National College of Art and Design,
Fine Art, Sculpture.

Marcel Duchamp and his search for the Fourth Dimension

by

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Submitted to the Faculty of History of Art and Design and Complementary Studies in Candidacy for the Degree. of Fine Art, 1995.

List of Plates.

Introduction.

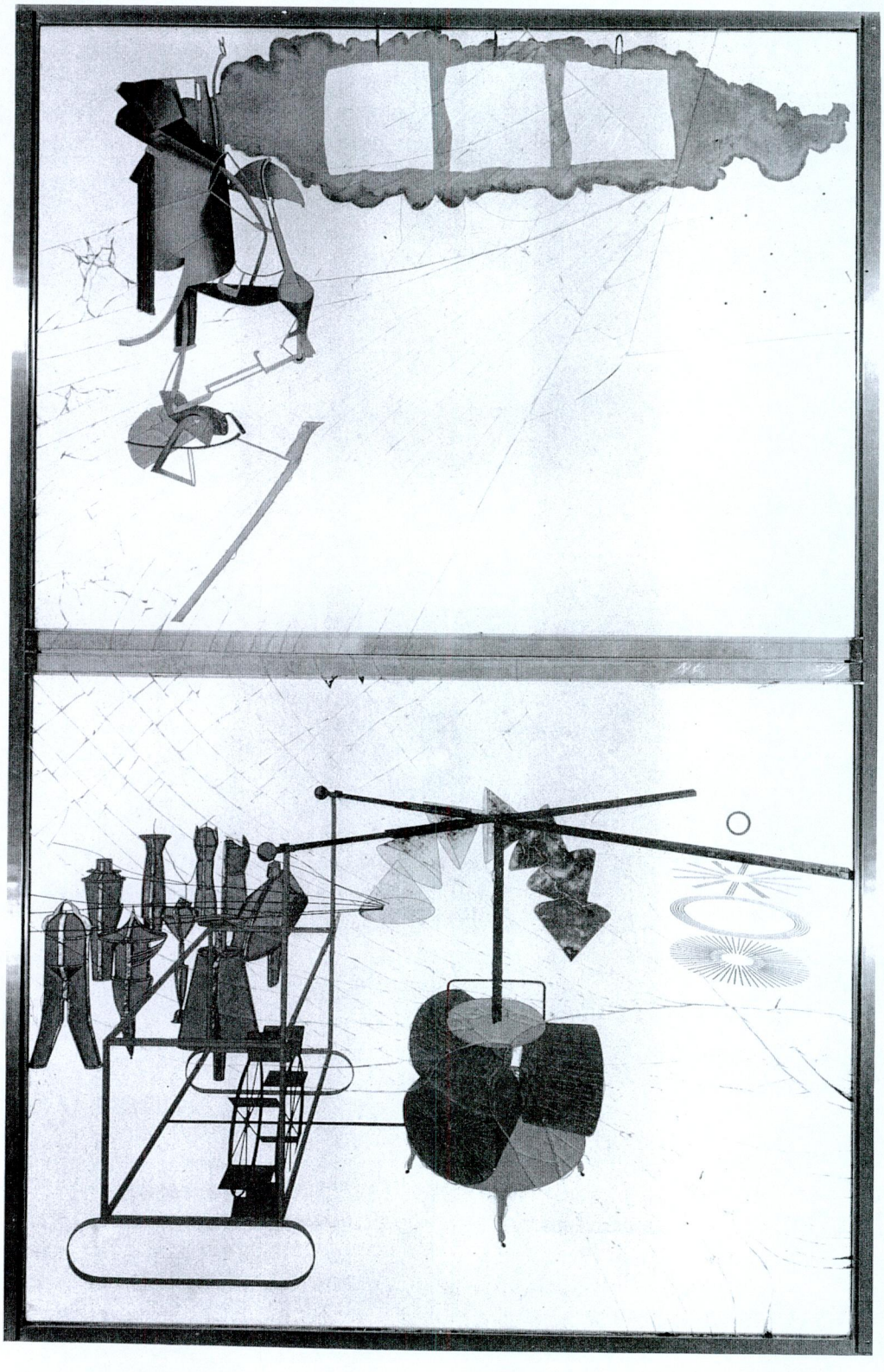
The complex spatial possibilities suggested by non-Euclidean geometry, were the outgrowth of developments in early nineteenth century geometry. Popularised during the later years of the century, these notions had begun to captivate the public's imagination by the same way as Black Holes have done in recent years. Like a Black Hole, the fourth dimension possessed mysterious qualities that could not be completley understood even by scientists themselves. Yet the impact of the Fourth Dimension was far more comprehensive than that of Black Holes or any other recent scientific hypothesis except the Theory of Relativity. In fact it was the popularization of Einstien's General Theory of Relativity with it's redefinition of the fourth dimension as time instead of space, which brought an end to this era in which writers, artists and musician's believed they could express higher spatial dimensions.

Marcel Duchamp's statements late in life on the degree of his involvement with the Fourth Dimension have left a curiously contradictory record. In 1967 Duchamp portrays himself as a dabbler in higher dimensions and does not even mention non-Euclidean geometry. However, it is clear that he was introduced to such a notion through his frienfship with cubist's. We can merely speculate why we began to take notice of the Fourth Dimension. Perhaps for the irreverant artist for whom nothing is sacred, avant-garde mathematics and science provided ideal tools for discrediting longstanding beliefs still held by the majority of the public. In the minds of most people, conditioned by the extreme positivism of the nineteenth century, the world was still clearly three dimensional and Euclidean. How revolutionary and subversive, then, the Fourth Dimension and Non-Euclidean geometry must have seemed to Duchamp.

From the evidence available it seems that Duchamp spent a lot of time patiently working out how the application of the new geometry for his art- it is here his seemingly ever present ironical stance dissappears temporarily.

His research came to peak between 1915 and 1925 with his "magnum opus" The Bride Stripped Bare by her Bachelors, Even". This work became the physical manifestation of his ideas at the time, which included the Fourth Dimension. This interest seems to have declined after this period, just as time began to become accepted as the Fourth Dimension. He has given many reasons for this lack of interest, some of which will be discussed later. "The Bride Stripped Bare by her Bachelors, Even" (The Large Glass) will be my focal point for this work and ideas at the time. In the first chapter I will outline what happened in the scince world which led to new attitudes in art, of which Duchamp was a main component.

In the second chapter I will outline his thoughts and works which lead to The Large Glass. And in the final chapter I will discuss the Large Glass within the context of non-Euclidean Geometry, arguing that it is more important than it's subject matter, which most books concentrated on.



Marcel Duchamp, *The Bride Stripped Bare by Her Bachelors, Even (The Large Glass)*, 1915-1923, oil, varnish, lead foil, lead wire, and dust on glass panels encased in glass, Philadelphia Museum of Art, Bequest of Katherine S. Dreier.

