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Fractals

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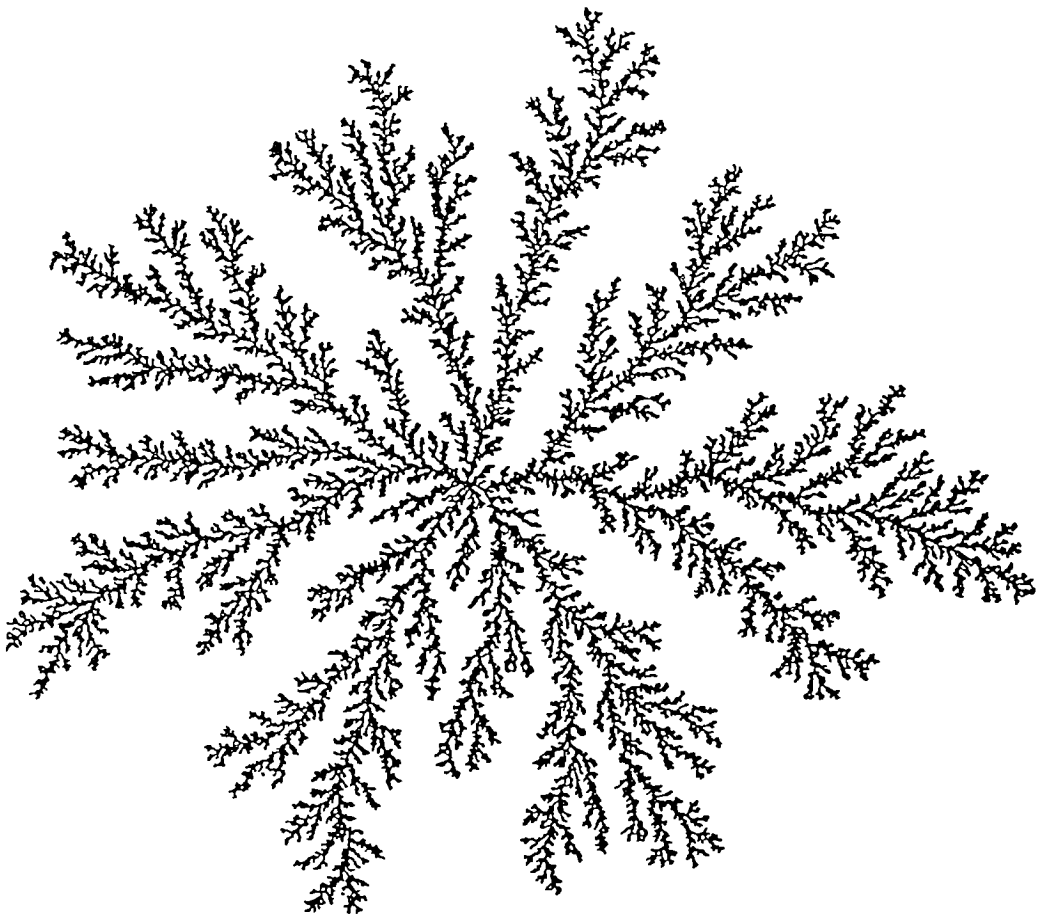

DLA fractal cluster
of 10^6 particles

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SYMMETRY: A SPECIAL FOCUS ON FRACTALS

OPINIONS
(ESSAY)

Benoit B. Mandelbrot

Mathematician, (b. Warsaw, Poland, 1924).
Address: Mathematics Department, Yale University, New Haven, CT 06520, USA; IBM Fellow Emeritus, Physics Department, IBM T. J. Watson Research Center, Yorktown Heights, NY 10598, USA;
E-mail: pkumar@yktvmz.bitnet.
Fields of interest: Fractal geometry and its applications.
Awards: the 1993 *Wolf Foundation Prize* for Physics; the 1985 *Barnard Medal* for Meritorious Service to Science granted by the U.S. National Academy of Sciences and Columbia University; the 1986 *Franklin Medal* for Signal and Eminent Service in Science from the Franklin Institute of Philadelphia; the 1988 *Charles Proteus Steinmetz Medal* from IEEE and Union College; the 1988 *Science for Art Prize*; the 1989 *Harvey Prize* for Science and Technology from the Technion in Haifa; and the 1991 *Nevada Prize*. He also received a distinguished *Service Award* for Outstanding Achievement from Caltech, and a *Humboldt Preis* from the Alexander von Humboldt Stiftung.
Publications: *Les objets fractals, Forme, hasard et dimension*, 1975, 1984, and 1989, Paris: Flammarion (translated into Italian, Spanish, Portuguese, Basque and shortly into Bulgarian and Romanian); *Fractals: Form, Chance and Dimension* 1977, San Francisco: W. H. Freeman; *The Fractal Geometry of Nature*, 1982, New York: W. H. Freeman, 460 pp., (translated into Japanese and German).

INTRODUCTION

Fractal geometry was not built from the top down, but from the bottom up. That is, its goals and its scope were not set in advance, to be later developed according to a master plan; instead, they emerged very gradually. Today, many observers find the existence of this new geometry (hence its very possibility) seem so obvious, that they find hard to believe that it emerged so recently, and that it was only formulated gradually, as I was developing it and implementing a variety of uses in a number of diverse fields (Mandelbrot, 1982).

It is hardly necessary to note out that this gradual emergence did not proceed smoothly. To take an example: in the 1960s and early 1970s. I had to struggle to gain acceptance for multifractals, and the resistance they met made me realize that measures are a complicated topic and that it was best to first gain with acceptance for fractal sets. On the other hand, the development of fractal geometry was not perceived as haphazard, thanks in large part to the essential role played by a number of attitudes and opinions on my part. They arose early, were strongly felt, were shared by no one else (or so it seemed), and have long remained controversial. To this day, many scientists may nod casual approval when I advance these opinions, but recoil as soon as their practical consequences become apparent. Since these opinions continue to be essential to my work, they deserve to be aired explicitly.

Above all, I have always been deeply enamored of explicit and visual geometry, even when it was generally distrusted or even despised. Furthermore, I felt that an exclusive devotion to the search for increasingly remote foundations (hidden under the flag of explanation - a goal with which it is hard to argue) was often distracting the scientific community from the equally challenging search for the complicated consequences of ideas and observations that are basic but do not qualify as fundamental. Also, I was distressed that physicists exhibited a self-destructively limited knowledge of, and respect for, the tools of probability theory other than the most elementary ones. Finally, and increasingly so as fractal geometry flourished, I was dismayed by the time taken away from useful work by concerns about definitions. I felt that definitions must not be rushed, because it is unlikely that a young field could grow without its definitions having to be revised constantly. In addition, I was familiar with many mature fields that had matured happily without ever expressing their goals in truly formal fashion.

Since these opinions were crucial to my work, they were often expressed forcibly in my lectures, but only one was actually published, as a "Manifesto" in praise of geometry opening my contribution to the Proceedings of the Edinburgh Stat Phys XV meeting (Mandelbrot, 1984). This text failed to provoke much comment, and I have long felt that it deserves being reprinted. The first issue of is new journal on fractals seems to offer a superb opportunity for such a reprint (in lightly edited form), and a superb opportunity for the actual publication of additional *Opinion* pieces I wrote and rewrote over the years for my own enjoyment. The title of this article is meant to warn the reader that he should expect many assertions, few definitions and few measured arguments; little harm can result from interpreting 'geometric' as meaning 'relative to actual pictures'.

