

Mathematical Models and Art in the Early 20th Century

For thousands of years, artists as well as mathematicians have been interested in solid geometric forms. The simplest of these are polyhedra, or “many-sided solids.” The drawing and painting of polyhedral models can be simply a teaching tool, but for other artists and thinkers, polyhedral solids have represented perfection and truth itself. Plato, for instance, associated the Platonic solids (see Figure 1) with the elements of fire, earth, air, water, and with the universe itself.

In the nineteenth century, mathematicians began to produce less regular and more startling solid figures. The strange beauty of these forms had an effect on many artists, as we shall see.

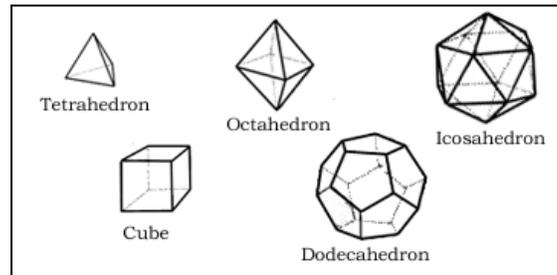


Figure 1: There are only five “convex regular polyhedra” – these are the so-called *Platonic Solids*.

Models of Surfaces

In the mid 1600's, René Descartes and Pierre de Fermat were both developing *coordinate geometry* which allows points in a plane (a geometric concept) to be represented by a list of numbers (an algebraic object). Using coordinates, mathematicians can consider the set of solutions to an algebraic equation as a geometric object. For instance, the set of all solutions of the equation $x^2 + y^2 = 1$ is a circle.

In the mid 1700's, mathematicians began to study solids in space in a similar way. The solutions of a polynomial equation in three variables will be a surface suspended in three-dimensional space. For instance, the solutions of $x^2 + y^2 + z^2 = 1$ form a sphere. Some of these surfaces, like the sphere, are relatively easy to visualize, and can be sketched on paper. Other surfaces are far trickier to visualize or to sketch on paper.

In the mid-nineteenth century, a fruitful period in the investigation of surfaces in space began. To accompany this study, mathematicians built models for teaching and illustration out of a variety of materials, including plaster, cardboard, metal, and string (see Figure 2 for an example).

Many of these models were reproduced and sold by publishing houses to schools and museums around the world. At the turn of the century there were a large number of models of surfaces available, but by the 1930's, interest in model building began to dwindle, and the great models sitting on dusty shelves in universities and museums became a quaint anachronism.

Mathematics and Art

These models of geometric surfaces have an eerie beauty; it is not surprising that some artists would be intrigued with them. It is even less surprising when you put their interest in context. The mid- to late- nineteenth century was a turbulent time in mathematics. Old ideas, such as Euclidean geometry (the geometry that's generally taught in US high schools), were being turned on their heads. Many of these revolutionary mathematical ideas made their way into the public sphere and sparked the imagination of writers and artists alike. Writers such as H.G. Wells and artists such as Marcel Duchamp were fascinated with non-Euclidean geometry and the idea of a spatial fourth dimension. The



Figure 2: A model of *Kuen's Surface*, published by Brill-Schilling, Leipzig, Germany. Kuen's surface has constant curvature and other special properties. A drawing of this surface was included on the cover of the catalog of the 1936 International Surrealist Exhibition in London.

surrealists found that “non-Euclidean geometry signified a new freedom from the tyranny of established laws”¹ Mathematics represented both progress and the potential for chaos.

Artists Encounter Mathematical Models

Two very different artistic movements, the surrealists and the constructivists, discovered mathematical models at approximately the same time. Constructivist Naum Gabo began to draw direct inspiration from the forms of mathematical models in the early 1930’s, and he seems to be the first constructivist to have done so. Surrealist photographer and painter Man Ray did a series of photographs in 1936 of mathematical models housed at the Poincaré Institute in Paris. The degree to which these almost simultaneous discoveries are linked, however, is unclear.

Naum Gabo and the Constructivists

Constructivism was an artistic and architectural movement of Russian origin that began early in the 20th century. Naum Gabo and his brother Antoine Pevsner, were, to a large extent, responsible for popularizing and spreading the movement outside of Russian, notably to Paris and England. Constructivists also had an influence on the Abstraction-Creation group, the de Stijl movement, and the Bauhaus.