Chapter One

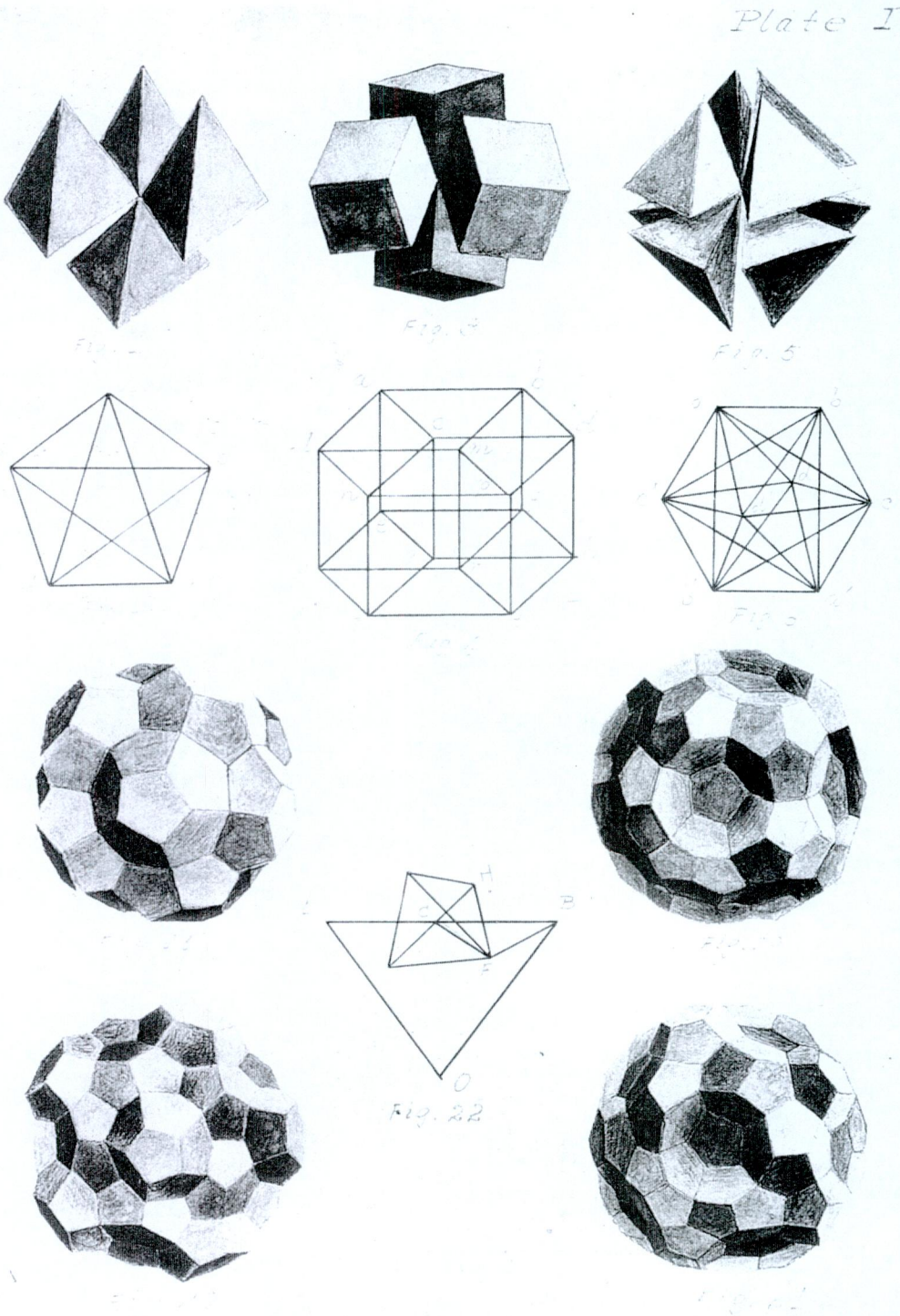
The Nature of Space at the turn of the century.

> In an autobiographical sketch Einstien recalled two incidents early in his life which filled him with wonder about the physical world. The first was when he was shown a compass by his father- the way the needle always pointed in one direction suggested that there was something deeply hidden in nature". Then later on when he was twelve he discovered a book on Euclidean Geometry with proportions which seemed to be about a universal and homogenous space. These early memories embodied two views about the nature of space. (Kern. 1983, p131)

I have included this quotation as a point of departure for my thesis and to underline the simalarities between art and science at the turn of the century. Both Einstien and Duchamp were aware that space was not absolute as Newton had acclaimed and through their work they paved the way for new ways of looking at space. This chapter is devoted to comparing the events that happened in these two subjects, that lead to this new way of seeing.

New ideas about the nature of space in this period (1900) challenged the popular notion that it was homogenous and argued for its heterogeniety. Artists dismantled the unoiform perspectival space that had governed painting since the Renaissance and reconstructed objects as seen from several perspectives. "Novelists used perspectives with the versatality of the new cinema, such as Joyce and Praust" (Kern 1983 p132). Yet their most serious challenge came from Science itself with the introduction into the popular domain of Non-Euclidean geometry.

Geometry is the branch of mathematics most directly concerned with the nature of space. Euclid stated without proof certain axioms and postulates that seemed evident, and from there derived other theorems by deductive logic. This geometry was made up of two and three dimensions and for two millenia was considered the only true geometry. At the beginning of the 19th century it lay at the heart of classical physics but during the course of the century, other geometries challenged the idea that Euclids was the only valid one. Crucial to it (Euclidean geometry) was the fifth postulate: that through a point in a plane it is possible to draw only one straight line in the same plane. The non-Euclidean geometries replaced the postulate with others and modified the rest of the theorems accordingly. It was around 1830 that the Russian mathemetician Nicholi Lobatchewsky announced a two dimensional geometry in which an infinfite number of lines could be drawn through a point parralel to another line in the same plane.



W. I. Stringham, "Regular Figures in *n*-Dimensional Space," *American Journal of Mathematics*, 1880,

In 1854 the German mathemetician Bernhard Riemann devised another two dimensional geometry - his space was elliptical. These alternative spaces contrasted with the flat planar surface of Euclids two-dimensional geometry, and so by the end of the 19th century many new geometries were found for all kinds of spaces- a doughnut, the inside of a tunnel and many more. The assault on Euclidean geometry was well under way - the Vandels were at the gates.

While physical scientists were trying to come to terms with the heterogenity of abstract space, natural scientists began to invesigate the relationship between the structure of living organisms and their spatial orientation. In 1901 the Russian physiologist Elie de Cyon published an article on the "natural" foundation of Euclidean geometry based experiments he conducted over a period of 20 years, on the physiological origins of space. He suggests the origins are rooted in the semicircular canals of the ear. Animals with two canlas experience only two dimensions and those with one canal are orientated in one. Humans have three canals set in perpendicular planes so we experience 3 dimensions and 3-D Euclidean space corresponds to the physiological space determined by the orientation of these canals. From these experiments Cyon concluded that the sense of space must not be inherent and that Kant's theory that a priori, was wrong. Needless to say as Stephen Kern reports " The boldness of these claims particularly the attack on Kant, triggered a good deal of scholarly criticism". (Kern 1983, p136) However Cyon continued to extend his theory and the following year his results were incorporated into Jacob Von Vexkulls, Unwelt und Innenwelt dev. Tiere.