The discussion that will follow is divided into the following chapters:

1. In praise of explicit and visualized geometry
2. Variations on the theme of Plato's *Allegory of the Cave*
3. In praise of a 'constructive' form of physics
4. In praise of an 'anomalous' probability theory as a tool of physics
5. In praise of allowing some 'open' definitions in mathematics

1. IN PRAISE OF EXPLICIT AND VISUALIZED GEOMETRY

A theme that runs increasingly strongly in my work is that explicit and visualized geometry has been important in science and in mathematics and that its usefulness should again be recognized.

Blind analytic manipulation *is never enough.*

Formalisms, however effective in the short run, *are never enough.*

Mathematics and science are, of course, rife with quantities that originated in geometry but eventually came to be used only in analytic relationships. There is no reason to spurn such use; witness, for example, the fact that continuously varying formal dimensions are useful in physics in certain renormalization arguments.

In a similar vein, one of the first effects of fractal geometry upon physics has been to provide yet another *analytic* quantity to evaluate and with which to work. This quantity, of course, is the fractal dimension D. In some cases, the fractal codimension was already known as the exponent of a correlation. But correlation *is not enough.* To forget geometry and to simply identify D with an analytic exponent destroys much of its meaning: It *is not enough.*

Attempts to use fractals while continuing to disregard geometry have been at the root of much confusion. As a first example, note that the spectrum is an analytic property; from this view point all $1/f$ 'noises' are a single phenomenon. But let us arrange for such noises to be traced on an oscilloscope. Even the untrained observer will notice that noises from different sources exhibit deep geometric differences that are bound to be symptoms of deep physical differences. Therefore, I think that the hope of finding a unique physical explanation for all $1/f$ noises is very dubious. As a second example, recall that various disputes arose at one time about the 'true' value of the fractal dimension D, with claims that D can take any of two or more values for the 'same fractal'. All these disputes can be attributed to the neglect of the geometry. In some cases, an apparent ambiguity in the definition of dimension ended by either merely confirming or revealing that several *different* sets are in fact inherent in the *same* physical problem. In other cases, some of these values concern statistical *populations* of shapes, whereas dimension should carefully be kept as a property of *sample* shapes. If explicit geometry is kept in mind throughout, such errors would be avoided and the progress of fractal geometry would be swifter and smoother.

There is a counter-contention by yesterday's mathematicians. They claimed to have completely reduced geometry to analysis. But in fact they have not: the same geometric shape, when examined more carefully, often reveals fresh geometric features that affect physics and are obvious to the eye. Yet the geometric features have not been tamed by the existing analytic tools and therefore demand entirely new analytic tools. This is how I was led to introduce the notion of *lacunarity.* Scaling geometry is not merely a reflection of scaling analysis but a genuine counterpart of it. It is rich in features of its own, and it celebrates the power of simple rules to create geometric shapes of extraordinary and seemingly chaotic complexity, which analysis is then called upon to explain. The allegation that geometry is dead deserves nothing but scorn.

2. VARIATIONS ON THE THEME OF PLATO'S *ALLEGORY OF THE CAVE*

For better or worse, much of our thinking - scientific as well as political - is carried out in terms that can be traced back to Plato (427-347 B.C.). It is not totally surprising, therefore, that the first part of his celebrated *Allegory of the Cave* should come to mind when pondering the contrast that I see between two approaches to physics: the standard one, which is purely analytic even when it deals with geometric concepts, and the one I advocate, which is geometric and also visual.

Since I had to look up Plato before writing this part of the mentioned *Manifesto*, I do not fear to insult the reader by inserting a shortened quote from *The Republic* (Plato, 1941).

"Here is a parable to illustrate the degrees in which our nature may be enlightened or unenlightened. Imagine the condition of men living in a sort of cavernous chamber underground, with an entrance open to the light and a long passage all down the cave. Here they have been from childhood, chained so that they cannot move and can see only what is in front of them. At some distance higher up is the light of a fire burning behind them; and between the prisoners and the fire is a track with a parapet built along it, like the screen at a puppet-show, which hides the performers while they show their puppets over the top ...

And suppose their prison had an echo from the wall facing them. When one of the people crossing behind them spoke, they could only suppose that the sound came from the shadow passing before their eyes.

In every way, then, such prisoners would recognize as reality nothing but the shadows of those artificial objects ...

Now consider what would happen if their release from the chains and the healing of their unwisdom should come about in this way ..."

Plato continues by discussing various successive levels of increased understanding, with great emphasis on those most abstract and furthest removed from the shadows. On earlier occasions, for example in the foreword I wrote for (Peitgen, 1991), I have commented on Plato's emphasis on the abstract as a burden and as a poor example. But here I shall argue that the above *Allegory* does have a clear relevance to physics.

I tend to be involved with physics that uses many *analytic scaling relations*. On the other hand, this physics is also full of self-similar objects one can call *geometrically scaling*. I think that those objects are a deeper form of reality than analytic scaling, and, whenever possible, they deserve to be an object of study for themselves. The analytic relations remind me of shadows cast on different walls of Plato's cave. Geometric objects and the models of physics may not be real, they may be nothing but forgeries or *puppets*, yet they come closer to reality than the shadows.

Thus, consider a standard fractal set like the Cantor dust or the Sierpinski gasket. At a certain depth of analysis, the ultimate reality behind them is an ideal mathematical shape that goes beyond any physically drawn picture. Proofs of some

essential but nonintuitive facts (like the nondenumerable character of the Cantor dust) require consideration of this reality. As to actual drawings, they may be nothing but forgeries or puppets, yet inspecting them directly has proven to have strong intuitive power. In particular, an effort to describe them accurately necessarily uncovers a multiplicity of analytic scaling relations; each is obvious by inspection, and increasingly careful and skilled inspection uncovers yet another valid analytic scaling relation. The main steps of the derivations of those relations are also obvious by inspection, and the formal steps are then filled-in very easily. To the contrary, if only the algorithms were known and actual inspection was impossible, I feel that at least some of the analytic relations would be missed and that deriving any one relation from another would be a daunting task.

Yet, the identification of ultimate reality with an ideal picture is not beyond being questioned. It is tempting to follow Plato's lead and to move further into abstraction by seeking the ultimate at a 'higher level', for example, in the algorithms that serve to generate those ideal pictures. Those algorithms are surprisingly simple, since one of the prime achievements of fractal geometry is the discovery that shapes of exquisite variety and apparently chaotic complexity can be created by very simple rules. But this step towards a 'higher level' happens to inject a vital complication: one can obtain the same ideal shape by any one among several algorithms. Among the gasket's construction, the best known ones use triangular generators, stick generators and the chaos game, but we can add 'L-systems' and cellular automata, with which some readers may be familiar. The equivalence of these constructions is not at all obvious, and achieving an understanding of this equivalence may well be viewed as a step towards wisdom. Different goals favor different algorithms (often in unexpected ways), and none is absolutely the best.