It is likely that Gabo saw mathematical models on display while he studied in Munich in the early twentieth century. Gabo had some interest in art as a teen, but went to the University of Munich to study medicine. He took other scientific coursework while he was there, particularly physics and engineering. Notably, he also followed some courses at the Technical University in Munich, where there were certainly mathematical models on display, as TU Munich was one of the great centers of model-building. In his 1936 book *Cubism and Abstract Art*, Alfred Barr made even more of Gabo's connection with models, stating that Gabo “had been studying mathematics in Munich and had made mathematical models.” This statement is inaccurate, but it does show that the topic of Gabo’s connection with mathematical models had surfaced during Barr’s research.

Gabo’s early cubist-influenced sculptures such as *Head No. 2* (see Figure 3) are reminiscent of cardboard models of surfaces made with interlocking cross-sections, such as would have been on display at the university. Pictures of such models could also be found in encyclopedias of the time.

This early similarity of Gabo’s work to certain mathematical models may simply be coincidence, but later influence of models on Gabo’s work in the 1930’s and beyond is indisputable. In their book, *Constructing Modernity: The Art and Career of Naum Gabo*, Christina Lodder and Martin Hammer note that a 1936 drawing *Study for Construction in Space: Crystal* appears to be a tracing of a figure from the article on Mathematical Models in the 14th edition of the Encyclopedia Britannica. Indeed, the Encyclopedia drawing has similarities to the sculpture *Construction in Space: Crystal*, and it bears an even more striking resemblance to Gabo’s *Construction*, 1936.



Figure 3: Naum Gabo's *Head No. 2* (1916). Compare with Figure 4.



Figure 4: Cardboard models of surfaces made with interlocking sections.



Figure 5: Gabo's *Sketch for a Stone Sculpture*, 1933. This is a sketch of a model of a ruled surface.

¹ Henderson, L. (1983) *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*. Princeton: Princeton University Press. Page 339.

Others of Gabo's sculptures and drawings show evidence of his encounter with mathematical models. For instance, Gabo's 1933 *Sketch for a Stone Carving* (Figure 5) is a sketch of a model of a ruled surface² which would have been on display at the Poincaré Institute in Paris. Gabo was living in Paris at the time this sketch was done.

Antoine Pevsner was the brother of Naum Gabo. Constructions of Pevsner's from the mid-1930's show evidence of a possible influence of mathematical models. Pevsner began his artistic career as a painter, and during the 1920's Gabo had been encouraging his brother to pursue sculpture and had been teaching him constructive techniques. Pevsner always denied any direct influence of mathematics on his work. However, his *Developable Surface* series was perhaps inspired by models of ruled surfaces (see Figure 6). The term *developable surface* is a mathematical term which refers to surfaces which can be "swept out by lines" – precisely in the manner of Pevsner's sculptures. If there was no influence, then the coincidence is quite amazing.

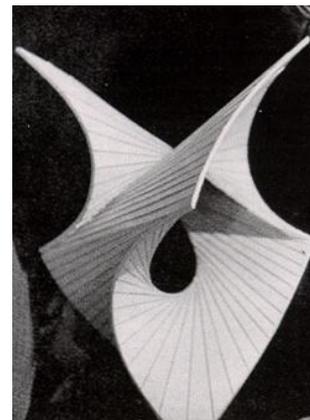


Figure 6: Pevsner's *Surface Développable*, 1938 - 1939.

British sculptor Barbara Hepworth had contact with Naum Gabo while Gabo was in England – from 1936 to 1946. Hepworth may have seen mathematical models before she encountered Gabo. In December 1935, Hepworth sent a letter to her husband Ben Nicholson in which she said that architect John Summerson had told her that there were "some marvelous things in a mathematical school in Oxford -- sculptural working out of mathematical equations -- hidden away in a cupboard" and that she intended to go and look at them soon.³ Some of Hepworth's work exhibits mathematical influence. The sculpture *Helicoids in Sphere* (1938), for instance, has similarities to a mathematical model of a surface known as *Steiner's Roman Surface*. Other sculptures, such as *Pelagos* (1946), echo mathematical models in their form and in their use of string (see Figures 7 and 8). During the 1930's, Hepworth was producing sculptures using string and plaster – both materials were unusual for sculpture of the time, and both were materials widely used in the mathematical models that would have been displayed in many universities.



Figure 7: Hepworth's *Pelagos*, 1946. Compare to the helicoid in Figure 8.