In this book Vexkull himself, asks the biologist to set aside everything that he takes for granted in his own world - nature, earth, heaven, objects in space - " and focuses on the environment a particular organism can actually experience". (Kern 1983 p 136) Although all animals have their own surrounding world (Unwelt). Each spieces responds to the outerworld in their own way, and that response creates its special inner-world (Innerwelt). The lower animals react to stimuli directly and only higher animals with some organ od sight develop a proper sense of space. Their brains recognise the surrounding world not merely by direct contact but are able to mirror objects and spatial relations in the environment. This mirror world or counterworld (Gyegenwelt) differs wqhich each type of nervous system. Thus the inner worlds, surrounding worlds and counterworlds vary with "the building blocks of each animal and constituate different sense of space" (Kern, 1983 p137)

Vexkull modified and extended Cyon's theory to the entire animal kingdom and concluded that the sense of space of all animals however rudimentary varied with their unique physiology. Each sense of one-celled animals. His appreciation of the creative force generated by the needs and structured patterns of animals led him to a critique of Darwin's theory of natural selection. " It is not true, as people think, that nature compels the animal to adapt, but on the contrary the animal forms its nature according to its spacial need". (Kern 1983 p137). Among the throng of worlds and living spieces he speculated, there might be higher worlds of greater dimensions that we are unable to see as the amoebe is unable to see the stars of the sky.

Speculation that there are other dimensions other than the one descibed by Euclid, and that our experience of space is subject to and a function of our own unique physiology, was disturbing to the popular mind.

The profileration of the geometrical and the physical spaces had a great effect on mathematics and physics. This impact went further into the realm of art. The multiplication of points of view created a new way of seeing and rendering objects in space and challenged the traditional notion of homogeneity.

"The depiction of space in painting reflects the values and conceptual categories of a culture". (Kern, 1983 p140) During the middle ages, the importance of people and things in heaven and earth determined their size and position in space. With the introduction of perspective during the Renaissance, objects were rendered to scale according to their actual size and were located in space to repeoduce the relations of the visible world. Although there were occasional variations or intentional violations of the values of perspective, they governed the rendering in art until the 20th century. Then suddenly, under the impact of the Impressionists, Cezanne and the Cubists, the perspectival world of the Renaissance were shattered.

When the Impressionists left their studies and went outside to paint thay discovered a variety of points of view as well as colour. However varied the scope and angle of the Impressionist space, it wae essentially one space as seen from one point of view. Cezanne though was the first to introduce a truly heterogenous space in a single canvas with multiple perspective of the same point of view. Cezanne was obsessed by the shape of Mount Sainte-Victoire and painted it hundreds of times. By using different perpesctives for different parts of the landscape "he gradually pulled it out of the distant background toward the foreground until in the later paintings it loomed large as a symbol of his life-long fascination with form and space". (Kern 1983 p141).

Cezannes primary objective was to the composition of forms on forms on the flat surface of the canvas; conventions for accurately rendering volume and depth were secondary. Although he never entirely abandoned the techniques for showing depth, he did compromise them when necessary. And so he broke up linear perspective in the landscape by painting objects in the distance as brighter than those in the foreground. He sought to reconcile the properties of volumes in 3D space, with the two - dimensionality of the picture plane, and his paintings vibrated from the tension. Experience tells us that the opening of the vase is circular but when viewed from the side we see it as an ellipse. Cezanne combined the two perceptions visually with multiple perspectives.

These daring innovations were only possible for someone with a sharp sense of space. In a letter to his son in 1906 he reveals;

> "Here on the edge of the river the motifs are plentiful the same subject seen from different angles gives a subject for study of the highest interest and so varied that I think I could be occupied for months without changing my place, simply bend more to the right or to the left."
> (Rewald 1946 p262 as quoted in Kern 1983 p 142)

Small differences in perspective seemed to have occupied him for months. He wrestled with them until as Marleau-Ponty believed, he created " the order of an object in the art of appearing, organising itself before our eyes". (Marleau-Ponty 1964 p14 as quoted by Kern 1983 p142) For Cezanne the object in space was a multitude of creations of the seeing eye thet varied dramatically with the most minute shifts in point of view.

"One of the great fallacies of historical reconstuction is the characterisation of events as transitional" (Kern. 1983, p142) The work of Cezanne is well documented in History but it is misleading to view his work as being the transition into Modern Art. Nevertheless the important innovations he made in rendering of space - the reduction of pictorial depth, and the case of multiple perspective were carried further by the Cubists in the early 20th century. The Cubists repeatedly expressed their depth to Cezanne and used his techniques to create even more radical treatments of space. Their use of multiple perspectives also shows a strong simalarity to the cinema, which broke up the homogeneity of visual space.

The two pioneers of Cubism, Picasso and Braque, incorporated the innovations of Cezanne and the cinema and brought about the most important revolution in the rendering of space in painting since the 15th century. They abandoned the homogenous space of linear perspective and painted objects in a multiplicity of spaces from multiple perspectives. Picasso's first Cubist work Les Demoiselles d'Avignon(1907) showed two figures in frontal pose but with noses in sharp profile. The seated figure has her back to the viewer but her head is seen from the front.

One explanation for multiple perspective was that it enabled the Cubists to transcend the temporal limitation of traditional art. In 1913 Apollinaire commented that Cubism had followed science beyond the third dimension and "have been led quite naturally.... to preoccupy themselves with new possibilities of spatial measurement which in the language of the modern studies, are designated by the term; the fourth dimension." (Kern. 1983, p145)

In geometry and physics, biology and sociology, art and literature attacks were launched on the traditional notions that there is one and only one space and that a single point of view is sufficient to understand anything. In the 20th century perspectism was formalised by the Spanish philospher Jose Ortega y Gasset. Rationalists argue that there is one and only one truth that can be grasped by factoring out the errors that arise from viewing things from a subjective point of view. Rejecting this approach, Ortega formulated his own theory of perspectivism in 1910: "this supposed immutable and unique reality... does not exist; there are as many realities as points of view". (Kern, 1983, p151)

In a lecture on the historicall significance of Einstein, Orteya linked perspectivism and the general theory of relativity and maintained that the coincidence of the publication in 1916 was a sign of the times. The two doctrines signified the breakdown of the old notion that there is a single reality in a single absolute space.

> " There is no absolute space because there is no absolute perspective. To be absolute, space has to cease to be real- a space full of phenomena- and become an abstraction. The theory of Einstein is a marvellous proof of harmonious multiplicity of all possible points of view. If the idea is extended to words and aesthetics, we shall come to experience history and life in a new way."
> (Ortega, 1961 p143 as quoted by Kern 1983 p151)

Like Duchamp and many other artists at the time, Ortega shared their restlessness with conventional notions about the sanctity of a single space or point of view. And like them, Ortega challenged what he felt to be arrogance deeply embeddled in Western culture, an egocentrism that believed that one point of view - be it that of a mathematician, philosopher or nation - was alone correct. As he suggests it is our subjective view that gives us our sense of reality, " in the current of life which flows from speices to speices from people to people, from generation to generation, and from individual to individual, gradually possessing itself of more and more universal reality". (Kern, 1983, p152)

It is worth pointing out that such a philosophy of perspective can be in danger of becoming a runny undisciplined idea, an excuse for having no point of view at all. But in this period it provided a point of departure for artists such as Duchamp to challenge " the aesthetic egotism that had dominated Western culture for so long." (Kern 1983 p152).