This is, however, not the place for a further discussion of this search for an increasingly 'high understanding'. Within physics, it coincides with the search for increasingly elementary or fundamental particles. But - contrary to the opinion of people who (often unknowingly) are overwhelmed by the ideas of Plato - physics is not limited to this search. The part of physics in which I tend to be interested works in the opposite direction: towards a better understanding of the ways in which elementary parts aggregate in complicated wholes. Restated in Plato's terms, those cases raise a vital question: is it enough to examine shadows or better also to examine the puppets. My opinion is that, when reality involves a geometric object, even only as a model, this object should also be examined directly. Restricting examination to its analytic properties *is not enough*.

One of the original tasks of fractal geometry was to gain acceptance for geometric scaling as a full-fledged counterpart of analysis. Therefore, while I have harbored the above considerations for a long time, I thought it neither necessary nor politic to state them as boldly as I do now. In the down-to-earth practical study of fractal sets, the differences between the two kinds of scaling did not matter much. If a stronger statement has become necessary today, it is because more recent examples have proven altogether different. In particular, even from a down-to-earth practical viewpoint, explicit and visual geometry has proved essential to the study of multifractals and that analysis *is not enough*.

3. IN PRAISE OF A 'CONSTRUCTIVE' FORM OF PHYSICS

Since Chapter 1 was written, advances in computer graphics have given wide use to the term *visualization*. This opens a new problem. The eye deserves to be made an integral part of the process of scientific thought. To use visualization simply to illustrate results obtained by traditional methods *is not enough*. I think that the ability to draw 'computer forgeries' gives fresh proof of the superior power of explicit and visual geometry. Yet, these computer forgeries often elicit from friend or foe a dismissive query: "is this really physics?" To respond, I would like to strengthen the preceding *Opinion*.

I submit that the answer to the question "What is physics?" is not unique and absolute; it depends on the social and technological environment in which the question is asked.

In many branches of physics, theoretical predictions need no longer be limited to numbers and formulas. We know today how to express them in pictures that the eye can compare directly to the works of nature that they purport to describe. The formulas and what the eye sees are less misleading when combined than when taken separately.

I submit that, when convincing forgeries of nature are conceivable, the ability to produce them should be added to the old and accepted criteria for a convincing physical theory.

In the wake of this fight, it may be that quantum theory has struggled to gain acceptance of abstraction as both indispensable and adequate. Physics is punishing itself by adopting abstraction beyond necessity. But abstraction need not be viewed as a sufficient goal when the phenomena that are chaotic, complex or disorderly and also can be implemented visually.

The topics that interest me most in physical science fall very far from quantum mechanics, halfway (in some metaphorical sense) to a different extreme. The value of visualization is particularly great in biochemical synthesis, where the goal is not only to provide an abstract construct whose analytic properties would match those of a real molecule but also to provide the best possible forgery of reality. Also, in the esoteric field I like to call *rational botany*, A. Lindenmeyer's algebraic rules of growth of weeds did not become fully convincing until their graphic implementation by P. Prusinkiewicz showed that they suffice to produce weed-like pictures.

I contend that much about these visual goals extends beyond biochemistry or botany. When possible, the ability to provide convincing forgeries should be added to the purely analytic goals that tradition assigns to a scientific model. A theory that fails to meet either the analytic or the geometric goal should be viewed as incomplete.

In many cases, even the customary standards cannot be met, therefore the imposition of even higher standards is not necessarily welcome. For example, the $1/f$ form of the spectra of electric noises has not yet been satisfactorily predicted from first principles. Therefore, it may be premature to say that any prediction will be

incomplete unless it also includes rules that allow geometric forgeries of those noises.

I contend, nevertheless, that the proper goal is the more ambitious one; it could be described as a fully constructive form of physics.

4. IN PRAISE OF AN 'ANOMALOUS' PROBABILITY THEORY AS A TOOL OF PHYSICS

On superficial examination, fractals and multifractals can be classified either as nonrandom (e.g., the Cantor dust and the Sierpinski gasket) or random (e.g., Brownian motion). In practice, however, all fractals and multifractals are random. The reason is that the interesting questions do not concern the Cantor dust or the Sierpinski gasket as separate from the observer, but as seen from an origin that belongs to the set. Since - unavoidably - fractals and multifractals fail to be translationally invariant, their structure depends upon the origin that is selected. In practice, this origin must be viewed as chosen at random, which is equivalent to saying that the fractal itself is random.

A consequence of this randomness is that the study of fractals demands probabilistic arguments at various critical junctures. Many fractalists would question this claim and would put forward their own work as proof that one can manage without probability theory. In my experience, however, these would-be counter-examples only demonstrate that certain probabilistic arguments can be carried out correctly even if one is not aware of their being probabilistic. More often, these very same arguments are made more natural, simpler and clearer when their probabilistic nature is fully acknowledged.

This is not always an obvious task. Indeed, it is a widespread view among physicists that all the probability theory that they will ever need to know can be mastered in less than an hour, without a tutor. Indeed, most physicists are satisfied with the bold shortcut that reduces probability theory to the following 'folk theorems'. Population (ensemble) moments are 'normally' finite; sample averages 'normally' converge to population averages; random variables can 'normally' be expected to be Gaussian; and when they are not Gaussian, they can 'normally' be characterized by their moments of all orders. In this view, the remainder of probability theory is incomprehensible and useless.

Contrary to this parochial view, the study of fractals, of multifractals and of 'anomalous' noise demands probability theory far beyond the scope of the folk theorems. In other words, it is not sensible to view those phenomena as 'anomalous'; it is the widespread view of what is 'normal' that is *unwarranted*. For example, to understand multifractals and to avoid errors in handling them, it is necessary to know probability theory well beyond any folk theorem.

It is, unfortunately, a widespread view among today's probabilists that their field did not become mathematically respectable until it was provided with foundations and an expository style that, taken together, nearly identify it with measure theory. This view splits probability theory into two parts. On the one hand, there is an

elementary and old-fashioned part - including arguments rooted in combinatorics or in classical analysis - that hardly deserves being taught and can be learned without a tutor. On the other hand, there is a living and noble part that is solely accessible to specialists who have overcome a 'potential barrier' by achieving mastery of measure theory. It is not surprising, therefore, that most physicists find nonelementary probability theory to be difficult to learn and hard to love.

The pressures that caused probability theory to develop as described in the preceding paragraph were a belated but faithful replay of the very same pressures that half a century earlier had made set theory and measure theory develop as they did. The process is familiar to readers of *The Fractal Geometry of Nature* (Mandelbrot, 1982). First, a drastically original conceptual step is taken, one that contradicts views that mathematicians had come to hold obvious. This feat is often accomplished by introducing 'anomalies' called counterexamples. Soon afterwards, theories of rapidly increasing generality develop, and the original counter-examples become submerged as overly special cases. The resulting situation is summarized by words I used in (Mandelbrot, 1982), at the end of p. 9: "Mathematicians are to be praised for having devised (the Cantor dust and its kin) long ago, and scolded for having discouraged us from using them."