Henry Moore is another British sculptor who is sometimes associated with constructivism. Moore stated more than once that his use of string in his sculpture, which began in 1937, was influenced by seeing models at the Science Museum in London. "I was fascinated by the mathematical models I saw there, which had been made to illustrate the difference of the form that is halfway between a square and a circle. One model had a square at one end with 20 holes along each side... Through these holes rings were threaded and lead to a circle with the same number of holes at the other end. A plane interposed through the middle shows the form that is halfway between a square and a circle... It wasn't the scientific study of these models but the ability to look through the strings as with a bird cage and see one form within the other which excited me."⁴ The influence of such models can be seen in pieces such as *Stringed Figure No. 1* (1937, see Figure 9).

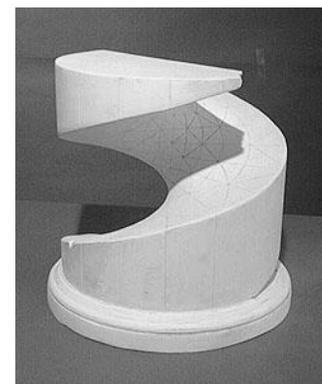


Figure 8: A model of a helicoid. This surface is generated by a straight line tracing out a helix.

Man Ray and the Surrealists

² This ruled surface is similar to the photo of the "Ruled Surface of Order 3" which can be found in Fischer, G., ed. (1986) *Mathematische Modelle* (Mathematical Models). Braunschweig: Friedr. Vieweg & Sohn.

³ Hammer, M. and Lodder, C. (1996). Hepworth and Gabo: a Constructivist Dialogue. In D. Thistlewood (ed.) *Barbara Hepworth Reconsidered* (pp. 109-133). Liverpool: Liverpool University Press.

⁴ Hedgecoe, J. and Moore, H (1968). *Henry Spencer Moore*. New York: Simon and Schuster. Page 105.

In *The History of Surrealist Painting*, Marcel Jean suggests that it may have been Max Ernst who brought the mathematical models into the surrealist consciousness. “Max Ernst had originally come across these constructions in the Institute Henri Poincaré and had mentioned them to the director of *Cahiers d’Art*, Christian Zervos, who in his turn had asked Man Ray to photograph them.”⁵ This is backed up by Neil Baldwin’s account in his book on Man Ray, in which he says this was a series “of photographs of items created in the 1880’s by a physicist attempting to render algebraic formulae correctly. Max Ernst had taken Man Ray to see the objects on display at the Poincaré institute in Paris and had photographed them in a deliberately impressionistic style.”⁶ Man Ray’s own account in the film *A Life in the Day of Man Ray* backs this up to some extent. He says that he “was told about some mathematical objects at the Institute Poincaré in Paris” -- although he does not mention who told him.

In any case, Man Ray certainly executed a series of photographs, entitled *Mathematical Objects*, which were studies on models at the Poincaré Institute. Some of these photographs appeared in a 1936 issue of *Cahiers d’Art* along with an essay on mathematics and abstract art by Christian Zervos.

Man Ray's photographs, as well as his series of paintings based on the *Mathematical Models* series (see Figure 10), gave mathematical models a lot of exposure. The surrealists displayed mathematical objects in their May 1936 show “Exposition Surréaliste d’Objets” at the Galerie Charles Ratton in Paris. The objects made a splash at the show and the *Cahiers d’Art*. In his famous “Crisis of the Object,” André Breton writes, “The laboratories of mathematical institutions throughout the world already display side by side objects constructing according to both Euclidean and non-Euclidean principles, equally mystifying in appearance to the layman, but which nevertheless bear a fascinating and equivocal relationship to each other in space as we generally conceive it.”⁷

Man Ray’s interest in the mathematical objects also may have had an influence on the 1936 International Surrealist Exhibition at the New Burlington Galleries in London. This show was supported financially and organized by Roland Penrose, who was befriended by Man Ray and André Breton in Paris. Man Ray “shuttled back and forth” carrying art between London and Paris in preparation for the show. His photographs of mathematical objects were on display at the show, which was open from June 11 through July 4, 1936, with attendance of 1,500 people per day.⁸ Even the catalogue from this exhibition reveals a fascination with mathematical models -- the front cover of the catalog is a collage by Max Ernst featuring a statue with a reptilian head holding and standing near a number of mathematical models.⁹ Man Ray’s photographs showed up at yet another big exhibition of the time, the 1936-37 “Fantastic Art, Dada, and Surrealism” exhibition at New York’s Museum of Modern Art.



Figure 9: Moore's Stringed Figure No. 1 (1937)



Figure 10: Man Ray, *King Lear* (1948). Based on *Kummer Surface with 8 double points*, a model published by Brill-Schilling.