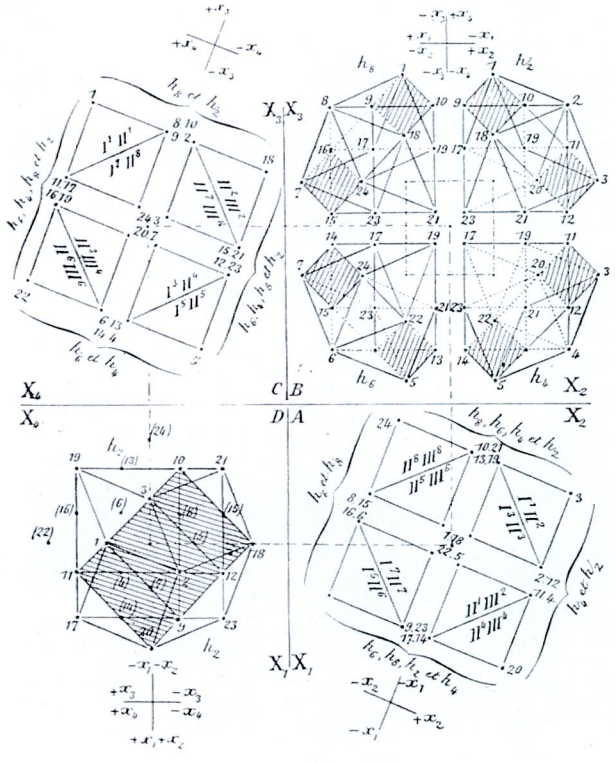
Chapter 2

Duchamp's introduction to the Fourth Dimension.

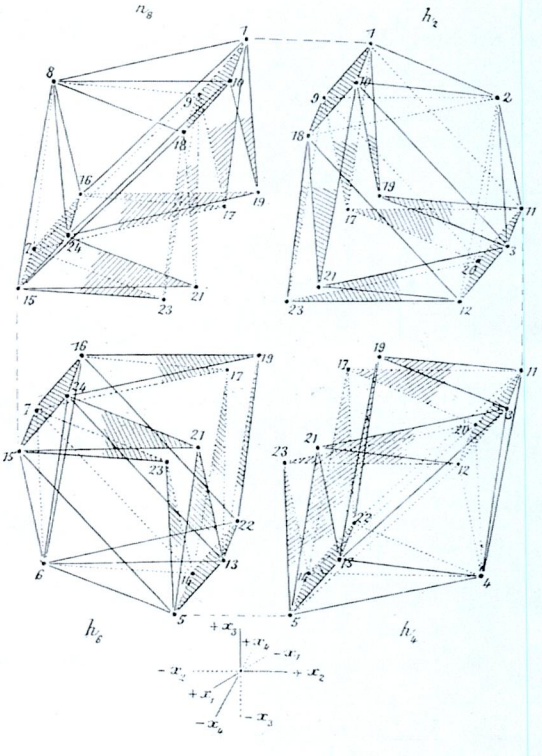
Duchamp's statements late in life on the degree of his involvement with Non-Euclidean geometry have been contradictory, possibly a trait from his Dadaist days. When asked in an interview about his knowledge on Non-Euclidean geometry, he replied " Very little, I was never the scientific type." (Cabanne. 1971, p39.) Yet it is hard to believe this is true given the time he matured as an artist. As I pointed out in the last chapter the aesthetics during the turn of the century were very much concerned with perception, and both the art world and science were striving for new ways to understand it. Non-Euclidean geometry was new to understand. Even popular fiction at the time was influenced by the alternative dimensions. Jouffret's, Traite elementaire de geometrie a quatre dimensions gives a detailed look at a 2D world adeling to an already growing genre, such as Abbott's Flatlands. Indeed the interest in popular fiction in the 4D could be compared today with the rise in popularity of topics such as blackholes, which Stephen Hawkins has introduced into the popular domain.

Whatever his reason for dismissing his interest in non-Euclidean geometry, Duchamp's reference to Jouffret and Poincare occur in a group of notes for the Large Glass. These notes were rediscovered by Duchamp in 1964 and were published in 1966 as Al'infinitif. These notes will be my main reference to his work as they are essential to his work as they are essential for the understanding of the Lerge Glass. Even the final collection of Duchamp's notes published in 1980 does not equal Al'infinitif in geometrical interest. Indeed Al'infinitif reveals a "Duchamp quite different ftom his traditional image as a dadaist practitioner of Black Humour" (Dalrymple Henderson. 1983 p121).

The product of the union of Duchamp's ironical outlook and his scholarship was what he referred to as a "playful physics" created by "slightly distending the laws of physics and chemistry" (Dalrymple Henderson. 1983, p121). As Duchamp explained "It was not for the love of science that I did this; on the contrary, it was rather in order to discredit it, mildly, lightly, unimportantly. But irony was present." (Cabanne. 1971, p39) This seems to be Duchamp's raison d'etre; an irreverent artist for whom nothing is sacred delves into avant-garde mathematics and science in secret so as to discredit longstanding beliefs still held by the majority of the people. Although they had actually existed for over 50 years, information about the 4D and non-Euclidean geomtry and their possible scientific ramifications were only gradually becoming available to non-specialists in this period.



"Plane Projections of the Sixteen Fundamental Octahedrons of an Ikosatetrahedroid," from E. Jouffret, *Traité élémentaire de géométrie à quatre dimensions*, Paris, 1903, Fig. (1)



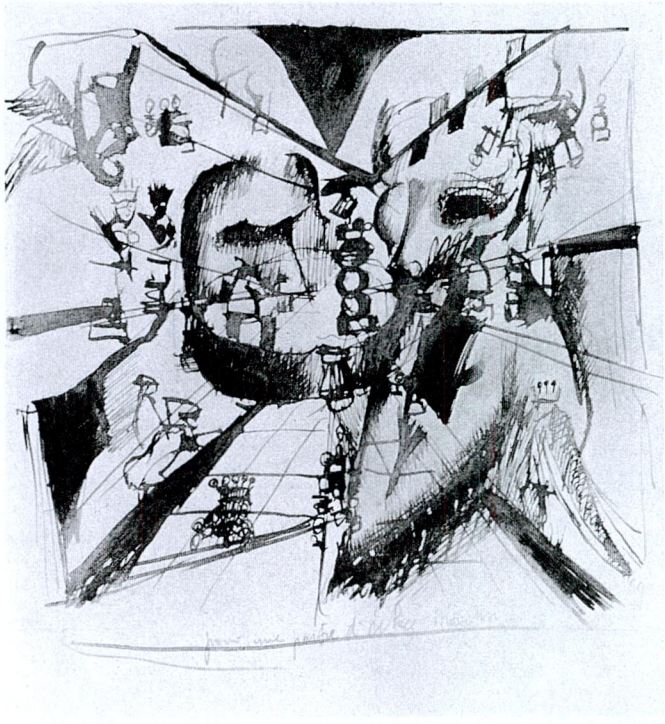
"*Perspective cavalière* of the Sixteen Fundamental Octahedrons of an Ikosatetrahedroid," from E. Jouffret, *Traité élémentaire*,

In the minds of most people, conditioned by the overriding positivism of the 19th century, the world was still clearly 3D. Yet he retained his ironic stance perhaps he suspected that its truth, too, was relative.

However Duchamp did go very deep into the realms of non-Euclidean geometry and from the evidence available, it seems that Duchamp spent a lot of time working out the applications of this new geometry for his art. Decades later, the notes in Al'infinitif have an air of mystery and "require of the reader a preparation similar to Duchamp's in order to penetrate their forbidding elevion." (Dalrymple Henderson. 1983, p122).