To be specific, the counterparts of Euclid in probability theory are the folk theorems mentioned earlier, and the counterparts of the Cantor set and its kin include the following: (a) the stable Lévy probability distributions and the related but far less developed and known Mittag-Leffler distribution and (b) the Cramèr large deviations theory. As to the theories of maximum generality that prevailed in 1963-1976, let me mention that at one time the only available treatise on probability theory was one due to M. Loève (1963); this treatise disposed of Lévy stability in one or two disparaging pages. Large deviations from the mean warranted no book until (Deutschel and Stroock, 1989); it suffices to observe that this monograph starts with these words: "1.1. *The General Idea.* Let *E* be a *Polish space.*"

Needless to say, my work in the 1950s and the 1960s made me rebel against this intellectual environment. It is widely known that my later but very similar battle against the pre-fractal intellectual environment of Cantor sets was won, with major help from illustrations. The former battle, however, stopped in a stalemate, although I like to believe that the recent flourishing of works on Lévy stable processes was at least in part triggered by my work (see Cambanis, Samborodnitsky, and Taqqu, 1991, and, more particularly Menger, 1932). If the study of noise and of multifractals is to progress, this battle must resume, and at long last I feel that it has a good chance of being won.

One feature common to much of the probability theory specific to fractals is (to paraphrase from Mandelbrot, 1982, end of p. 19) a "divergence syndrome. Some quantity that is commonly expected to be positive and finite turns out either to be infinite or to vanish. It may be an expectation, a variance or a higher moment, or it may be a 'probability'. At first blush, such misbehavior looks most bizarre and even terrifying, but a careful reexamination shows it to be quite acceptable, as long as one is willing to use new methods of thought."

5. IN PRAISE OF ALLOWING SOME 'OPEN' DEFINITIONS IN MATHEMATICS

My concern with the precise role of definitions in mathematics is, of course, strengthened by the fact that there is no precise mathematical definition of the terms *fractal* and *multifractal.*

It is, of course, true that mathematics thrives on precision, and this perhaps may be why its practitioners seldom publicize a peculiar little secret. This secret is that many widely used and important mathematical notions allow competing 'definitions' to survive forever, side by side, with none becoming either precise or universally accepted. Entire fields of mathematics thrive for centuries with a clear image in most people's minds, and certainly in the minds of their practitioners, but without anything resembling a definition.

For a first example, let us consider the question "what is it that we call a curve?" Works of Camille Jordan and Giuseppe Peano (late 19th century) transformed what seemed a straightforward notion into one that is obscure, full of controversies and altogether unpalatable - a situation known to very few. P. S. Urysohn and K. Menger attempted in the 1920s to create a proper theory of curves, but the attempt petered off after a book by K. Menger (1932).

The second example, chosen for the sake of contrast, concerns one of the most durable core topics of mathematics: "What is it that we call complex analysis?" The question is addressed without reticence in the preface of a splendid textbook by Ralph P. Boas (1987). In a review G. Piranian (1989) quotes from the book approvingly, as follows (setting his quote in italics): "Boas avoids the folly of an impossible definition by making a modest declaration. In his preliminary statement to students he writes: *Complex analysis was originally developed for its applications; however, the subject now has an independent and active life of its own, with many elegant and even surprising results.* The declaration does not characterize complex analysis; but complex analysts know that no reasonable description of their territory could ever have remained satisfactory for more than a quarter century ... Complex analysis began as the art of using complex-valued functions in the analysis of various physical problems and today it is primarily the study, by analysis and synthesis, and with geometric, topological, algebraic, number-theoretic, or other cultural orientations, of complex-valued functions in spaces of one or more complex variables."

An attempt to answer the question of "What is it that we call probability theory" would fare even worse. But again, there is a quirky complication discussed in Chapter 4. Not so long ago, probabilists like Paul Lévy were not accepted as full-fledged mathematicians, and the desire to gain full acceptance has led some of their heirs to willingly narrow the scope of probability theory to fit a clear definition.

Acknowledging this background, there could be no embarrassment in rushing to assert, before one is asked to concede, that the above-quoted words by Boas remain true when one replaces *complex analysis* with *fractal geometry.* If anything, the situation is even more fluid, simply because the field was founded within the memory of many who practice it today. To take an example, I am in the process of writing

down, this very day, an account of new research results that has no choice but to apply the term *fractal* to yet another object that *fails* several tempting existing definitions of this notion.

For reasons of this kind, my first book, (Mandelbrot, 1975), took a very informal approach to the meaning of the term *fractal* and discussed *multifractals* even more informally (and, at that point, without coining a word for them). But I regret to say that my English books, (Mandelbrot, 1977), gave in to criticism and agreed to link the very general notion of fractal with the related but far more specialized notion of Hausdorff-Besicovitch dimension. I have been trying ever since to loosen this link.

I trust that, if fractal geometry proves sufficiently useful to survive, the search for needless precision in the definition of fractals will one day disappear.

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SFS: SYMMETRIC FORUM OF THE SOCIETY (BULLETIN BOARD)

All correspondence should be addressed to the editors: György Darvas or Dénes Nagy.

ANNOUNCEMENT

Katachi U Symmetry: An International Symposium

Tsukuba Science City (near Tokyo), Japan, November 21-25, 1994

Katachi is the principal Japanese word expressing form, shape, figure, pattern, and also distortion of form (cf., the concept dissymmetry), while *U* refers to union. The symposium will focus on artistic and scientific activities related to *katachi* and *symmetry*. An additional goal is to compare the Western preference for symmetry and the Eastern tendency for symmetry breaking. Obviously these goals are very close to the main interest of ISIS-Symmetry, thus we encourage our members to join this event.

Actually, the symposium will be organized in cooperation with *ISIS-Symmetry* and five Japanese societies or groups: *Ars*$^+$, *Katachi no bunka kai* (Form and Culture Society), *Katachi no kagaku kai* (Society for Science on Form), *Kojigen kagaku kai* (Institute of Hyperspace Science), and the *Origami Science Forum*. The General Chairman of the Organizing Committee is Tohru Ogawa (Tsukuba Science City), the Honorary Chairman is Kodi Husimi (Tokyo). They are assisted by a Japanese Committee and an international Advisory Board. The main language of the symposium is English. The Japanese participants may give their lectures in Japanese, but those will be translated.

In the framework of this symposium, ISIS-Symmetry proposes a session entitled

Symmetry, dissymmetry, broken symmetry in art and science: Dialogue of East and West,

which will be chaired by György Darvas and a Japanese colleague. Briefly about this session: According to the famous phrase by Pierre Curie, "the dissymmetry makes the phenomenon". Indeed, there is no perfect symmetry in nature or art, but rather some symmetry violations make the phenomena or events more useful or exciting for the researcher and the artist (practical and aesthetical values). The idea of broken symmetry plays an important role in the oriental, especially Japanese, arts. On the other hand, Western art and science also discovered the advantage of

creating and seeking broken symmetry. The session will discuss these aspects in both interdisciplinary and intercultural contexts.

