MATHEMATICS AND TWENTIETH CENTURY ART

Selections from the McCrory Corporation Collection

BARUCH COLLEGE GALLERY, 135 EAST 22 STREET, NEW YORK CITY

Cubic Limit Manfred Mohr

FOREWORD

"Mathematics and Twentieth-Century Art" represents a variety of collaborative efforts. The McCrory Corporation Collection itself, one of the nation's most distinguished corporate collections, evidences an alliance between business and art. Making its collection available to Baruch College exemplifies further cooperation between a private corporation and a public university. Baruch College is a particularly appropriate site for the exhibition because the college curriculum combines education in business administration with a firm grounding in the humanities and sciences. Within the School of Liberal Arts and Sciences, the departments of mathematics and art have long cooperated in interdisciplinary teaching and research. The curators of this exhibit, Harry Bixler, professor of mathematics, and Richard Wengenroth, professor of art, have worked collaboratively on every aspect of its organization and presentation.

We are grateful to Celia Ascher, curator of the McCrory Collection, for her generosity in lending the work, as well as for her moral support and advice. We also thank Barbara Kowaleski, who assisted us in the numerous details of organizing an exhibit and producing a catalogue.

The project would not have been possible without the enthusiastic support of President Joel Segall, former Provost Philip Austin, Vice-President Stephen Wertheimer, and Dean Martin Stevens. Throughout the planning period the curators and gallery director had the encouragement of the College Gallery Committee, which includes Professors John Gillen, Roslyn Bernstein, Pamela Sheingorn, Harry Bixler, and Marilyn Mikulsky. Funds for the exhibit, the catalogue and the renovation of the gallery were provided by a generous grant from The Baruch College Fund.

Katherine B. Crum
Director
The Baruch College Gallery

MATHEMATICS AND TWENTIETH-CENTURY ART: Selections from the McCrory Corporation Collection by Harry Bixler

Harry Bixler
Richard Wengenroth
Co-curators

Twentieth-century abstract art embraces two broad categories of shapes, the organic/biomorphic and the geometric. The organic/biomorphic tradition, with its flowing, irregular, curvilinear forms, is associated with movements such as Surrealism and Abstract Expressionism and is not represented in this exhibition. The distinction of the McCrory Corporation Collection lies in its inclusive representation of the geometric tradition, with its predominance of straight-edged and circular shapes, together with various principles for relating these shapes to one another.

The collection includes works that exemplify virtually every motivation artists in our time have had for making geometric art. For many artists, the properties of geometry have suggested both universality and adaptability to mass production: good design for all in a technological age. Artists of the Bauhaus exhibit some of the most influential examples of this approach. Other artists — some of the Russian Suprematists and the Dutch de Stijl — often used geometry in more Platonic, sometimes mystical ways, as visual metaphors for non-material states. For many of these artists, regardless of motivation, this tendency toward the purity of geometry signals a refusal to make art by depicting the specific and transitory visual experiences of the real world and, instead, a search for more universal shapes and relationships that are true for all time.

It is this same striving for universal and eternal "truths" of form and relationship that has characterized mathematics since its formal beginnings in the sixth century B.C. The architecture and engineering of ancient Egypt, where temples and pyramids had to be squared at their bases and lands resurveyed each year following the Nile flood, gave rise to many practical schemes for "earth measurement," or "geometry" (figure 1). It remained for the Greeks of the ensuing three centuries to create pure mathematics by divorcing these geometric ideas from the practical world of architecture and surveying. A "triangle" was no longer a stretched rope, nor was a "rectangle" an earthen field: mathematical ideas became abstractions, and the relationships among these entities became further abstractions. It is precisely these mathematical abstractions, these pure relationships, which have become part of the visual content, either by design or otherwise, of much of twentieth-century geometric art.

FIG. 1 Egyptian Geometric Device: A rope knotted into 12 equal segments when stretched will create a 3-4-5 triangle with a right (90°) angle opposite the longest side.

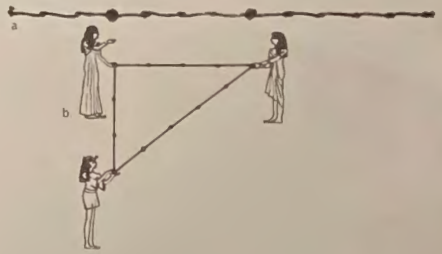


FIG. 2 Euclidean Relations. Lines parallel (l_1 and l_2), intersecting (l_1 and l_3), perpendicular (l_1 and l_4), lines perpendicular to the same line (l_4 to l_1 and l_5 to l_1) are parallel to each other (l_4 and l_5).

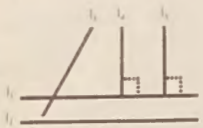


FIG. 3 Euclidean / non-Euclidean Depiction of Depth.
a. Depth with Euclidean parallels: parallel lines stay the same distance apart no matter how far extended.
b. Depth with non-Euclidean parallels: lines parallel to one another all meet at a "vanishing point" (or point at infinity).

Original Image

a.

b.

This exhibition, therefore, does not examine its featured works from within the generally accepted art historical categories, but rather from this uncommon, yet perfectly logical viewpoint — as mathematical ideas. This approach does not attempt to decide whether such mathematical ideas as may appear in a work of art were the conscious intention of the artist or merely a consequence of the artist's exploration of space. Neither does it pretend to "explain" the artist's motives. Instead, it makes mathematical observations which are supported by the structures of the works themselves, without reference to history, iconography, or color. Looking at art from this different, mathematically informed vantage point is not too unlike viewing the earth's geography from the new technological perspective of the space capsule.

Art in the Plane

The most obvious shared quality of the exhibited works is their rejection of deep three-dimensional space and, in place of it, the assertion of the flat two-dimensional picture plane and, sometimes, the shallow space immediately behind it, as in Franziska Clausen's painting (plate 2). Although new to Western art, this flatness — employing the shapes and relationships of Euclidean geometry — is an ancient tradition in Islamic art. To depict depth, the Islamic artist simply tilted planes at various angles away from the picture plane (figure 3a). This same approach to space can be seen in Jack Tworkov's *R-Ch-no. 1* (plate 4). From the Renaissance to the twentieth century, however, the Western artist presented a more "solid" space through the use of linear perspective, in which parallel lines get closer together as they recede to meet at a vanishing point (figure 3b and Albert Flocon's *Croisements* [plate 3]).

The essential characteristic of the plane as described by Euclid is that *parallel lines* (l_1 and l_2 in figure 2) stay the same distance apart no matter how far extended. Lines not parallel are called *intersecting* (l_1 and l_3). Intersecting lines that form four equal angles are called *perpendicular* (l_1 and l_4). A Euclidean proposition states that lines perpendicular to the same line are parallel to each other (l_4 and l_5). These concepts are exemplified in Thomas Ring's drawing (plate 1) and Roy Lichtenstein's *Modern Painting* (plate 5).