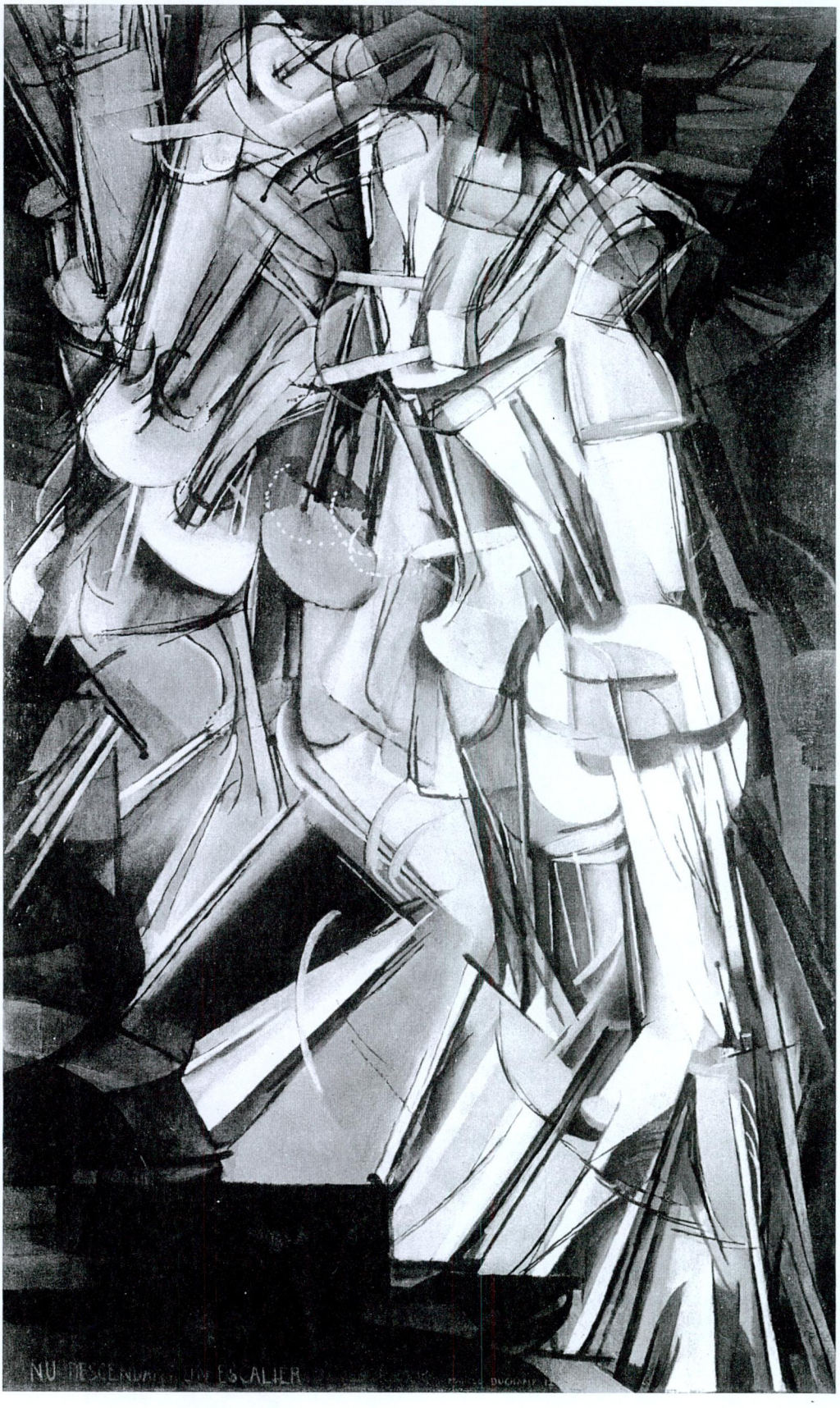
While the 4D may have been brought to Duchamps attention by popular literature, the connection of the 4D with cubism would only have been discovered once Duchamp met members of the cubist circle. In the spring of 1911 Duchamp, along with his brothers, Jacques Villon and Raymond Duchamp - Villon and certain other members of the Societe Normande de Peinture Moderne, had seen the first public manifestation of Cubism in Salle 41 of Salon des Independants. Although Duchamp was a member of the Salon d'Automme hanging committee that placed works by members of both groups together in salle 8, few of the painters had actually met those of the other group. After the closing of the exhibition of the 8th of November, the two groups began to meet jointly for their discussions, Appolinare was invited to these gatherings. The 4D must have quickly become a shared concern, for at the subsequent joint exhibition at the Galerie d'Art Ancien Contemporaire (20th November to 16th December 1911) Appolinaire gave his first lecture discussing the new art in relation to the 4D.

So by October 1911 Duchamp must have heard of Jouffret's "Traite elementaire de geometrie a quatre dimensions." In that same month he began making drawings for Portrait of a Chess Player, which became a turning point for his work. The metaphor of chess had already been used by Jouffret himself in his introductory discussion of the possible reality of the 4D. If, Duchamp did not know of Jouffret when he commenced his studies, he must have by the time he finished his final version in 1911. By this time the parralels with Jouffret would have been too obvious. In his introduction to the Traite elementaire, Jouffret explains that despite the great mathematical value of non-dimensional geometry it is virtually impossible to "see" in one's mind the non-dimensional bodies that are its subject matter. Nevertheless he does compare this marvellous ability to that of a blindfolded chess player-



Marcel Duchamp, *Study for "Portrait of Chess Players,"* 1911, ink and watercolor on paper, The Solomon R. Guggenheim Museum, New York, Gift of Katherine S. Dreier Estate.

Marcel Duchamp, *Portrait of Chess Players*, 1911, oil on canvas, Philadelphia Museum of Art, The Louise and Walter Arensberg Collection.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> There is really no more difficulty in concieving 4D shapes, than concieving solid shapes, nor is there any mystery at all about it. When the faculty is acquired or rather when it is brought into conciousness - for it exists in everyone in imperfect form - a new horizon opens. The mind requires a development of power, and in this use of ampler space as a mode of thought, a path is opened by using that very truth which, when first, stated by Kant, seemed to close the mind within such fast limits. Our perception is subject to the condition of being in space, but is not limited as we at first thought. For instance chess players who have the ability to conduct several games simultaneously without looking." (Dalrymple Henderson, 1983. p124)

For Duchamp who was an enthusiastic chess player and who already had painted a naturalistic painting entitled "Chess Game" a reinterpretation of the chess theme in the new 4D Cubist idium would have been an exciting challenge.

The six preparatory drawings done in October 1911 contribute important clues to the final "Portrait of Chess Players." While the definitive version shows chessmen only on one plane between the heads of the two players and grasped in one players hand, the earlier drawings show a multitude of chessboards, chessmen and even additional heads seemly, representing the minds of the players at different stages of the game. The subject of the Chess Players seem to be "the mental process involved in a chess game, the succession of psychological states of the players," (Dalrymple Henderson. 1983, p124). Although it is not a blindfold match, Duchamp is attempting to portray the "mental chess - board and interior mirror" (Dalrymple Henderson. 1983 p124) described by Jouffret.

If Duchamp's portrait of Chess Players was somehow connected to Jouffret's suggestion (and that connection is not too far-fetched) that the opinion of the chess players mind is similar to the visualization of the 4D then as Linda Dalrymple Henderson points out, "this painting is far more sophisticated than most Cubist paintings of the time." (Dalrymple Henderson. 1983, p126)

Perhaps this sophistication led to the eventual dissatisfactionDuchamp had with the Cubist technique for evoking the 4D. Indeed it appears as if Duchamp merely flirted with Cubism as his handful of Cubist paintings testifies to. Nude Descending the Stairs, perhaps his most famous Cubist painting, seems to use movement as a means to incorporate the 4D in painting. This painting led to Duchamp being asked to leave the Cubist movement as many of his contemporaries thought the painting was too similar to their rival group the Futurists. Whether it was the general dissatisfaction with this approach, the scene was set for the Bride Stripped Bare by her Bachelors, Even.