The list of the planned sessions (not yet final):
- Science on form,
- Geometrical arts and morphology,
- Invisible - visible: Viewing invisible images by comparing them to visible form,
- Sensing order,
- Symmetry, dissymmetry, broken symmetry in art and science: Dialogue of East and West.

The participants may present (*a*) papers, or (*b*) artistic works (and performances). The registration fee is ¥en 40,000.

Please request up-dated information from the General Chairman and send all correspondence, including the abstracts, to his address:

Tohru Ogawa, *Katachi U Symmetry*, Institute of Applied Physics, University of Tsukuba, Tsukuba Science City, Ibaraki-ken, Japan 305;
Phone and Fax: 81-298-53-5028.

SYMMETRIC NEWS

Exhibition Ars (Dis)Symmetrica '93

The exhibition *Ars (Dis)Symmetrica* was organised in Budapest, Hungary, in the *Kilátó Gallery* at the old water-tower on the Margaret Isle. The exhibition was open from **10th June** to **11th July 1993.**

Ars (Dis)Symmetrica has been organised by *Symmetrion* – The Institute for Advanced Symmetry Studies. As it is well known, Symmetrion was founded by the *International Society for the Interdisciplinary Study of Symmetry* (ISIS-Symmetry) in 1991; *ISIS-Symmetry* was formed in August 1989, parallel with its first exhibition *Symmetry/Asymmetry* in the *Hungarian National Gallery* of Budapest. The second exhibition of ISIS-Symmetry, *Symmetry of Patterns* took place in the *Synergetics Institute*, Hiroshima, Japan, August 1992.

Ars (Dis)Symmetrica followed the positive traditions of these former artistic-scientific events. It has been planned to be the first exhibition of a regular series. The main goals of *Ars (Dis)Symmetrica* were to represent close connections between, and the mutual influence of, arts and sciences.

The jury selected works of the following artists to display:

Bartnig, Horst (Berlin), *Bérczi, Szaniszló* (Budapest), *Bortnyik, Éva* and *Tubák, Csaba* (Vienna), *Bunke, Zsuzsa* (Budapest), *Carmi, Eugenio* (Milano), *d'Angelo, Aldo* (Firenze), *Dewar, Robert E.* (Altadena, California), *Erdély, Dániel* (Budapest), *F. Farkas, Tamás* (Budapest), *Huff, William S.* (Buffalo, N.Y.), *Hutira, Péter* (Baia Mare, Romania), *König, Frigyes* (Budapest) *Kovács, Attila* (Budapest), *Kuchta, Clara* (Geneva), *Langdon, John* (Philadelphia), *Lengyel, András* (Budapest),

Maurer, Dóra (Budapest), *Molnár, Vera* (Paris), *Newman, Rochelle* and *Boles, Martha* (Haverhill, MA), *Pataki, Tibor* (Budapest), *Pimenta, Emanuel Dimas de Melo* (Lisboa), *Rákóczy, Gizi* (Budapest), *Rigby, John F.* (Cardiff), *Robbin, Tony* (New York), *Sheridan, Sonia Landy* (Harschaw, Wisconsin), *Székely, Pierre* (Párizs), *Szemenyey-Nagy, Tibor* (Nagykanizsa, Hungary), *Türk, Péter* (Budapest), *Zalavári, József* (Budapest).

The main patron of Ars (Dis)Symmetrica was *Miklós Marschall* Deputy Mayor of the city of Budapest. Ars (Dis) Symmetrica '93 was sponsored by the City of Budapest, the Budapest Gallery, the International Symmetry Foundation, and the Göncöl Foundation. The Chief Curator of the exhibition was *László Beke*. The Exhibition was opened on 10th June, 1993 by *Otto Mezei*.

Change of Dénes Nagy's address

The President of ISIS-Symmetry, Dénes Nagy joined the University of Tsukuba in Tsukuba Science City, Japan. During his visiting professorship, he spends less time at his other affiliations at the University of the South Pacific, Fiji and at the Eötvös Loránd University, Hungary. His primary address (until August, 1995) is the following: Institute of Applied Physics, University of Tsukuba, Tsukuba Science City, Ibaraki-ken, Japan 305. Phone: 81-298-53-6786; Fax: 81-298-53-5205; E-mail: nagy@kafka.bk.tsukuba.ac.jp .

SYMMETRIC EVENTS (CALENDAR OF SYMMETRY RELATED EVENTS)

Here we list not only the events which are organized, or co-organized, by ISIS-Symmetry (those are indicated in the first line), but also other meetings and exhibitions having some connection with the general topic of symmetry or focusing on art-science relationships. Addresses of Board Members of ISIS-Symmetry are on the inside covers.

Regular events

Monthly meetings – Budapest, Hungary ISIS-Symmetry
Szimmetria Kör / Symmetry Circle. No meetings in summertime. Invited speakers (in chronological order): Árpád Szabó, Dániel Czakó, Ernő Lendvai, Sándor Kürthy, István Gazda, Ervin Deák, Ferenc Vidor, György Darvas, József Zsolnai, Béla Lukács, Oszkár Papp, Szaniszló Bérczi, Tibor Tarnai, György Kampis, László Beke. Information: György Darvas, refer to the Board of ISIS-Symmetry.

1993

October 28-31, 1993 – Chicago, Illinois, U.S.A.
Science and Art: Creativity, Motivation, and the Joy of Learning. Information: Linda Marquardt, Chicago Academy of Sciences, 2001 North Clark Street, Chicago, IL 60614, U.S.A.; Phone: 1-312-549-3077.

November 3-7, 1993 – Minneapolis, Minnesota, U.S.A.
Fourth International Symposium on Electronic Art (FISEA). Information: Roman Verostko, Minneapolis College of Art and Design, 2501 Stevens Avenue South, Minneapolis, MN 55404, U.S.A.; Phone: 1-612-874-3754; Fax: 1-612-874-732; E-mail: fisea93@msc.net.

November 27, 1993 – Bristol, U.K.
Growth and Form: Art and Science Conference. Information: Interalia, 49 Bristol Hill, Brislington, Bristol BS4 5AA, U.K.; Phone: 44-272-720-704; Fax: 44-0272-776-390.

1994

January 20-22, 1994 – Lisbon, Portugal
Art and Science Looking into the 3rd Millennium. Information: Fundaçâo Calouste Gulbenkian, P-1093 Lisboa Codex, Portugal; Phone: 351-1-793-5131; Fax: 351-1-795-5206.

March 5-15, 1994 – Arizona, U.S.A.
XVth International Humanitas Congress. Information: Peter Horwath, Department of Foreign Languages, Arizona State University, Tempe, AZ 85287-0202, U.S.A.; Phone: 1-602-965-6382 or 1-602-965-6281; Fax: 1-602-965-0135.

March 27-29, 1994 – Renvyle (near Letterfrack), Ireland
Foams Euroconference. Information: Denis Weaire, Physics Department, Trinity College, Dublin, Ireland; E-mail: dweaire@vax1.tcd.ie.

June 10-12, 1994 – San Francisco, California, U.S.A.
Annual convention of the *Brewster Society.* Information: Cozy Baker, 9020 McDonald Dr., Bethesda, MD 20817, U.S.A.