Circle Packing, Grids, Tessellations

Having established the plane as central to twentieth-century geometric art, we now consider the artist, who must decide what to place into it, how to divide it up, how to arrange shapes within it, or, perhaps, how to cover it. It may come as a shock, or at least a surprise, to discover that space — the two-dimensional space of the picture plane — is anything but a passive agent that can be shaped and "pushed around" arbitrarily. Space, though seemingly empty, is a physical reality with its own constraints. It plays an active, even dictatorial role in determining which arrangements of shapes it will permit to exist within its confines and which it will not. For example, while exactly six equilateral triangles fit together around a point, no number of regular pentagons will. For artist, mathematician, and nature alike, space acts sometimes as ally, sometimes as antagonist, but always as an active force with which to contend.

Circles of equal radius, like pennies on a tabletop, can be closely packed together in two obvious ways: (1) the *hexagonal packing* (figure 4a and plate 5), and (2) the *square packing* (figure 5a and plate 6). These packings give rise to the *triangle grid*, (figures 4b, 4c) and the *square grid* (figures 5b, 5c). Western artists seem to prefer the square grid almost exclusively, sometimes emphasizing its grid points, as in Pieter Struycken's *Series 15* (plate 7), sometimes its square compartments, as in Zdenek Sykora's *Polychrome Structure* (plate 8). Still other artists, like Bridget Riley in *Red, Turquoise, Grey Curves* (plate 14), use a grid as metrical substructure for their work, while some, like Victor Vasarely in Tridim TT (plate 10), apply a grid pattern to a small portion of a larger work.

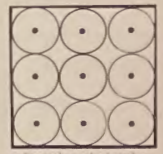
FIG. 4 Hexagonal Circle-Packing and Resulting Grid.

a. Hexagonally packed circles, each circle is tangent to six others.

b. Joining centers of tangent circles produces the triangle grid.

c. The triangle grid, used primarily by non-western artists.

FIG. 5 Square Circle-Packing and Resulting Grid.



a. Squarely packed circles; each circle is tangent to four others.

b. Joining centers of tangent circles produces the square grid.

c. The square grid, used by western artists since earliest times.

FIG. 6 The Three Regular Tessellations. Covering a surface with shapes that leave no gaps or overlaps (a tessellation or tiling) can be accomplished by exactly 3 regular (equal-sided) shapes: square, triangle, hexagon.

a. Tessellation by squares.

b. Tessellation by triangles.

c. Tessellation by hexagons.

We can think of the grid squares in Sykora's painting as tiles covering the canvas. Such a covering, or tiling, without gaps or overlaps is called a *tessellation of the plane*. There are only three regular shapes square, triangle, hexagon — which alone will so cover, or tessellate, a planar surface (figure 6).

The Symmetries of a Pattern

Artists, musicians, sociologists, anthropologists, dancers, poets, and scientists all have differing interpretations of the words "pattern" and "symmetry." But because the artist, mathematician, and natural scientist are all involved with arrangements of shapes within two-dimensional space, they share a common perception of "pattern" as a geometric phenomenon. A compromise among the vocabularies of art, mathematics, and science is offered in the following definition:

A pattern is the configuration that results when a basic shape, or motif, is repeated at equal intervals along a specified direction. The directions, or paths, along which a motif can be repeated — namely, around a point (figure 7), along a straight-line direction (figure 8), or along two different straight-line directions (figure 9) — determine the three basic categories of pattern.

Category 1: a *rosette* pattern results when a motif is repeated at equal angular intervals around a specified point, as in figure 7 and plates 9-13.

Category 2: a *frieze* pattern results when a motif is repeated at equal intervals along a straight-line direction, as in figure 8 and plates 14, 15.

Category 3: an *all-over pattern* results when a motif is repeated at equal intervals along two different straight-line directions to fill a plane, as in figure 9 and plates 7, 17.

In mathematics, both frieze and all-over patterns are infinite patterns, consisting of an unending number of repetitions of the motif; in art these patterns must be finite, set within the boundaries of canvas or frame.

The equal spacing of the motifs, the structural essence of every rosette, frieze, and all-over pattern, provides it with the extraordinary ability to appear unchanged even after it has been moved to certain new positions. For example, if someone turned Joseph Albers' *Structural Constellation* (plate 9) upside down on our wall — that is, rotated it 180° around its center — we would not be able to detect any change, as the drawing would appear to be in precisely the same position and orientation as before the turn. Further, assume the same drawing were on transparent plastic and flipped over on the wall, back to front. We would be able to detect the flip at once because the sense of the drawing would appear reversed, as if reflected in a vertical two-sided mirror through its center. The same flip, however, performed on Edwin Mieczkowski's *Monobloc no. 1* (plate 11) could not be detected. Finally, if either of these paintings was moved in a straight-line direction along the wall to hang from a new nail, the new position would be immediately apparent.

There are three kinds of rigid motions we perform on the plane containing a given rosette, frieze, or all-over pattern: a *rotation* (or turn) around a fixed center point, a *reflection* (or flip, or fold) along a fixed "mirror" line, and a *translation* (or slide) along a fixed straight-line direction. Each of these motions causes the pattern to move to an "after position" that may or may not be distinguishable from its original "before-position." Any rotation, reflection, or translation causing a pattern's after-position to be indistinguishable from (coincident with) its before-position is called a *symmetry of the pattern*. All symmetries of a given pattern, taken together, form *the symmetry group of the pattern*.

Rosette Symmetries. We shall find and compare the symmetry groups of Mieczkowski's painting (plate 11) and Ilya Bolotowsky's *Tondo with Reds* (plate 12). We can discover the symmetries of each painting by considering every possible rotation, reflection, and translation of the work and observing whether its after-position coincides with its before-position. We can test for this coincidence by copying the work in question onto a transparent overlay and then turning, flipping over or folding, and sliding the copy to see if it coincides with the work underneath it.

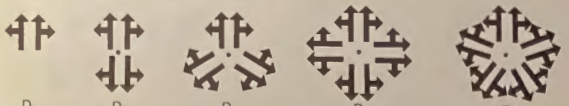
We shall show that Mieczkowski's painting has the same group of symmetries as the fourth rosette in the second row in figure 7. Among the infinite number of different rotations of this painting around its center, we discover (by turning our overlay copy) that there are exactly four distinct rotation symmetries namely, turns of 90°, 180°, 270°, 360°. By folding our copy along various suspected mirror lines and noting whether the folded half-rosettes coincide with each other, we find that there are exactly four reflection symmetries — reflections in one horizontal, one vertical, and two diagonal mirror lines. There are no translation symmetries of this, or any rosette, because sliding our copy in any direction for any distance moves it off center, preventing coincidence. Therefore, the full symmetry group of this work consists of eight symmetries — the four rotations and four reflections above — comprising the *dihedral group* D4 ("dihedral," or two-sided, denoting the presence of mirrors). Any work that has a dihedral symmetry group, like Mieczkowski's painting, is said to possess *kaleidoscopic symmetry*. The four rotations from D4 considered alone — that is, minus the reflections — comprise the cyclic group C4. Any work that has a cyclic symmetry group with rotation symmetries only, does not possess kaleidoscopic symmetry.

