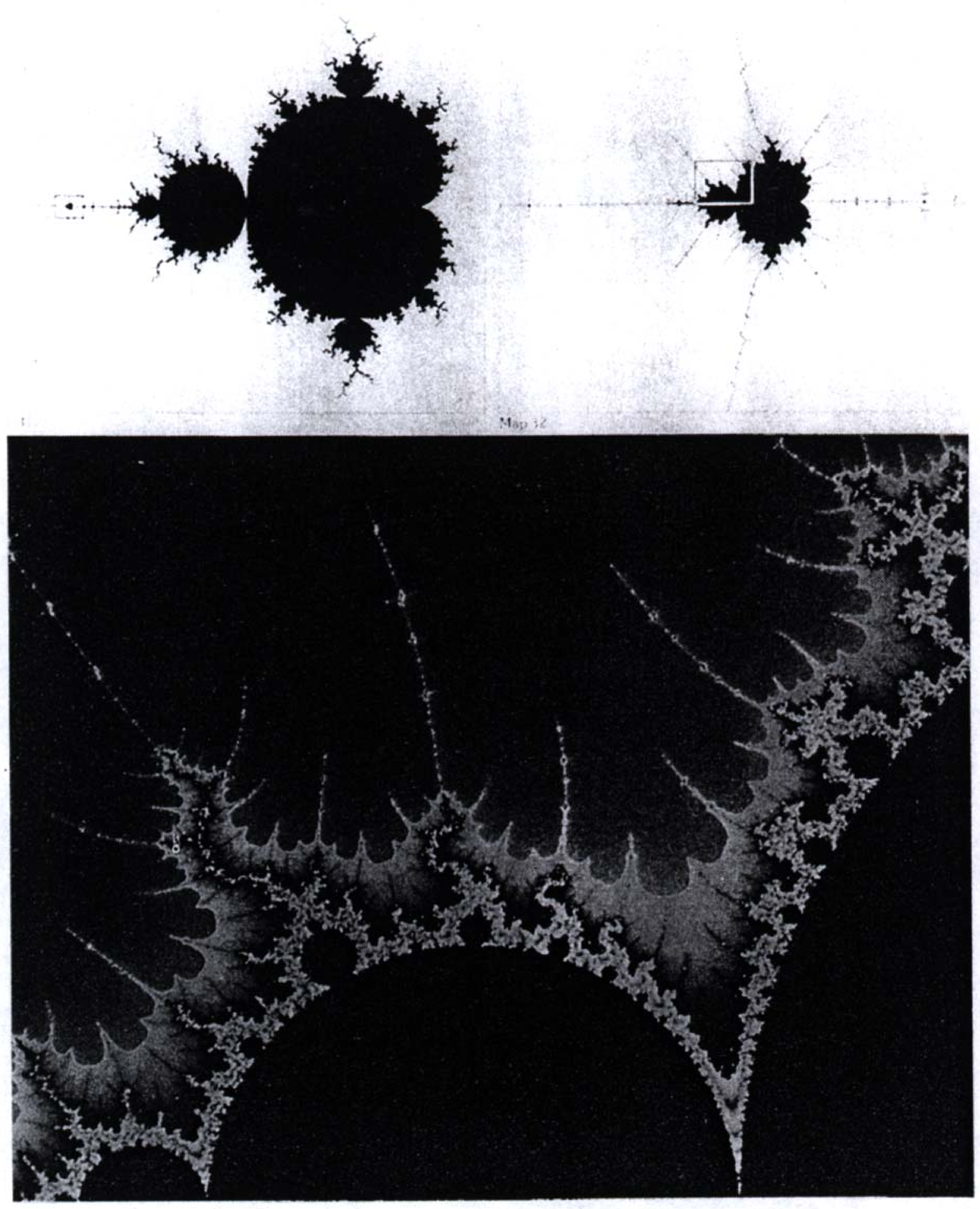

FIG. 6 Richard Voss, the Mandelbrot set, computer-generated image.

tations of fractal principles that are closely "similar" to certain ferns and mountains within actual nature.

As Mandelbrot, the founder of fractal geometry, has often said, "Mountains are not cones."[12] Not all fractal structures look real. Nature works on a limited number of scales. For example, a tree only ranges from a twig to a trunk. Mathematical fractals, like a Mandelbrot set, develop in potentially infinite scales for as long as the computer will keep generating them. Richard Voss has created one Mandelbrot *(fig. 6)* set that is equal in magnitude to Avogadro's number (or $10^{23}$).