June 12-18, 1994 – Berkeley, California, U.S.A.
Semiotics Around the World: Synthesis in Diversity, Fifth Congress of the International Association for Semiotic Studies (IASS). Solomon Marcus (refer to the Board of ISIS-Symmetry) is one of the Vice-Presidents of IASS. Information: Irmengard Rauch, 2036 Columbus Parkway #347, Benicia, CA 94510, U.S.A.; Phone and Fax: 1-707-746-7480; E-mail: irauch@garnet.berkeley.edu.

June 21-25, 1994 – Linz, Austria
Ars Electronica 94: Intelligent Environments – Festival for Art, Technology, and Society. Information: Ars Electronica, Brucknerhaus Linz, Untere Donaulände 7, A-4010 Linz, Austria; Fax: 43-732-7612-350; E-mail: schoeber@jk.uni-linz.ac.at.

June 27-July 2, 1994 – Bydgoszcz, Poland
Convex and Discrete Geometry. Information: Marek Lassak, Instytut Matematyki i Fizyki ATR, ul. Kaliskiego 7, PL 85-791 Bydgoszcz, Poland; E-mail: lassak@pltumk11.bitnet.

July 25-27, 1994 – Blumenau, Brazil
History and Pedagogy of Mathematics (HPM): An International Conference. Information: Ubiratan D'Ambrosio, Board member of ISIS-Symmetry, New address: Rua Peixoto Gomide 1772, ap. 83, 01409 Sao Paulo, S.P. Brazil; Phone and Fax: 55-11-280-0266.

August 3-11, 1994 – Zürich, Switzerland
International Congress of Mathematicians (ICM 94). There are some symmetry-related sections, including Nos. 4. Geometry, 7. Lie groups and representations, 17. Applications of mathematics in the sciences, 18. Teaching and popularization of mathematics, 19. History of mathematics. Information: ICM 94, ETH Zentrum, CH-8092 Zürich, Switzerland.

August 15-20, 1994 – Salzburg, Austria
Kunst und Religion: Weltmusik und Weltreligionen – Klänge und Texte, Kulte und Kulturen / Arts and Religion: Music and Religions of the World – Sound and Word, Cults and Cultures. Information: Wolfgang Roscher, Hochschule für Musik und darstellende Kunst "Mozarteum", Mirabellplatz 1, A-5020 Salzburg, Austria; Phone: 43-662-88-908 ext. 611; Fax: 43-662-872-436.

August 21-27, 1994 – Bielefeld, F. R. Germany ISIS-Symmetry
Structural and Dynamical Symmetry in Complex Systems. This research symposium will be co-organized by ISIS-Symmetry. Information: Andreas Dress and Dénes Nagy, refer to the Board of ISIS-Symmetry.

August 28-September 2, 1994 – Leipzig, F. R. Germany
15th European Crystallographic Meeting (ECM-15). Information: P. Paufler, Institut für Kristallographie, Universität Leipzig, Scharnhorsstr. 20, D-O-7030 Leipzig, F. R. Germany.

October 17-23, 1994 – Stavropol, Russia ISIS-Symmetry
Second International Conference on *Cyclic Processes in Nature and Society.* The sections of the conference include the following topics: General theory of cycles: methodological problems, cyclic processes in the society, in the inorganic systems, and in the biological systems. Information: Iu. N. Sokolov, University of Stavropol, pr. K. Marksa 34, Stavropol, 355008 Russia.

November 21-25, 1994 – Tsukuba Science City, Japan ISIS-Symmetry
Katachi U Symmetry. Katachi is the principal Japanese word expressing form, shape, pattern, while *U* refers to union. The symposium will be organized in cooperation with ISIS-Symmetry and five Japanese societies or groups. Information: Tohru Ogawa, Institute of Applied Physics, University of Tsukuba, Tsukuba Science City, Ibaraki-ken, Japan 305; Phone and Fax: 81-298-53-5028.

November 29-December 2, 1994 – Ohtsu (near Kyoto), Japan
Origami Science and Scientific Origami. Information: Koryo Miura, refer to the Board of ISIS-Symmetry; Mailing address: 3-9-7 Tsurukawa, Machida, Tokyo, Japan 195; Fax: 81-427-35-6946.

Contributions to *SYMMETRY: CULTURE AND SCIENCE* are welcomed from the broadest international circles and from representatives of all scholarly and artistic fields where symmetry considerations play an important role. The papers should have an interdisciplinary character, dealing with symmetry in a concrete (not only metaphorical!) sense, as discussed in 'Aims and Scope' on p. 336. The quarterly has a special interest in how distant fields of art, science, and technology may influence each other in the framework of symmetry (symmetrology). The papers should be addressed to a broad non-specialist public in a form which would encourage the dialogue between disciplines.

Manuscripts may be submitted directly to the editors, or through members of the Board of ISIS-Symmetry.

Contributors should note the following:

- All papers and notes are published in English and they should be submitted in that language. The quarterly reviews and annotates, however, non-English publications as well.

- In the case of complicated scientific concepts or theories, the intuitive approach is recommended, thereby minimizing the technical details. New associations and speculative remarks can be included, but their tentative nature should be emphasized. The use of well-known quotations and illustrations should be limited, while rarely mentioned sources, new connections, and hidden dimensions are welcomed.

- The papers should be submitted either by electronic mail to both editors, or on computer diskettes (5 ¼" or 3.5") to György Darvas as text files (IBM PC compatible or Apple Macintosh); that is, conventional characters should be used (ASCII) without italics or other formatting commands. Of course typewritten texts will not be rejected, but the preparation of these items takes longer. For any method of submission (e-mail, diskette, or typescript), four hard-copies of the text are also required, where all the necessary editing is marked in red (inserting non-ASCII characters, underlining words to be italicized, etc.). Three hard-copies, including the master copy and the original illustrations, should be forwarded to György Darvas, while the fourth copy should be sent to Dénes Nagy. No manuscripts, diskettes, or figures will be returned, unless by special arrangement.

- The papers are accepted for publication on the understanding that the copyright is assigned to ISIS-Symmetry. The Society, however, aiming to encourage the cooperation, will allow all reasonable requests to photocopy articles or to reuse published materials. Each author will receive a complimentary copy of the issue where his/her article appeared.

- Papers should begin with the title, the proposed running head (abbreviated form of the title of less than 35 characters), the proposed section of the quarterly where the article should appear (see the list in the note 'Aims and Scope'), the name of the author(s), the mailing address (office or home), the electronic mail address (if any), and an abstract of between 10 and 15 lines. A recent black-and-white photo, the biographic data, and the list of symmetry-related publications of (each) author should be enclosed; see the sample at the end.

- Only black-and-white, camera-ready illustrations (photos or drawings) can be used. The required (approximate) location of the figures and tables should be indicated in the main text by typing their numbers and captions (Figure 1: [text], Figure 2: [text], Table 1: [text], etc.), as new paragraphs. The figures, which will be slightly reduced in printing, should be enclosed on separate sheets. The tables may be given inside the text or enclosed separately.

- It is the author's responsibility to obtain written permission to reproduce copyright materials.

- Either the British or the American spelling may be used, but the same convention should be followed throughout the paper. *The Chicago Manual of Style* is recommended in case of any stylistic problem.