During July and August of 1912 Duchamp travelled to Munich where he made the first of a large group of notes for the Large Glass which he later published in different collections. Duchamp's post-Munich thinking on Dimensions and perspective were to be influenced by a job he took at the Bibliotheque-Sainte-Genieve, in November 1912. The atmosphere of the library and abundant information must have been a turning point for him. However it is difficult to access his progress until the notes for the Large Glass begin. What is clear is that through his rethinking of dimensions and perspective he decided to abandon conventional oil painting. Reacting against an art that he believed had become purely "retinal". "Too great an importance is given to the retinal" (Cabanne. 1971, p43). Duchamp wished to put painting once again "at the service of the mind" (Dalrymple Henderson. 1983, p129). His enthusiasm for his new direction is reflection in a 1913 letter from Gertrude Stein to Mobal Dodge in which Stien described meeting a young Duchamp who talked "very urgently about th Fourth Dimension" (Dalrymple Henderson. 1983, p130)

Chapter Three

The Large Glass and the projection of the Fourth Dimension.

The Bride Stripped Bare by her Bachelors, Even. (The Large Glass) is customarily dated 1915-1923. Even though Duchamp prepared notes for it before 1915, he did not begin work on the panels until 1915 when he moved to New York. The Large Glass represents Duchamp's conceptual approach at its best. The sense of the artist hand has been replaced as Duchamp wanted , by the look of machine fabrication in a variety of materials on glass. Not only has the technique become machine orientated but even the subject has become a machine.

The notes which Duchamp left behind are, invaluable in deciphering the images in the Large Glass. With these notes it is clear that this is a lovemaking machine with the Bride above and the Bachelors below with a clear separation between the upper and lower sections. It seems that Duchamp's statement is ultimatly a pessimistic one about the futlity of all attempts at meaningful human contact.

Duchamp's overriding concern in the Large Glass was the interrelation between the second, third and fourth dimension. Early in the initial planning of the Large Glass, Duchamp had determined that there should be a fundamental difference between the upper and lower sections - the Bride would be represented with strict application of Renaissance perspective.

This of course led to further distancing from the Cubist group as they had sought deliberatley to avoid all traces of traditional perspective "that infallible device for making all things shrink" (Dalrymple Henderson. 1983, p133) as Apollonaire had described it in 1913.

Duchamp's reevaluation of painting in forms of the relationship of dimensions to one another was more fundamental than the total rejection of perspective by the Cubists. Through his research he stumbled onto a way of incorporating higher dimensions in the Large Glass -

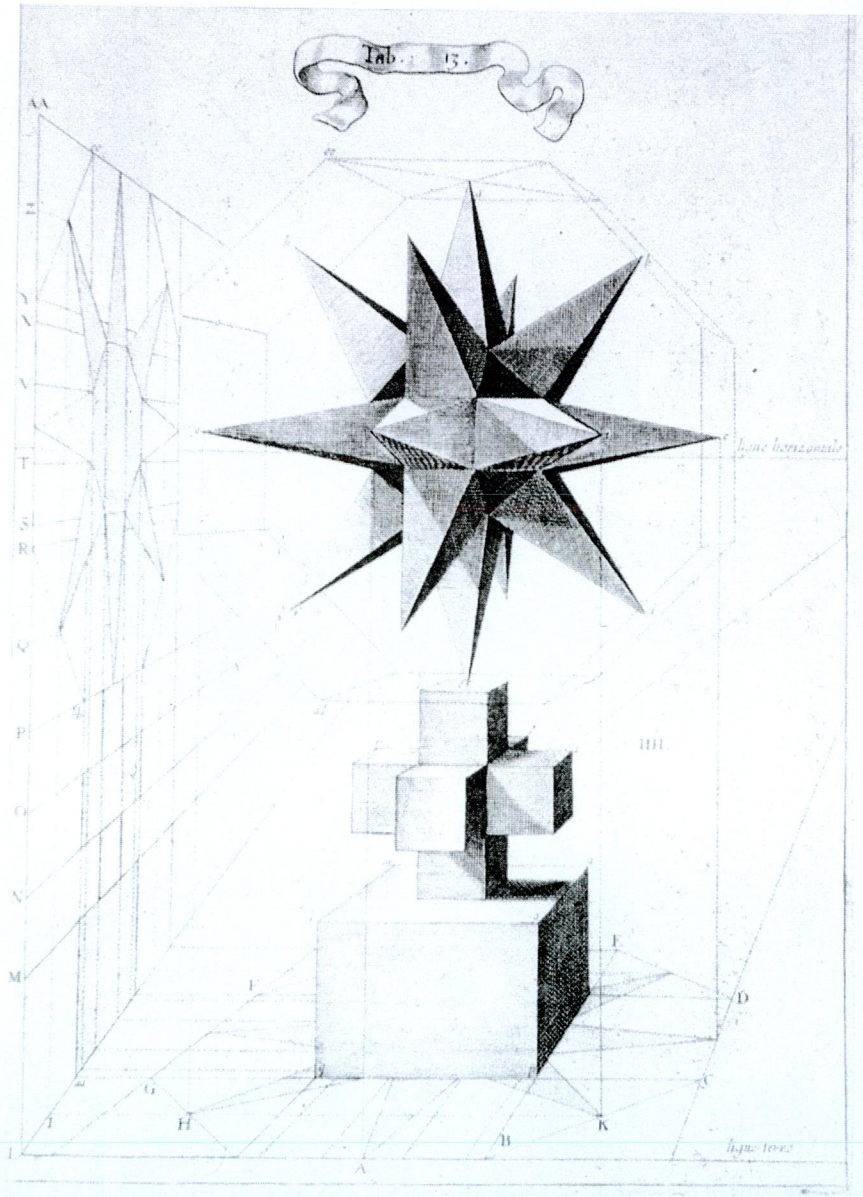
> Since I found one could make a cast shadow from a 3D thing - I thought by simple intellectual analogy, the 4D could project and object of 3D, or to put it another way, any 3D object, which we see dispassionatly is a projection of something we are not familiar with. (Cabanne. 1971, p40)

Indeed this analogy - the fact that a 3D object could be a cast shadow of a 4D object - was to be essential to his final solution.

To understand Duchamp's attempts to reevaluate dimensions in painting, it is necessary to look at Al'infinitif. Although there are other collections of notes on the Large Glass, Al'infinitif is primarily concerned with the relationship between dimensions, which for me is the important aspect of the Large Glass. The other collections are concerned more with the iconography of the painting (or as Duchamp put it, the projection). His first notes were made during his visit to Munich in 1912. These notes grew steadily larger and peaked in 1913. But after his departure for New York in 1915 they decreased and then finally stopped in 1921 or 1922. These notes were often scribbled down on scraps of paper or old bills until they were finally put together in 1966 as Al'infinitif. Duchamp had a direct imput in the putting together of these notes. However it does appear that they atr not in the tight order, but they all share the underlying theme of the relationship between dimensions.