FIG. 7 Rosette Types. The infinite number of different rosette types fall into two classes: Cyclic and Dihedral.

Cyclic Rosettes (rotation symmetries only)

C_1 C_2 C_3 C_4 C_5

Dihedral Rosettes (rotation and reflection symmetries)



D_1 D_2 D_3 D_4 D_5

Approaching the Bolotowsky painting, we might at first glance suspect that it has the same symmetrical structure as the fourth rosette in the first row of figure 7 namely, the four rotation symmetries comprising C4. But Bolotowsky overturns any such expectation by placing in his tondo four circular segments that do not have the same shape; hence, they will not coincide with one another when turned about the center. There are no rotation symmetries. Therefore, this work, lacking reflection symmetries as well, is totally asymmetrical. Like much of twentieth-century art, it is the tension between the classical exactness of our expectation and the surprising fulfillment of an unexpected reality that gives vibrancy to our aesthetic enjoyment of the work.

Analyzing John Willenbecher's *Night Study* (plate 13), we find that the symmetry group of this planetary/orbital arrangement of shapes is the dihedral group D9, containing eighteen symmetries — the nine rotations, R40, R80, R120, R160, R200, R240, R280, R320, R360, and nine reflections in mirror lines through the center.

The Albers drawing (plate 9) and the Vasarely painting (plate 10) have exactly the same symmetry group, C2. Works having the same symmetry group can be called *isomorphic* to each other, which is to say only that they have the same symmetrical structure.

As figure 7 summarizes: (1) there are an infinite number of different types of rosette; (2) each rosette has as its symmetry group either the cyclic group Cn (consisting of n rotations alone) or the dihedral group Dn (with n rotations and n reflections) and (3) rotation symmetries are the characteristic symmetries of every rosette.

Frieze Symmetries. The simplest pattern with translation, or sliding, symmetry is a frieze (Figure 8 and plate 14), which in theory extends infinitely in both directions. In *Red, Turquoise, Grey Curves* (plate 14) Riley employs a frieze fragment to create optical effects induced by the interplay of colors within equally spaced motifs. Copying this frieze onto a transparent overlay and sliding the copy some distance in the direction of the frieze axis may cause the copy to coincide with the work underneath it, depending on the distance of the slide. If x is the shortest distance (4 grid points in this case) which so produces a translation symmetry T_x, then sliding it for twice that distance is also a translation symmetry T_{2x}, as are T_{3x}, T_{4x}, etc., as well as the reverse slides, T_{-x}, T_{-2x}, etc. There are theoretically an infinite number of translation symmetries of this and every other frieze.

Reflection symmetries of a frieze are limited to horizontal (H) and/or vertical (V) reflections, as in figures 8b, 8c, 8d, 8g and plate 14. This is because when we fold a frieze, only horizontal and vertical folds (or mirror lines) can conceivably cause the folded half-friezes to coincide with each other. Similarly, we can verify that rotating a frieze only by 180° will cause the frieze axis to turn back onto itself, so that R180 is its only permissible rotation symmetry, as in figures 8e, 8g. A frieze may possess an additional kind of symmetry called a *glide* (figure 8f), which is simply a translation for half the basic distance followed by a reflection. This is the kind of symmetry found in a line of footprints on a wet sandy beach and a line of leaves along a stem, pointing alternately in opposite directions. The structural elements in Erich Buchholz's drawing (plate 15) approximate this kind of symmetry. The interaction of the four possible frieze symmetries (H,V,R,G) with the frieze's translations limits the number of different types of frieze to only seven.

Robert Strubin's *Music Painting no. 211, I.—Stravinsky, Fragment of Fire Bird* (plate 16) is not technically a frieze, yet consists of layers of frieze-like bands of colored rectangles. This rare visual fusion of art, mathematics, and music is patterned on 25 instrumental lines from Stravinsky's orchestral score, where musical time is measured out spatially into repetitive units called "measures," each containing an equal number of musical "beats."

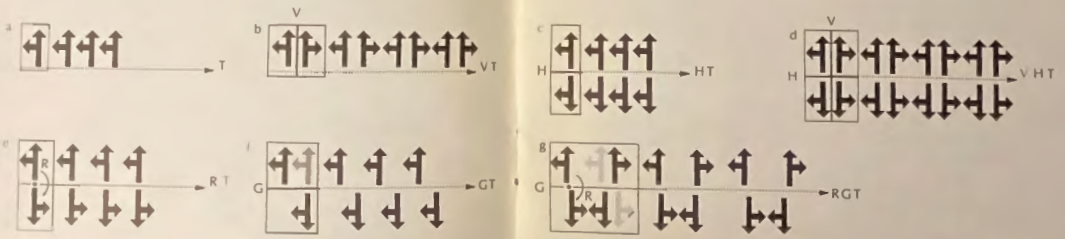


FIG. 8 The Seven Frieze Types ☐ *denotes basic repeated unit. Symmetries denoted by T (translation), H (horizontal reflection), V (vertical reflection), R (180° rotation), G (glide = 1/2 T then H).*

All-over Pattern Symmetries. When a motif, or a region containing some configuration of motifs, is repeated at equal intervals to fill the plane, an all-over pattern is created (figure 9 and plates 7, 17, 18). That there are precisely 17 types of all-over patterns is surely a surprising fact, one that could only have been suspected by art history's great patternmakers, like the Egyptian and Islamic artists, whose wonderful patterns exemplify all 17 types.

It wasn't until 1924, however, that mathematicians George Polya and Paul Niggli proved that planar space permits only 17 types of symmetrical arrangements within patterns, although ten years earlier crystallographers, like Sir Lawrence Bragg, were using X-rays to detect the same molecular arrangements in crystals.

As seen in figure 9, each pattern type may be seen in either of two ways (1) as a tessellation, or covering, of the plane by identically figured tiles, or (2) as a stenciled pattern with a single tile acting as a template or stencil. The simplest pattern type (figure 9a), of which Struycken's drawing (plate 7) is an example, has no symmetries other than the essential translations. The most complex type, with the greatest number of symmetries (figure 9q), can be seen in the benday dot patterns of Lichtenstein's work (plate 5) and the tessellations of triangles and hexagons (figures 6b, 6c). Peter Roehr's *Ty 38 N* (plate 17), an example of the pattern type in figure 9b, has two rotation symmetries (R180, R360) around the center of every motif N_1 as turning the work upside down will verify. Riley's *Fracture* (plate 18) can be viewed as a methodical deformation or shattering of a pattern which in its perfect state would have been of the type in figure 9j.