As one can observe from figure 7, reduction within fractal abstraction occurs, but is oddly different. There is a hierarchical reduction from large to small, but the small goes on forever in the case of mathematical fractals. Unlike classical geometries, which transform from complex to simple, from solid to point, fractals look the same across scales. As we reduce the scale of a fractal mountain, instead of getting smoother and simpler as in the reduction that occurs within classical geometries, the fractal mountain does not reduce its complexity. By understanding fractals, we can begin to comprehend that dualisms and hierarchies are not properties of all structures. I know of no other formal structures that so defy our tradition of dualistic and hierarchical conceptions of the world.

We can now see that "abstraction" is clearly not opposite to "reality" or hierarchically more important. Fractal structures are in between abstract (ideal) and real, and thereby share aspects from both formerly polarized opposites—for example, fractals are holistic and reductionistic at the same time *(see fig. 7)*. In fact, unlike classical geometries, where the real orange seems inferior and imperfect in relationship to the idealized Euclidean sphere, the opposite is true with fractals, for the fractal mountain or idealization is inferior in our eyes to the real mountain. Fractal mountains or ferns are "too perfect" and too regular to be "photographically real." To their frustration computer scientists do not know a mathematical formula that would introduce enough individuality to imitate natural objects.

With fractals we have an abstraction that is not an "ideal," or absolute perfection, in comparison with the real. Once knowing this, we can look back at the conventional way we have used geometry or abstraction—as the superior single alternative to the real—as limited thinking, as a kind of analysis, based only upon limited geometries.

Fractals take some getting used to, as do all major conceptual changes. Fractals in nature are not an exact concept, like the traditional classical geometric expectation of set figures and scales. Fractals are more of a general principle with which we can identify shapes and structures as well as measure the quality and quantity of overall dimensions of complex and irregular objects (as when we say that the fractal dimension of a cloud is 2.6). Moreover, even traditional Euclidean shapes can be organized into relationships that are fractal, like a Van Koch curve (triangular structures generated into fractal relationships).

So, the geometry that would have us judge DNA figure 2 as subjective and figure 1 as universal is now revisualized, with fractal geometry reconfiguring figure 2 as both subjective and universal. Just as no two leaves are exactly alike and are, thereby, subjective, leaves are also objective, as they can be based upon the same universal, fractal mathematical principle. DNA figure 2 is simultaneously eidos and entelechy, abstract and real, reductionistic and holistic, formal and naturalistic. To summarize my argument:

1. Because most of the world is better described as fractal, we can see that our conceptual framework of dualisms and hierarchies, based on classical geometries, created false values, like the devaluation of the real and the rejection of the "irregular."

2. Our conception of abstraction as a linear reduction from the complex to the simple—so centrally played out in art—is only one possible kind of abstraction.[13] Because most of nature seems to be patterned with fractal structures, then perhaps our brains have been unconsciously processing fractal structures all along, not only since their explicit discovery in 1975. We are now catching up by consciously knowing another kind of abstraction and expanding our horizons by learning how fractals are new possible