Other surrealists may have been inspired by seeing the models and their photographs. Max Ernst, who did the cover of the London exhibition catalog, did several other collages and paintings that seem to relate to mathematical models. Examples include *The Feast of the Gods* (1948), *Chemical Nuptials* (1948), and *Young*

⁵ Jean, M (1960). *History of Surrealist Painting*, translated from the French by S. Taylor. New York: Grove Press. Page 251.

⁶ Baldwin, N. (1988). *Man Ray: American Artist*. New York: Clarkson N. Potter, Inc. Page 199.

⁷ From Breton, A (1972). *Surrealism and Painting*, translated from the French by S. Taylor. New York: Harper & Row. Page 279.

⁸ From Baldwin (1988) and the exhibition catalog.

⁹ The models drawn on the cover included *Kuen's Surface*, see Figure 2.

Man Intrigued by the Flight of a Non-Euclidean Fly (1942-7) which contains several forms reminiscent of mathematical models such as the *Spindle Cyclide* and the *Horn Cyclide* (see Figures 11 and 12).

Scope of Influence

For the surrealists, the mathematical models were a perfect contradiction – at once fantastical and bizarre, yet coming from mathematics, a rational and scientific source. As Georges Hugnet says in the catalog for the surrealist show at the MOMA, “Over the mathematical object and the found object, on the practical utility of which one can speculate indefinitely, there reigns the same certitude, the same enigma; the rational and the irrational meet.”¹⁰ The surrealists were never interested in the mathematical ideas behind the strange forms, only in the tension that they symbolized between the real and the fantastic. As Man Ray says about his *Mathematical Objects* series, “...I went to see them [the models], although I am not particularly interested in mathematics. I didn't understand a thing, but the shapes were so unusual, as revolutionary as anything that is being done today in painting or in sculpture.”¹¹

The constructivists, on the other hand, drew heavily from science, and in particular from mathematics, in developing both their artistic vision and their vocabulary of form. For this they were sometimes criticized and many tried to distance themselves from scientific and mathematical influences later in their careers. Antoine Pevsner never admitted that his *Developable Surfaces* were taken from mathematics. Henry Moore also backed off of his stringed work which was inspired by mathematical models, stating that “They were fun, but too much in the nature of experiments to be really satisfying... When the war came, I gave up this type of thing. Others, like Gabo and Barbara Hepworth, have gone on doing it. It becomes a matter of ingenuity rather than a fundamental human experience.”¹²

Thus, while certain artists of the early twentieth century may have expanded their vocabulary of form with the aid of mathematical models, in the end many artists tried to distance themselves from that influence. This may be due, at least in part, to the lack of humanity in the models. For both the surrealists and the constructivists, contact with the mathematical models was limited to the models themselves – there was no dialogue between the mathematicians who built the models and the artists who looked to them for inspiration. The artists treated the mathematical models as if they were crystals grown in a lab under the harsh eye of the mathematicians, who never knew the beauty that they contained. Most references to the models’ origins creation simply say that they were created for instructional purposes. This is partly true, but they were also created to inspire, to catalogue varieties of forms in space, and to be outward manifestations of the hidden beauty of mathematics.

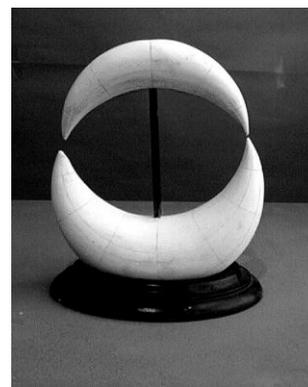


Figure 11: Model of a *Spindle Cyclide*. Cyclides are quartic surfaces whose “lines of curvature” (drawn on the model) are all straight lines or circles.

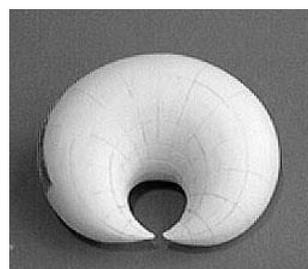


Figure 12: Model of a *Horn Cyclide*.

¹⁰ Hugnet, G. (1968). Essay from Barr, A. (ed.), *Fantastic Art, Dada, and Surrealism*. New York: Arno Press (reprint).

¹¹ Reinders, M. (Director). (1993). *Man Ray: A Life in the Day of Man Ray (Montparnasse Revisited, Vol. 4)* [videotape]. Homevision.

¹² Lake, C. (1962, January). Henry Moore’s World. *Atlantic Monthly*. 209 (1), 39-45.