When we realize that every pattern can be seen to grow out of a stenciling operation with a single template — and that the seemingly infinite number of different patterns in mathematics, art and nature are merely variations of the basic 17 types — then we can begin to appreciate Coleridge's definition of beauty as "unity in variety."

FIG. 9 The Seventeen All-Over Pattern Types. Each has a basic repeated unit that is a: parallelogram, rectangle, square or rhombus.

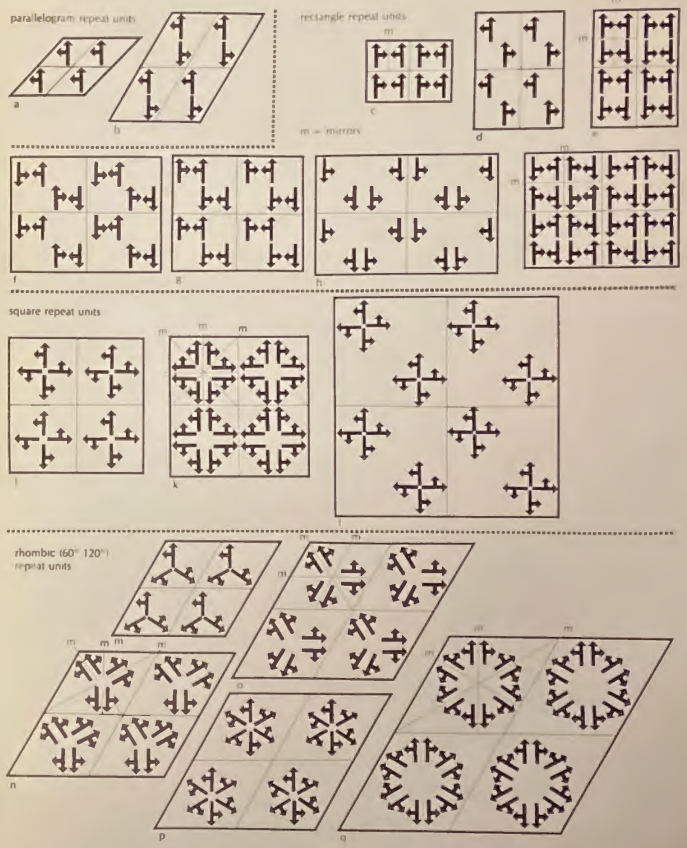
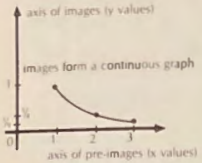
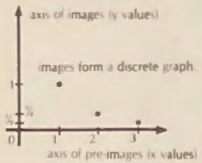


FIG. 10 Continuous and Discrete Transformations of Image.



a. The images (y values) are *transformed continuously* by the equation $y = (1/x)^2$ as the pre-images (x values) change continuously from $x = 1$ to $x = 3$.



b. The images (y values) are *transformed discretely* by the equation $y = (1/x)^2$ as the pre-images (x values) change in discrete, whole number steps from $x = 1$ to $x = 2$ to $x = 3$.

Transformations, Continuous and Discrete

In addressing symmetry, artists and mathematicians approach the same geometric phenomenon with differing theories and sensibilities. Quite the reverse is true when considering the "transformation of an image," which is a different phenomenon in art than in mathematics but is studied by both disciplines in theoretical ways that are remarkably similar and surprising.

In mathematics, an equation, say $y = (1/x)^2$, can be used to change certain given x values into y values. The y values are called the *images* of the x values (the x values being the *pre-images*), and we say that the y values (the images) are a *function of* the x values (the pre-images). For example, when $x = 3$, then $y = (1/3)^2 = 1/9$, and we say that $y = 1/9$ is the image of $x = 3$. We represent this graphically on a set of axes (figure 10a) by plotting the point (3,1/9), which is 3 horizontal units followed by 1/9 of a vertical unit away from the intersection of the axes, marked 0. If the x values change continuously through all the numbers from $x = 1$ to $x = 3$ (whole numbers, fractions, etc.), then the y values or images are *transformed continuously* from $y = 1$ to $y = 1/9$, giving rise to a continuous, curved graph. In this case, the images are a continuous function of the pre-images.

If x, on the other hand, changes in discrete steps from $x = 1$ to $x = 2$ to $x = 3$ (figure 10b), then the y values or images are transformed discretely, in a series of disconnected jumps, from $y = 1$ to $y = 1/4$ to $y = 1/9$, giving rise to a discontinuous graph of three isolated points. In this case, the images are a discrete function of the pre-images.

When viewing three-dimensional art, like Yaacov Agam's *Structural Painting, Two-sided* (plate 20), we become aware that our visual image of the work is being transformed continuously as our viewing position moves in a continuous path around the work. Like the example in figure 10a, our visual image is a continuous function of our viewing position (with viewing positions literally being our pre-images). If, however, we are led blindfolded along this path and permitted to remove our blindfolds only at isolated positions, our visual image is a discrete function of our viewing position.

To convey such a discrete transformation of images within a single work of two-dimensional art where the viewing position is presumed fixed, an artist must repeat the same image over and over again throughout the work, varying it at each repetition with regard to shape, scale, color, or some other attribute and doing so in accordance with some readily perceptible transforming principle. Awareness of the transforming principle places the viewer's focus as much on "process" as on "image."

Each band of Attila Kovacs' *Substrat K-H-7* (plate 19) presents a transformation from square to three-dimensional solid, glimpsed serially in eleven discrete images. Manfred Mohr's *Cubic Limit* (frontispiece) consists of 2304 discrete views of a cube, each view varying both the spatial orientation of the cube and the number and position of edges shown to us. As there are 4095 different combinations of a cube's 12 edges taking one at a time, then two at a time, then three at a time, etc., it is not surprising that Mohr uses a computer to help him make decisions of this type. It seems reasonable to conclude that most artists who use serial methods in creating art are asking us not to view the work at once, as a whole, but rather to allow its wholeness to emerge gradually, as we examine its series of changing images in ordered stages. During this serial perception of discrete images, the transforming principle becomes increasingly apparent and serves to unify the individual images, in much the same way as a mathematician comes to see more clearly the shape of an elusive curve by locating more and more of its individual points.