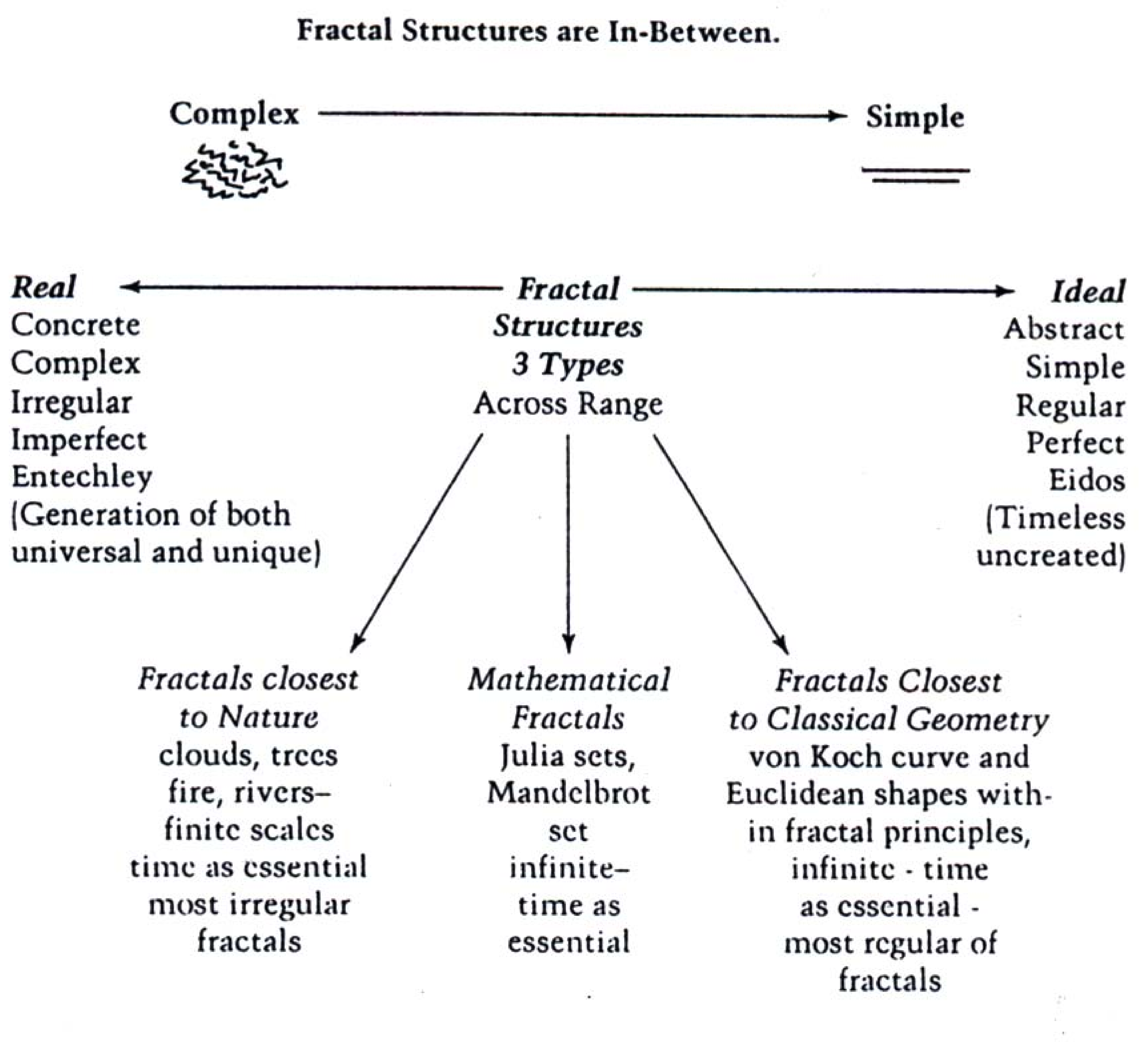


**FIG. 7** Chart illustrating that fractal structures are in between the standard categories of "real" and "ideal."

social, perceptual, and cognitive structures that reflect nonhierarchical and nondualistic principles.

Whatever one feels about postmodernist thinking, its portrayal of dualisms and hierarchies as limited cognitive structures was valid, but seemed nihilistic before fractals.[14] Because humans are pattern-seeking and correlation machines—and thereby order the inner and outer complexity of existence through structure using relationships of forms or geometries—we cannot abandon traditional hierarchies and dualisms without replacing them by an alternative structure. Fractal geometry gives us this alternative.

As an icon DNA is much better described and abstracted by fractal geometry. For as the fundamental unit of all living things, DNA is universal and yet individual at the same time. DNA's dynamism and movement, well expressed by its natural irregularity, is also quite fractal in concept—not smooth, static, and timeless as in classical geometries. The two DNA icons are symbols of visual changes now occurring in science.[15] They therefore provide a map for revisualizing what we need to reconsider in making art and understanding its history.

Notes

1. David Dean, *Museum Exhibition: Theory and Practice* (London: Routledge, 1994); and H. W. Janson, *History of Art*, 5th ed. (1962; New York: Harry N. Abrams, 1995). See also Philip Yenawine, *Key Art Terms for Beginners* (New York: Harry N. Abrams, 1995).

2. George Lakoff, *Women, Fire and Dangerous Things* (Chicago: University of Chicago Press, 1987); and Antonio Damasio, *Descartes Error* (New York: Putnam, 1994).

3. Rhonda Roland Shearer, "Chaos Theory and Fractal Geometry: Their Potential Impact on the Future of Art," *Leonardo* 25, no. 2 (March 1992): 143–52; and "From Flatland to Fractaland: New Geometries in Relationship to Artistic and Scientific Revolutions," Proceedings of Mandelbrot's 70th Birthday Symposium in Curaçao, *Fractals* 3 no. 3 (1995). For basic information on fractals, see Heinz-Otto Peitgen and Dietmar Saupe, eds., *The Science of Fractal Images* (New York: Springer, 1988). See also Benoit Mandelbrot, *The Fractal Geometry of Nature* (New York: W. H. Freeman, 1997).