The raison d'etre in the notes Apparance and Apparition found in Al'infinitif was to create 4D perspective or rather to show how a 3D being might percieve the 4D. He decided an examination of both the rules of perspective and the laws of 4D geometry would be necessary. A large group of notes chronicles his exploration of these subjects, a study that finally led him to the mirror as a symbol of the 4D. And so with the knowledge he had gained, Duchamp was able at last to achieve a complex new synthesis for representing his Bride.

From early 1913 Duchamp's job as a librarian at the Bibliotheque-Sainte-Genieve offered ready access to a wealth of information on perspective as well as geometry. The number of notes that deal with 3D perspective is a lot smaller than one would expect. It seems that the library had a large section on perspective but that Duchamp seems to have singled out, Niceron's Thaumatargus Optics, as the basis of his inquiry into perspective. Perspective was the magical element celebrated by Father Jean-Francois Niceron in his 1646 Latin treatise. In his book there are numerous complicated drawings by Niceron on the use of perspective, which must have delighted Duchamp. In one of the drawings Niceron illustrates the use of perspective for groups of complex solids. Niceron's cubic solid in the middle of his assembly of forms would have been recognized immediatly by Duchamp as the figure adopted on a popular level during the nineteenth century to represent the 4D - hypercube. Also Niceron's perpendicular projections of his figures onto the wall created sections of the figures by means of shadows, ideas which already concerned Duchamp.



Nicercon's Thaumatargus Optics

Opposite page

Duchamp's personal interest in shadows, mirrors and glass were all to recieve extra encouragement through his research into traditional perspective. The treatment of shadows is usually included in treatises on perspective and indeed mirrors are regularly discussed in books on perspective. Da Vinci himself often speaks of the advantages using a glass panal in perspective. However Duchamp had many reasons for using glass in the Large Glass. The appeal of the smooth surface of the painting behind glass gives the impression that the painting is free of touch of the artists hand, "It also took away any idea of the hand of materials. I wanted to change to have a new approach" (Cabanne. 1971 p142). Glass also eliminated the need to paint backgrounds, and as Duchamp explained " the glass.... was able to give its maximum effectiveness to the rigidity of perspective". (Cabanne. 1971, p141). Glass was ultimatly to assist in creating the 4D of the Bride, but "its bases in 3D perspective must have been emphasised for Duchamp in the perspctive books" (Dalrymple Henderson, 1983,p145).

Shadows, mirrors and glass would all play important roles in Duchamp's final understanding of the 4D for his representation of the Bride. Yet before he attempted the Large Glass he continued his research into the laws of 4 dimensional geometry,(including 4D vision) and the way 4D might be represented. It is important to point out here that during the course of his study of the 4D geometry Duchamp began interpreting it for his own use, so that only a few notes are simple records of theorems of 4D geometry. While these notes could have been taken from any text on 4D geometry, most have Duchamp's speculations on intersections of geometrically figures, these seem more personal and a number are not geometrically true. However most of these statements appear to reflect Duchamp's attempt to establish the way in which 4D vision would operate. When one considers this the notes "gain a conditional validity which you can not ignore when they are put into an aesthetic context rather that a scientific one" as Dalrymple Henderson puts it (1983, p146.) Duchamp's scheme for 4D vision equates the 4D eye's perception of a geometric figure with the human eyes perception of the figure of the next lower degree eg. 2D. Duchamp writes -

> On the 4-dim'l vision
> In the 4-dim'l continuum the plane is always seen as line
> It has no more perspective development.
> The line is seen as a point.
> Express how a value is seen.
> (Define this perception as a whole.)
> The 3-dim'l body when seen in the 4-dim'l continuum is seen as a whole.
> (does it have a reverse and front side like a plane seen in space?)
> (ed Sanouillet. 1975, p90)

The source for Duchamp's notion of the dimension-reducing characteristic of the 4D vision was undoubtedly Jouffret. Here he gives an explanation in which different dimensions interelate -

> Our space is only an elementary slice out of the 4D continuum that surrounds it on everyside. From the point of view of the 4D, it is infinitly thin and absolutly flat, and this is true for every entity it contains.
> (Jouffret. p183-84 as quoted by Dalrymple Henderson 1983. p147)

Jouffret was of course speaking only figuratively; 3 Dim'l space remains 3 dim'l within the 4D continuum. Duchamp however seems to have taken him literally.

Another aspect of Duchamp's individualised view of the 4D continuum is his fascination with the sphere as the basic element of the 4D line. In this case he is reversing his approach of reducing the number of dimensions of an object in order to imagine a 4D view of it. By thinking of the point as sphere he has raised its number of dimensions to three. Duchamp's idea of a 4D line produced by a series of nestling spheres of increasing rachi may have been derived from some popular contemporary source, but he did not recognise its futility in another note "this straight 4-dim'l line = 3 - dim'l space and does not get out of that space." (ed. Sanouillet. 1975, p95)
Nevertheless, the artist's speculation on the repitition of 3D spheres along a line into the 4D did suggest a means of producing a 4D continuum. This idea was to figure in Duchamp's final formulation of the nature of the continuum.

Duchamp had explored the process of generating figures of the higher degree in his motion studies of 1911 and 1912. Now in the notes for the Large Glass he returned to the motion in a purely geometrical context -

> Will the passage from volume to 4 dim'l figure be produced by parallelism? Yes but this elemental parralelism being a geometrical process requires an intuitive knowledge of the 4-dim'l continuum...
> A representation of the 4-dim'l continuum will be realized by a multiplication of closed volumes evolving by elemental parallelism along the 4D. Of course one still has to define intuitive knowledge and direction of this 4D. Hence the mirror?
> (ed. Sanouillet. 1975, p92).

If elemental parallelism had failed Duchamp in works such as Nude Descending a Staircase in 1912, in its purer geometrical context it became the key to his visualisation of the 4D continuum. Poincare provided the scholarly theory for Duchamp. In his final book Poincare declares -

> We know now what a continuum of dimensions is. A continuum has dimensions when it is possible to divide it into many regions by means of one or more cuts which are themselves continuations of dimensions.
> (Poincare, p67 as quoted by Dalrymple Henderson 1983, p149).

From these highly theoretical ideas on the repetition of the virtual images of an object to constructing a 4D continuum, Duchamp returned to more practical ways of representing a 4 dim'l Bride. The idea of a mirror mentioned earlier was now to play an important part. In the end the mirror was to help the 3D eye with grasping the 4D. As he writes in one of his last notes -

> For the ordinary eye in a space any point in the end of the line (whether straight or not) coming from a continuum.
> The eye could go endlessly around one point (in the 3 dim'l), it will never be able to percieve any part of this 4-dim'l line other than the point where it meets the 3-dim'l medium.
> (ed, Sanouillet, 1975, p91).

Here his notes highlight his worries on the impossibility of seeing the 4D with only 3D vision -

> It is certain that every point in space conceals hides, in the end of the line of the continuum. One would like to go around this point and percieve this direction which comes (at this point) into contact with space -
> A line of space also conceals a plane; it is like the section of this plane, the only one visible to the eye.
> (ed. Sanouillet, 1975, p95).

For Duchamp, it was the mirror that gave the elusive boarderline quality of the 4D to a 3D viewer. In his final statement on representing the 4D he states -

> Analogy between
> Reflection in a plane mirror of 3D section of a 4D body
> by a 3D space.
> For an ordinary eye, a point in space hides, conceals the
> 4th direction of the continuum - which is to say that
> this eye can try to percieve physically the 4th direction
> by going around the said point. From whatever angle it looks
> at this point, this point will always be the broader line
> of the 4th direction.
> (ed. Sanouillet, 1975 p91).