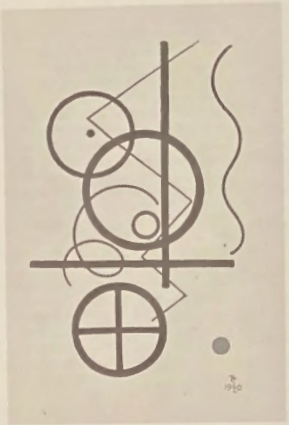


Plate 1 *Untitled* Thomas Ring

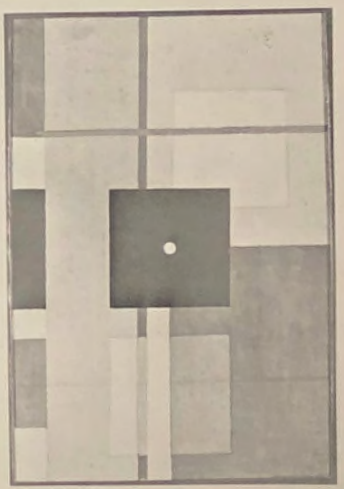


Plate 2 *Untitled* Franziska Clausen

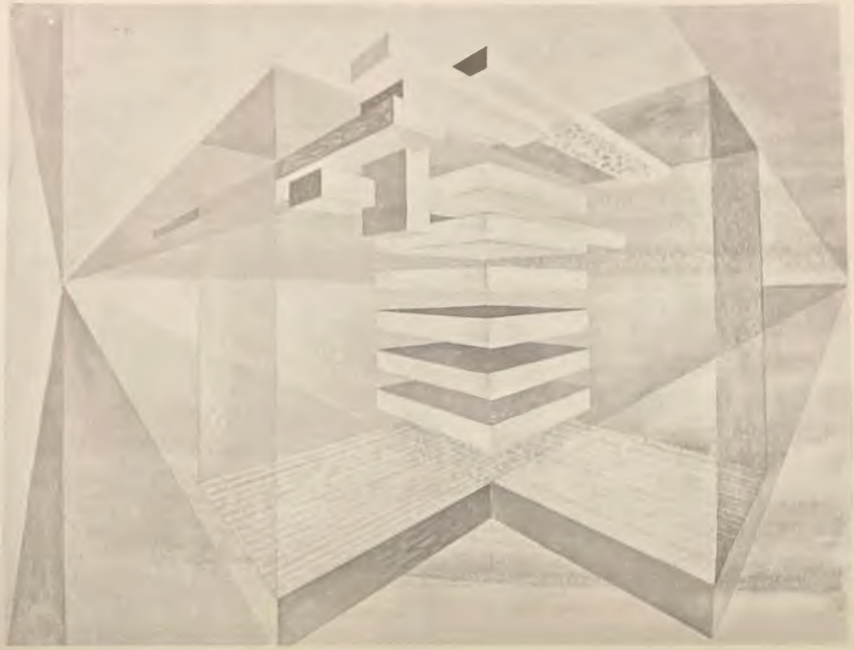


Plate 3 *Croisements* Albert Flocon

Plate 4 *R—Ch no. 1* Jack Tworkov

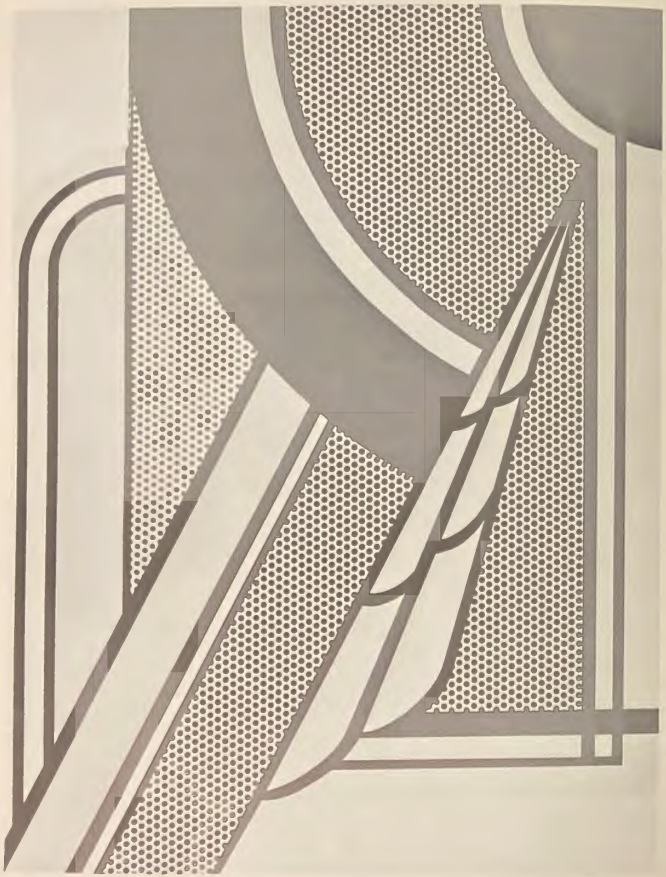


Plate 5 *Modern Painting* Roy Lichtenstein

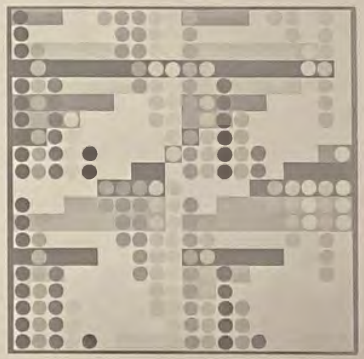


Plate 6 *Rhythms of Vertical Rows of Circles* Arend Fuhrmann

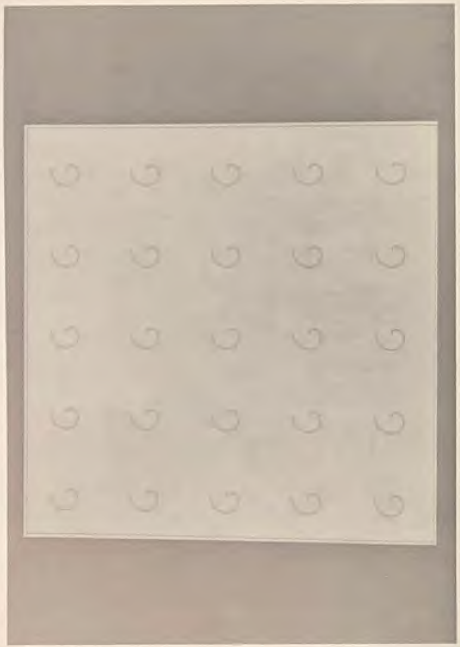


Plate 7 Series 15 Pieter Struycken

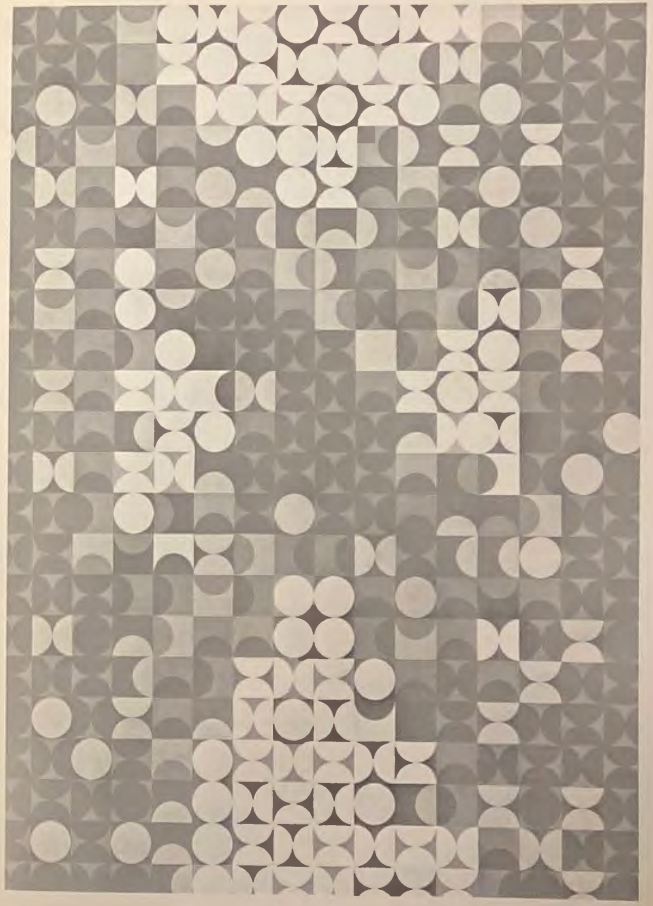


Plate 8 *Polychrome Structure* Zdenek Sykora