4. Starting in the 1980s, artists began learning about fractals and nonlinear science using this in their work. These artists include Ellen K. Levy, Tony Robbins, Jim Long, and me, among others.

5. Thomas S. Kuhn, *The Structure of Scientific Revolutions* (1962; Chicago: University of Chicago Press, 1970). See also I. Bernard Cohen, *Revolution in Science* (Cambridge: Belknap, 1985).

6. In Western religions the most important element is the spiritual (abstract) versus the material. In philosophy going back to the antique Greeks, the mind's superior status over the body has ruled, with holism as an exception. Human measure and reason, both abstractions, are the productions of science and mathematics where (since Galileo) the unruly and irregular are discarded as garbage and noise. In correlation with the above cultural factors, art has been a mirror of society's dualisms: mind/body, nature/culture, masculine/feminine, abstract/real. Also see Norman Bryson, *Looking at the Overlooked: Four Essays on Still Life Painting* (London: Harvard University Press, 1990), which addresses the dualistic and hierarchical view of nature in art history: "Art history as taught in most universities . . . still life continues to struggle with the prejudice that while (of course) it would be a subject worth investigating, the real stakes lie elsewhere, in the higher genres where (of course) things have always been more interesting" (p. 8).

7. The scientific "fractalization" of DNA goes beyond my argument about present iconography into the internal pattern of DNA's morphology. Scientists like Richard Voss have discovered scale-invariant fractal patterns in the large-scale positions and sequencing of DNA's four nucleotides—adenine, guanine, cytosine, and thymine (A, G, C, T, for short). See Phillip Yam, "Noisy Nucleotides: DNA Sequences Show Fractal Correlations," *Scientific American* 267, no. 3 (September 1992): 23–27. See also Ivan Amato, "DNA Shows Unexplained Patterns Writ Large," *Science*, August 7, 1992, 747.

8. Rhonda Roland Shearer, *The Flatland Hypothesis: Geometric Structures of Artistic and Scientific Revolutions* (New York: Springer, forthcoming), refers specifically to my work and theory, the Flatland Hypothesis, which states that changes in both art and science can be seen not only as changing images or ideas but also as changes in geometries. My generalized theory is distinct from Linda Henderson's work; see Linda Dalrymple Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art* (Princeton: Princeton University Press, 1983), in which she illustrates the importance of new geometries at the beginning of modern art singly and specifically. Henderson's main mission was to discredit the notion that Einstein's relativity theory was instrumental in the development of Cubism and modern art, showing instead that nondimensional and non-Euclidean geometries were inspirational sources. The Flatland Hypothesis posits the fundamental importance of geometries in perception and cognition, which, I argue, is demonstrated by the linkage of geometric change with large-scale innovation and creativity whether in art or science.

9. Shearer, "Chaos Theory and Fractal Geometry."

10. Henderson, *Fourth Dimension.*

11. Albert Einstein, *Essays in Science* (New York: Philosophical Library, 1933), 50–51. Distinguised from Euclidean geometry's regular, even space, Riemanian geometry's space and corresponding forms are curved, like the surface of a sphere; therefore, certain axiomatic rules from Euclidean geometry were no longer "absolute truth" about the world. For example, two parallel lines *will* meet and the three angles of a triangle add up to *more* than 180°, on the surface of a sphere.

12. Mandelbrot, *Fractal Geometry of Nature*, 1

13. Nonobjective art's claim to be a complete removal from nature and more real than "reality" does not make it exempt from my assertion of the existence of only one possible kind of abstraction (before fractals), that is, a reduction from the real to abstract. Nonobjective art, in view of my argument, can be considered the quintessential example of nth-degree classical abstraction, as it is so removed from nature it no longer has a direct tie to nature. Moreover, describing nonobjective art objects as more "real" than "reality" is clearly a Platonic reference and assumption reminiscent of Plato's cave. See Kasimir Malevich, *The Non-objective World* (Chicago: I. S. Berlin, 1959).

14. Linda J. Nicholson, *Feminism/Postmodernism* (New York: Routledge, Chapman and Hall, 1990).

15. The shift of scientific iconography from the distinct high-tech look of outer space in the futuristic and rectilinear *(Star Wars)* to the blurred boundaries between the organic, everyday nature and scientific technology *(Jurassic Park)* are similar to the shift from the regular, idealized, and Euclidean geometric representations in science to those of fractals.

RHONDA ROLAND SHEARER, *a New York artist and writer, has had numerous solo museum exhibitions and has written* The Flatland Hypothesis: Geometric Structures of Artistic and Scientific Revolutions *(Springer, forthcoming).*