- Subtitles (numbered as 1, 2, 3, etc.) and subsidiary subtitles (1.1, 1.1.1, 1.1.2, 1.2, etc.) can be used, without over-organizing the text. Footnotes should be avoided; parenthetic inserts within the text are preferred.

- The use of references is recommended. The citations in the text should give the name, year, and, if necessary, page, chapter, or other number(s) in one of the following forms: ... Weyl (1952, pp. 10-12) has shown...; or ... as shown by some authors (Coxeter et al., 1986, p. 9; Shubnikov and Koptsik 1974, chap. 2; Smith, 1981a, chaps. 3-4; Smith, 1981b, sec. 2.12; Smith, forthcoming). The full bibliographic description of the references should be collected at the end of the paper in alphabetical order by authors' names; see the sample. This section should be entitled *References*.

Sample of heading (Apologies for the strange names and addresses)

SYMMETRY IN AFRICAN ORNAMENTAL ART
BLACK-AND-WHITE PATTERNS IN CENTRAL AFRICA
Running head: Symmetry in African Art
Section: Symmetry: Culture & Science

Susanne Z. Dissymmetrist and Warren M. Symmetrist
8 Phyllotaxis Street Department of Dissymmetry, University of Symmetry
Sunflower City, CA 11235, U.S.A. 69 Harmony Street, San Symmetrino, CA 69869, U.S.A.
E-mail: symmetrist@symmetry.edu

Abstract

The ornamental art of Africa is famous ...

Sample of references

In the following, note punctuation, capitalization, the use of square brackets (and the remarks in parentheses). There is always a period at the very end of a bibliographic entry (but never at other places, except in abbreviations). Brackets are used to enclose supplementary data. Those parts which should be italicized — titles of books, names of journals, etc. — should be underlined in red on the hard-copies. In the case of non-English publications both the original and the translated titles should be given (cf., Dissymmetrist, 1990).

Asymmetrist, A. Z. (or corporate author) (1981) *Book Title: Subtitle*, Series Title, No. 27, 2nd ed., City (only the first one): Publisher, vii + 619 pp.; (further data can be added, e.g.) 3rd ed., 2 vols., ibid., 1985, viii + 444 + 484 pp. with 2 computer diskettes; Reprint, ibid., 1988; German trans., *German Title*, 2 vols., City: Publisher, 1990, 986 pp.; Hungarian trans.

Asymmetrist, A. Z., Dissymmetrist, S. Z., and Symmetrist, W. M. (1980-81) Article or e-mail article title: Subtitle, Parts 1-2, *Journal Name Without Abbreviation*, [E-Journal or Discussion Group address: journal@node (if applicable)], B22 (volume number), No. 6 (issue number if each one restarts pagination), 110-119 (page numbers); B23, No. 1, 117-132 and 148 (for e-journals any appropriate data).

Dissymmetrist, S. Z. (1989a) Chapter, article, symposium paper, or abstract title, [Abstract (if applicable)], In: Editorologist, A.B. and Editorologist, C.D., eds., *Book, Special Issue, Proceedings, or Abstract Volume Title*, [Special Issue (or) Symposium organized by the Dissymmetry Society, University of Symmetry, San Symmetrino, Calif., December 11-22, 1971 (those data which are not available from the title, if applicable)], Vol. 2, City: Publisher, 19-20 (for special issues the data of the journal).

Dissymmetrist, S. Z. (1989b) *Dissertation Title*, [Ph.D. Dissertation], City: Institution, 248 pp. (Exhibition Catalogs, Manuscripts, Master's Theses, Mimeographs, Patents, Preprints, Working Papers, etc. in a similar way; Audiocassettes, Audiotapes, Compact Disks, Computer Diskettes, Computer Software, Films, Microfiches, Microfilms, Slides, Sound Disks, Videocasettes, etc. with necessary modifications, adding the appropriate technical data).

Dissymmetrist, S. Z., ed. (1990) *Dissimmetriya v nauke* (title in original, or transliterated, form), [Dissymmetry in science, in Russian with German summary], Trans. from English by Antisymmetrist, B. W., etc.

Phyllotaxist, F. B. (1899/1972) *Title of the 1972 Edition*, [Reprint, or Translation, of the 1899 ed.], etc.

[Symmetrist, W. M.] (1989) Review of *Title of the Reviewed Work*, by S. Z. Dissymmetrist, etc. (if the review has an additional title, then it should appear first; if the authorship of a work is not revealed in the publication, but known from other sources, the name should be enclosed in brackets).

In the case of lists of publications, or bibliographies submitted to *Symmetro-graphy*, the same convention should be used. The items may be annotated, beginning in a new paragraph. The annotation, a maximum of five lines, should emphasize those symmetry-related aspects and conclusions of the work which are not obvious from the title. For books, the list of (important) reviews, can also be added.

Sample of biographic entry

Name: Warren M. Symmetrist, Educator, mathematician, (b. Boston, Mass., U.S.A., 1938).

Address: Department of Dissymmetry, University of Symmetry, 69 Harmony Street, San Symmetrino, Calif. 69869, U.S.A. *E-mail:* symmetrist@symmetry.edu

Fields of interest: Geometry, mathematical crystallography (also ornamental arts, anthropology — non-professional interests in parentheses).

Awards: Symmetry Award, 1987; Dissymmetry Medal, 1989.

Publications and/or *Exhibitions*: List all the symmetry-related publications/exhibitions in chronological order, following the conventions of the references and annotations. Please mark the most important publications, not more than five items, by asterisks. This shorter list will be published together with the article, while the full list will be included in the computerized data bank of ISIS-Symmetry.

There are many disciplinary periodicals and symposia in various fields of art, science, and technology, but broad interdisciplinary forums for the connections between distant fields are very rare. Consequently, the interdisciplinary papers are dispersed in very different journals and proceedings. This fact makes the cooperation of the authors difficult, and even affects the ability to locate their papers.

In our 'split culture', there is an obvious need for interdisciplinary journals that have the basic goal of building bridges ('symmetries') between various fields of the arts and sciences. Because of the variety of topics available, the concrete, but general, concept of symmetry was selected as the focus of the journal, since it has roots in both science and art.

SYMMETRY: CULTURE AND SCIENCE is the quarterly of the *INTERNATIONAL SOCIETY FOR THE INTERDISCIPLINARY STUDY OF SYMMETRY* (abbreviation: *ISIS-Symmetry*, shorter name: *Symmetry Society*). ISIS-Symmetry was founded during the symposium *Symmetry of Structure* (*First Interdisciplinary Symmetry Symposium and Exhibition*), Budapest, August 13-19, 1989. The focus of ISIS-Symmetry is not only on the concept of symmetry, but also its associates (asymmetry, dissymmetry, antisymmetry, etc.) and related concepts (proportion, rhythm, invariance, etc.) in an interdisciplinary and intercultural context. We may refer to this broad approach to the concept as *symmetrology*. The suffix *-logy* can be associated not only with knowledge of concrete fields (*cf.*, biology, geology, philology, psychology, sociology, etc.) and discourse or treatise (cf., methodology, chronology, etc.), but also with the Greek terminology of proportion (cf., *logos*, *analogia*, and their Latin translations *ratio*, *proportio*).