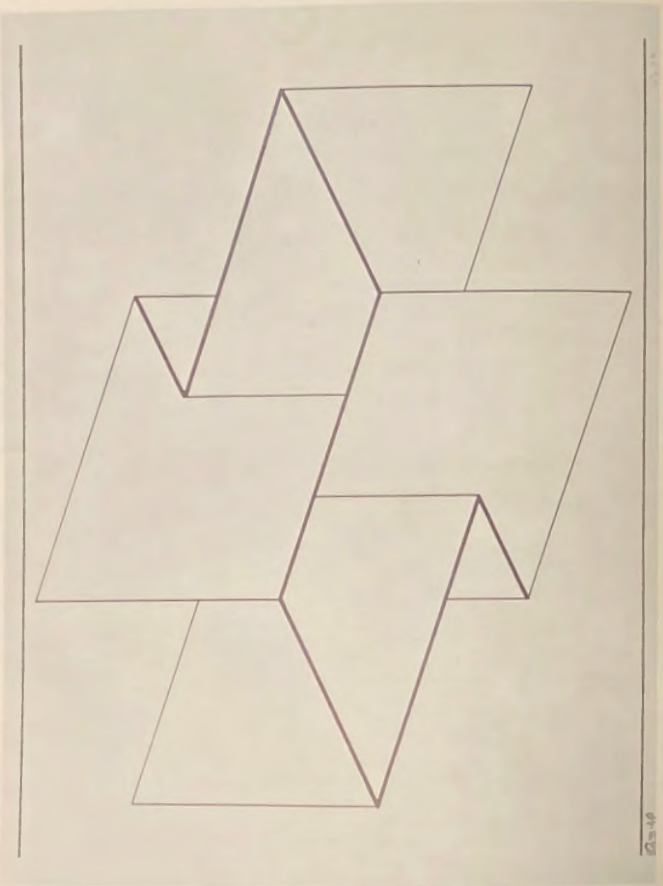


Plate 9 *Structural Constellation* Josef Albers

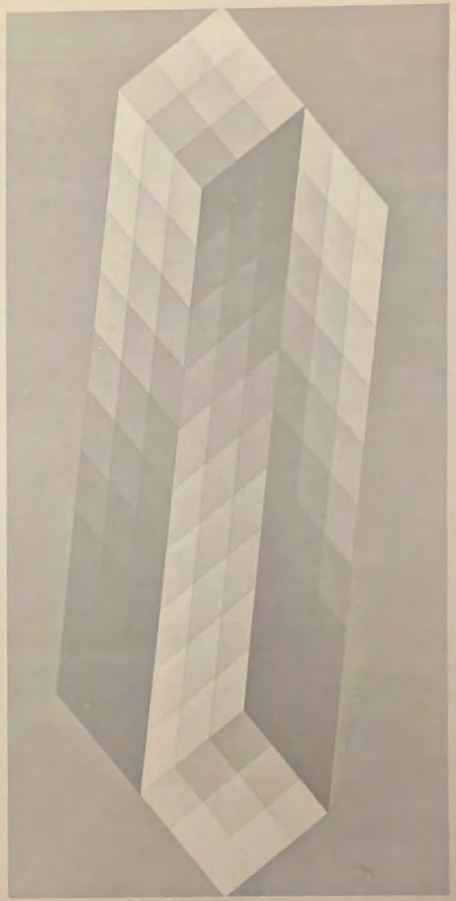


Plate 10 *Tridim TT* Victor Vasarely

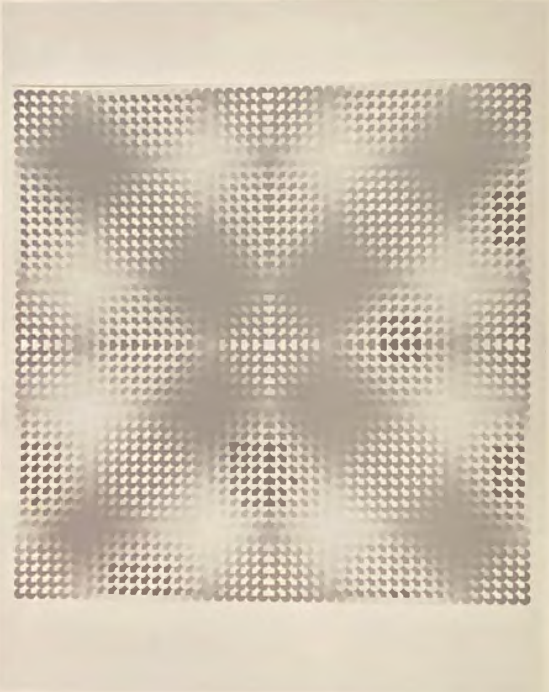


Plate 11 *Manobloc No. 1* Edwin Mieczkowski

Plate 12 *Tondo with Reds* Ilya Bolotowsky

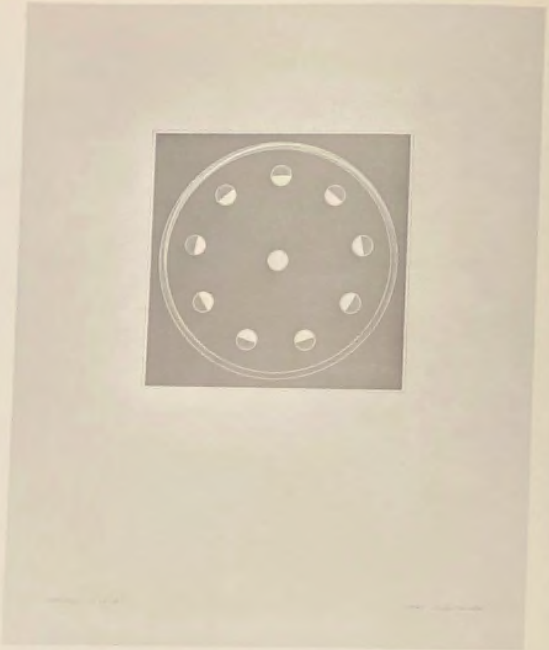


Plate 13 *Night Study* John Willenbecher

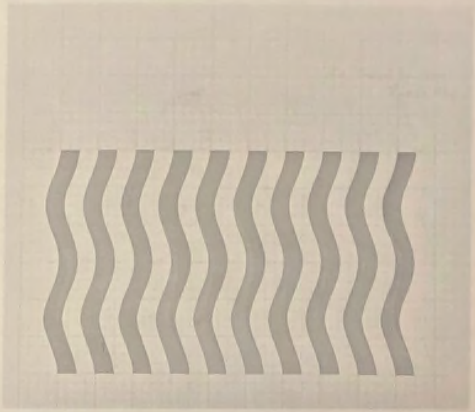


Plate 14 *Red, Turquoise, Grey Curves* Bridget Riley

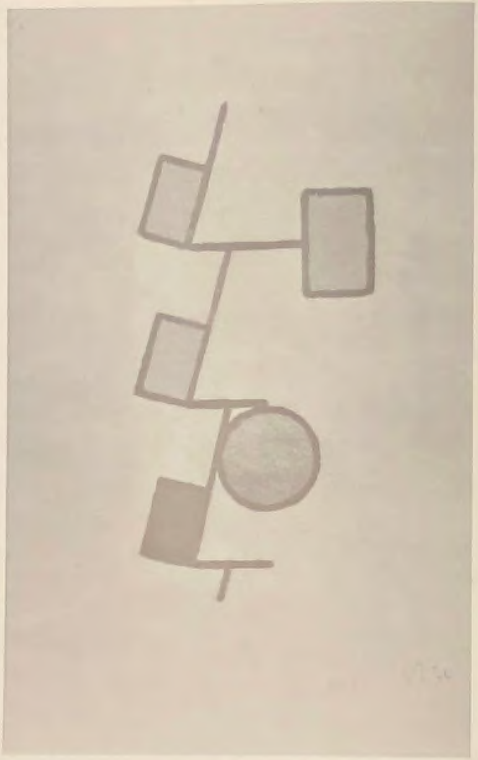


Plate 15 *Untitled* Erich Buchholz

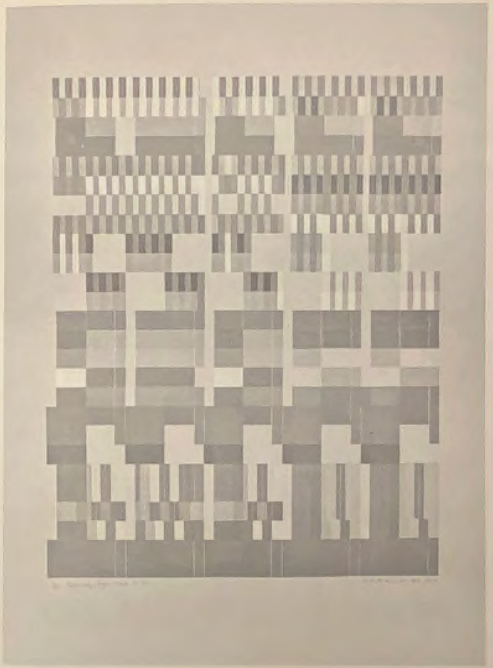


Plate 16 *Music Painting No. 211* Robert Strubin

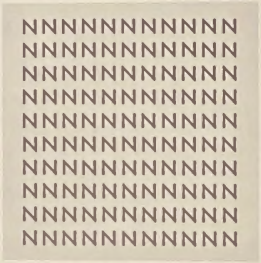


Plate 17 *Ty 38 N* Peter Roehr

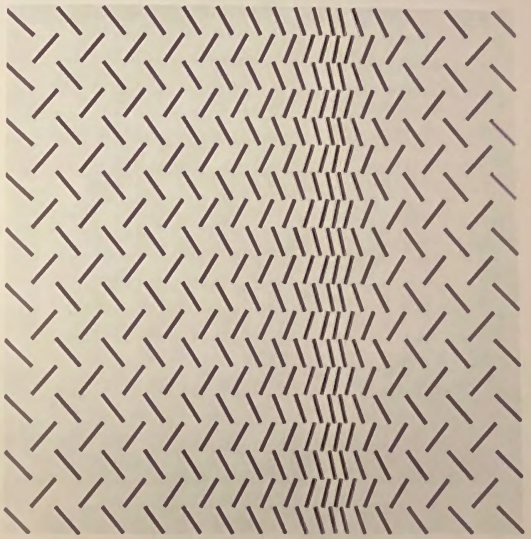


Plate 18 *Fracture* Bridget Riley

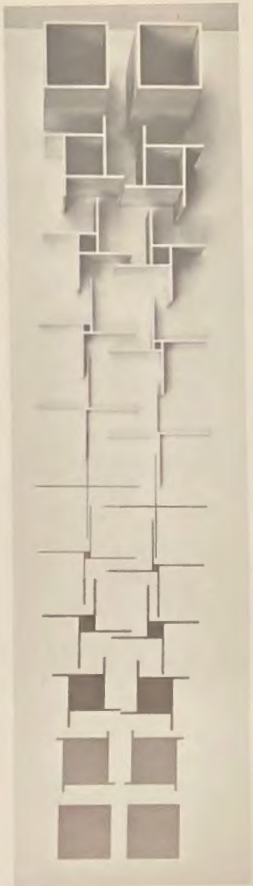


Plate 19 *Subirat K.H.7* Attila Kovacs

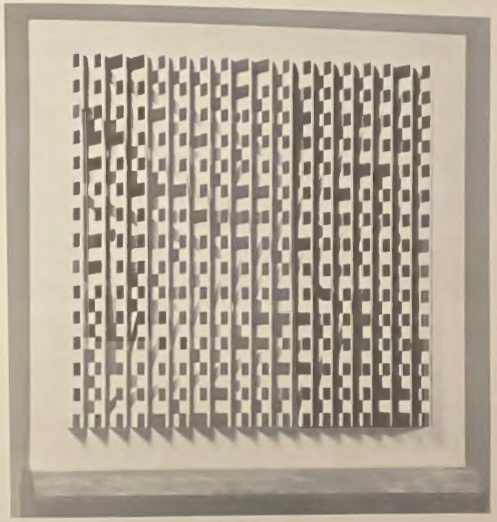


Plate 20 *Structural Painting, Two-sided* Yaacov Agam

OBJECTS IN THE EXHIBITION
Rotzler numbers
refer to the definitive catalogue of
the McCrory Corporation Collection
by Willy Rotzler,
Constructive Concepts:
A History of Constructive Art
from Cubism to the Present
(Zurich: ABC Edition, 1977).
Dimensions are given in inches,
height preceding width.