The basic goals of the *Society* are
(1) to bring together artists and scientists, educators and students devoted to, or interested in, the research and understanding of the concept and application of symmetry (asymmetry, dissymmetry);
(2) to provide regular information to the general public about events in symmetrology;
(3) to ensure a regular forum (including the organization of symposia, and the publication of a periodical) for all those interested in symmetrology.

The Society organizes the triennial *Interdisciplinary Symmetry Symposium and Exhibition* (starting with the symposium of 1989) and other workshops, meetings, and exhibitions. The forums of the Society are *informal* ones, which do not substitute for the disciplinary conferences, only supplement them with a broader perspective.

The Quarterly — a non-commercial scholarly journal, as well as the forum of ISIS-Symmetry — publishes original papers on symmetry and related questions which present new results or new connections between known results. The papers are addressed to a broad non-specialist public, without becoming too general, and have an interdisciplinary character in one of the following senses:
(1) they describe concrete interdisciplinary 'bridges' between different fields of art, science, and technology using the concept of symmetry;
(2) they survey the importance of symmetry in a concrete field with an emphasis on possible 'bridges' to other fields.

The Quarterly also has a special interest in historic and educational questions, as well as in symmetry-related recreations, games, and computer programs.

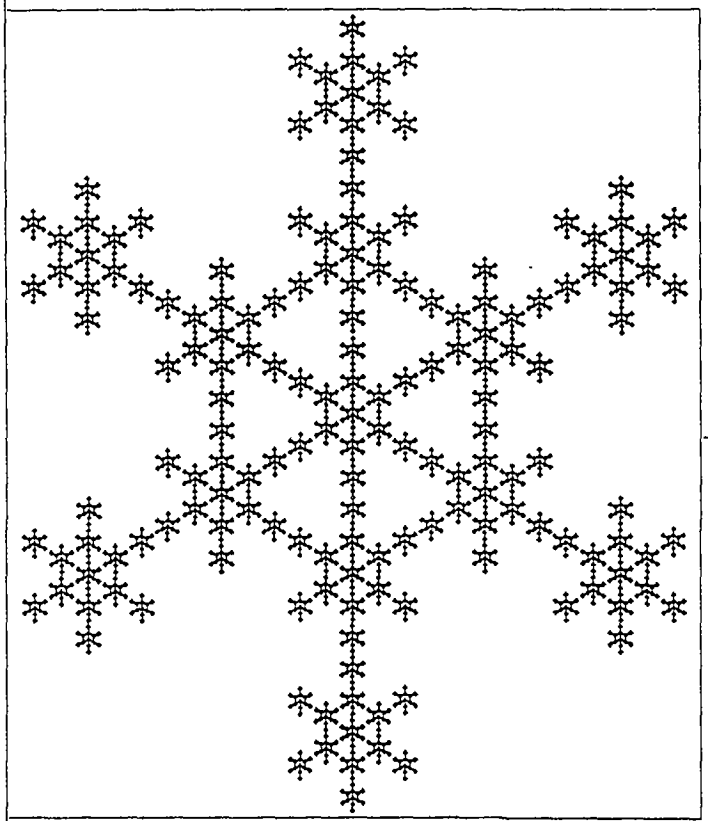
The regular sections of the Quarterly:
- **Symmetry: Culture & Science** (papers classified as humanities, but also connected with scientific questions)
- **Symmetry: Science & Culture** (papers classified as science, but also connected with the humanities)
- **Symmetry in Education** (articles on the theory and practice of education, reports on interdisciplinary projects)
- **Mosaic of Symmetry** (short papers within a discipline, but appealing to broader interest)
- **SFS: Symmetric Forum of the Society** (calendar of events, announcements of ISIS-Symmetry, news from members, announcements of projects and publications)
- **Symmetro-graphy** (biblio/disco/software/ludo/historio-graphies, reviews of books and papers, notes on anniversaries)
- **Reflections: Letters to the Editors** (comments on papers, letters of general interest)

Additional non-regular sections:
- **Symmetrospective: A Historic View** (survey articles, recollections, reprints or English translations of basic papers)
- **Symmetry: A Special Focus on ...** (round table discussions or survey articles with comments on topics of special interest)
- **Symmetry: An Interview with ...** (discussions with scholars and artists, also introducing the Honorary Members of ISIS-Symmetry)
- **Symmetry: The Interface of Art & Science** (works of both artistic and scientific interest)
- **Recreational Symmetry** (problems, puzzles, games, computer programs, descriptions of scientific toys; for example, tilings, polyhedra, and origami)

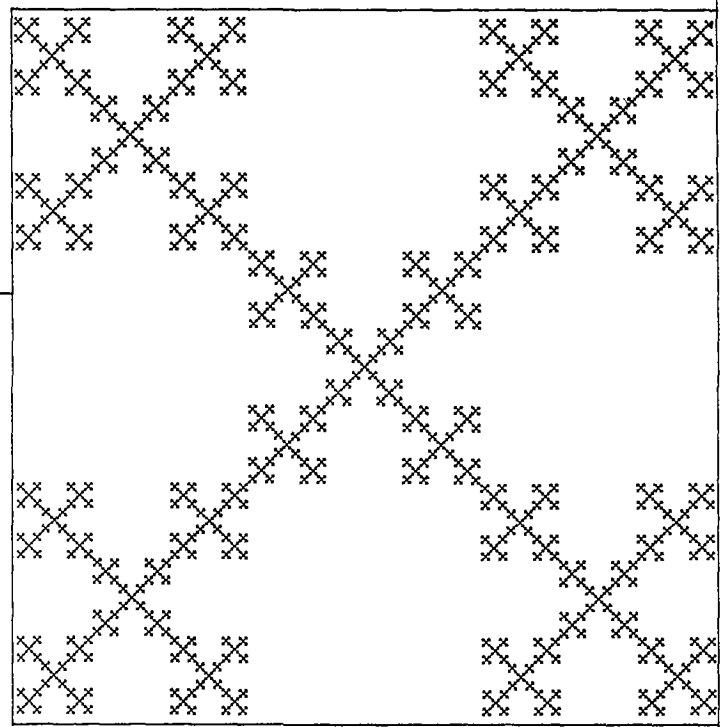
Both the lack of seasonal references and the centrosymmetric spine design emphasize the international character of the Society; to accept one or another convention would be a 'symmetry violation'. In the first part of the abbreviation *ISIS-Symmetry* all the letters are capitalized, while the centrosymmetric image iSIS! on the spine is flanked by 'Symmetry' from both directions. This convention emphasizes that ISIS-Symmetry and its quarterly have no direct connection with other organizations or journals which also use the word *Isis* or *ISIS*. There are more than twenty identical acronyms and more than ten such periodicals, many of which have already ceased to exist, representing various fields, including the history of science, mythology, natural philosophy, and oriental studies. ISIS-Symmetry has, however, some interest in the symmetry-related questions of many of these fields.

continued from inside front cover

ISIS-Symmetry
Budapest, P.O. Box 4
H-1361 Hungary



Symmetry



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