1. **Yaacov Agam**
Structural Painting, Two-sided
1964
oil on wood relief
14 3/4 x 14 1/2 x 2
Rotzler No. 2

2. **Josef Albers**
Structural Constellation
1956
India ink
6 3/4 x 8 3/4
Rotzler No. 7

3. **Richard Anuszkiewicz**
Untitled
1970
paint on Masonite
5 x 8

4. **Jennifer Bartlett**
Untitled
1972
silkscreen and baked enamel on steel
2 plates, 12 x 12 each
Rotzler No. 31

5. **Bodo Baumgarten**
Untitled
1973
gouache on perforated cardboard
mounted on canvas
11 5/8 x 11 5/8
Rotzler No. 39

6. **Ernst Benkert**
Woodstock Trio #10
1971
black and red ink on paper
20 X 28 1/2
Rotzler No. 47

7. **Ernst Benkert**
Woodstock Trio #7
1971
black and red ink on paper
20 x 28 1/2
Rotzler No. 48

8. **Ilya Bolotowsky**
Tondo with Reds
1972
acrylic on canvas
47" diameter
Rotzler No. 72

9. **Erich Buchholz**
Untitled
1920
black, red and gold gouache
7 1/4 x 4 1/2
Rotzler No. 83

10. **Marcelle Cahn**
Untitled
c. 1952
gouache and ink on board
10 7/8 x 8 1/8
McCrory No. 1251

11. **Antonio Calderara**
Element A
1966
oil on wood
10 1/2 x 1 1/4
Rotzler No. 95a

12. **Antonio Calderara**
Element B
1966
oil on wood
10 1/2 x 1 1/4
Rotzler No. 95b

13. **Antonio Calderara**
Quadrato del Quadrato
1972
watercolor
6 x 6
Rotzler No. 97

14. **Franziska Clausen**
Untitled
1930
gouache
11 1/2 x 7 3/4
Rotzler No. 107

15. **Paul Colin**
Pythagorean Altar, B-Version
(green panel)
1973
acrylic on canvas
48 x 48
Rotzler No. 111a

16. **Judd Fine**
Untitled
1973
pencil drawing
18 x 12
Rotzler No. 159a

17. **Albert Flocon**
Croisements
1948
gouache
19 1/4 x 24
Rotzler No. 165

18. **Arend Fuhrmann**
Rhythms of Vertical Rows of Circles
and Horizontal Rows of Rectangles,
Penetrating, Painting no. 705
1970
oil on canvas
35 1/2 x 35 1/2
Rotzler No. 173

19. **Johannes Itten**
Ascending Spiral
1966
crayon and ink
13 3/4 x 10 1/2
Rotzler No. 267

20. **Jiri Kolar**
Triangle
1967
collage on cardboard
38 1/2 x 26
Rotzler No. 289

21. **Attila Kovacs**
Substrat K-H-7
1967/71
polystyrol, white on wood, black
acidic ink
12 1/4 x 41 3/4 x 7
Rotzler No. 301

22. **Roy Lichtenstein**
Modern Painting
1967
baked enamel on shaped steel, 5/6
35 x 44 1/2
Rotzler No. 339

23. **Verena Loewensberg**
Painting No. 127
1953
oil on canvas
28 x 28
Rotzler No. 355

24. **Pavel Mansurov**
Pictorial Formula
1922/68
silkscreen on aluminum, 5/150
15 3/4 x 5 1/4
Rotzler No. 377

25. **Edwin Mieczkowski**
Monobloc No. 1
1966
oil on hardboard
47 1/4 x 47 1/4
Rotzler No. 395

26. **Manfred Mohr**
Cubic Limit
1975
ink on paper
23 1/2 x 23 1/2
McCrory No. 1109

27. **Francois Morellet**
A real artificial flower for Celia
1978
pencil and collage
13 3/4 x 6 1/4
McCrory No. 254

28. **Herbert Oehm**
Additive Layers of Color 6.8.66
1966
acrylic on canvas
39 1/2 x 39 1/2
Rotzler No. 434

29. **Antoine Pevsner**
Composition
1917/18
oil on canvas
9 x 7 1/2
Rotzler No. 450

30. **Francis Picabia**
Untitled
1919
watercolor and ink
9 1/2 x 6 1/2

31. **Bridget Riley**
Red, Turquoise, Grey Curves
1967
gouache on graph paper
11 x 12 1/2
Rotzler No. 477

32. **Bridget Riley**
Fracture
1964
emulsion on board
33 1/4 x 33 1/4
Rotzler No. 473

33. **Thomas Ring**
Untitled
1920
ink
12 1/2 x 8 1/4
Rotzler No. 481

34. **Peter Roehr**
Ty 38 N
1964
typosetting
2 1/8 x 2 1/8
Rotzler No. 490

35. **Peter Roehr**
Ty 73 C
1964
typosetting
1 3/8 x 1 5/8
Rotzler No. 491

36. **Jan J. Schoonhoven**
T - 71.26
1971
India ink
19 7/8 x 12 7/8
Rotzler No. 513

37. **Kenneth Snelson**
Maquette
1967
stainless steel and wire
h. 30 1/2 dia. 17 1/4
Rotzler No. 530

38. **Robert Strubin**
Music Painting No. 211,
I. Stravinsky, Fragment of Fire Bird
1959
gouache on grey paper
27 1/2 x 19 3/4
Rotzler No. 541

39. **Pieter Struycken**
Series 15
1973
plotter drawing (one of two)
13 1/2 x 13 1/2
Rotzler No. 544

40. **Pieter Struycken**
Series 15
plotter drawing (one of two)
13 1/2 x 13 1/2
Rotzler No. 544

41. **Zdenek Sykora**
Polychrome Structure
1965
oil on canvas
86 1/2 x 63
Rotzler No. 549

42. **Jack Tworkov**
R - Ch no. 1
1972
charcoal
19 x 26
Rotzler No. 568

43. **Victor Vasarely**
Tridim TT
1969
acrylic on cardboard
35 1/2 x 17 3/4
Rotzler No. 576

44. **John Willenbecher**
Night Study
1965
gouache
22 1/2 x 18
Rotzler No. 588

45. **Gillian Wise Ciobotaru**
Four Square Progressions in
Eight Parts on the Theme of
Symmetry and the Square
1972
set of anodized photo prints
4 x 32 1/4
Rotzler No. 594

"Mathematics and Twentieth-Century Art: Selections from the McCrory Corporation Collection" an exhibition at The Baruch College Gallery April 26 to June 1, 1984

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