This was the light at the end of the tunnel he was looking for. On one level Duchamp looked at the 4 continuum as the mirror of the 3D, "the strangley self-sufficient space within a mirror" (Dalrymple Henderson 1983, p101). But he also saw the mirror as having one less dimension than the object reflected. Duchamp treated the mirror image as its mould. While these interpretations are opposite to each other, it shows the magic as the symbol of 4D continuum.

As he approaches his conclusion he seems to rely less and less on geometrical texts in favour of personal geometrical reasoning by the process of analogy. It is here that mathematical errors creep into his notes. Just as his ideas on the figures that result from geometrical intrepretation could only be accepted if intrepreted in terms of 4D vision, the last statements in his notes are not strictly true in geometry.

The problem seems to stem from his use of the word couper in his notes. In his notes based on Poincare's discussion of Dedekind cuts, he demonstrates the correct understanding of a cut - "a line cuts a plane, a plane cuts a 3D space and a 3D space cuts a 4 dim'l continuum." ed. Sanouilet 1975. p89). Yet as Dalrymple Henderson points out in notes on The Continuum, Duchamp states "A point does not cut a 3 dim'l continuum, a line does" (Dalrymple Henderson. 1983 p152). While the first half of the statement is correct, the second is not. A line is not one but two dimensions short of 3D. He repeats the mistake again - "just as a point cuts a line and does not cut a plane so a line of infinite length or surface element cuts a volume and does not cut a 4 dim'l solid. But the plane or surface cuts this 4 dim'L solid" (Dalrymple Henderson. 1983. p152).

It is hard to believe that Duchamp could be confused on this issue. However as Dalrymple Henderson suggests if you use the word couper in a slightly different sense, for instance "to cross" (rathar than to cut) in the sense of entering and exiting from a higher dimension then you arrive at a different perspective on his logic. (Dalrymple Henderson. 1983, p152). Don't forget it was the interrelation between dimensions which interested Duchamp the most. So as a result Duchamp seems to have concluded that a one dimensional line would be swallowed up by a 4D continuum. Thus the point would be totally surrounded like a pont in a plane or in a 3D space. Duchamp's speculation on the need for a 4D line with greater volume than the ordinary one - dimensional line, comes from his own personal intrepretation of geometry.

Even though this is not pure geometry his thoughts are obviously ingenious attempts at proving the four dimensionality of a mirror. And indeed are truer to the thoughts of an artist than a scientist. Here is the key note to his interest in the space within the mirror -

> Comparison form; A point does not cut <cross> a 3 dim'l continuum, a line does. By analogy, given a cube- its reflection in a mirror - one could say that a straight line perpendicular to the plane in the mirror will not cut the cubes image (will not hide the cubes image). Because the eye goes around the line without thickness. This line will stop at the mirrors plane. On the contrary, a plane or any opaque surface, touching the mirror, will cut or hide from the observers eyes a part of, or whole image of the cube in the mirror. The 4 dim'l continuum is essentially the mirror of the 3 dim'l continuum.
> (ed. Sanouillet 1975. p91-92).

Duchamp begins here by setting up his condition that a point does not cut <cross> a 3D continuum whereas a line does. By analogy he reasons, a line does not cut <cross> a 4D continuum but a plane does. The experimental proof to demonstrate the number of dimensions within the mirror is carried out with the image of a cube in the mirror. For this situation Duchamp defines "to cut" as "to hide the cubes image" with the result that a line does not hide the image while a plane does. Therefore accordingly to the artists personal brand of logic, the image not cut by a line must be 4 dim'l.

So now the independance of the space within a mirror has been villiated. Here Duchamp's rule - a line does not cut a 4D continuum is again central to this argument, for it alone can explain the way in which a line perpendicular to the surface of the mirror cannot enter the mirrors space.

Instead, the line slips through as if it were a point, and continues on its own 3D space.

When it came to the actual fabrication of the Large Glass, his research and, eventual understanding of visualizing the 4D proved less fruitful for the technical side. The 4 dim'l continuum as a mirror of the 3 dim'l continuum could only be appreciated after a detailed geometrical proof and so could not be convincing or visual evidence alone. So Duchamp returned to his original idea that "the shadow cast by a 4 dim'l figure on our space is a 3 dim'l solid." Put differently in another quote -

> Each ordinary 3 dim'l body, inkpot, house, captive balloon is the perspective projected by numerous 4 dim'l bodies upon the 3 dim'l medium.
> There are 3 dim'l bodies which correspond to fewer perspective projections (in the 4 to 3 dim'l region) than others. One would have to construct/determine those which are the projection of a single 4 dim'l body (4 dim'l perspective)
> (ed. Sanouillet. 1975, p96).

This is how the Bride came to be. She is now a projection of the 4D in the form of a 3D geometrical section, which in turn has ben reduced to the two dimensions of the glass.

For somebody who is interested in the passage from one dimension to another as Duchamp was, the production of the Bride was a particularly interesting experiment. Duchamp had originally planned to transfer her image photographically onto glass. When this method proved impossible, he carefully painted her in tones of black and white, preserving the look of 3D. While a mirror was not actually used in the reduction of the Bride to two dimensions, she may nevertheless be thought of as a kind of mirror image of the 3D Bride. "From a visual illusion of the 4D created by a mirror as 4 dim'l reflection of the 3D world, Duchamp finally settled on his alternative view ot the mirror as 2 dim'l world with 3 virtual dimensions" (Dalrymple Henderson 1983, p156-157)

Duchamp was equally concerned with the lower section of the Large Glass, the elements of the Bachelor apparatus are set in a strict perspective system which establishes them as 3D forms. While the glass panels allow the Bride to hang free of any indication of space she inhabits, the form of the Bachelor apparatus appear to be actual 3D objects spread out on the floor in front of you. So the nature of the glass panel itself adds to the distinction between the Bride as a 2 and 3D reflection or projection of the 4D and "the unfortunate earthbound Bachelors" (Dalrymple Henderson. 1983, p156).

In the production of the Large Glass, Duchamp made use of his knowledge gained during his study of Non-Euclidean geometry. Even though his notes are not flawless his knowledge was far greater than any of his peers at the time. While he took Non-Euclidean geometry as the point of departure as they did, he soon developed and went beyond to form his own unique view of the fourth dimension.

* continuum - a continous thing, a quantity, or substance; a continous series of elements passing into each other. (The Shorter Oxford English Dictionary)

Conclusion.

Although Duchamp's Dadaist persona has dominated our perception of him, in the pre-world war one era, " he recognised the radical redefinition of reality occurring in contemporary science" (Robbin. 1992, p15). Like other Cubist's at the time he was eager to explore these new definitions of space for his own art. As an alternative to perspective, he and many others found in the popular notion of the 4D, encouragement "to explore new kinds of spatial structures that could explain spaces more complex than what we could perceive" (Robin. 1992, p16). The Cubist's used multiple viewpoints, often blending together, and so blending together, and so denying the viewer any 3D reading of the object. However Duchamp went further than the popular non-mathematical literature to actually explore 4D gometry itself.

He was interested in unifying art and science with a view to creating a new aesthetic one which "would place art at the service of the mind once again" (Cabanne 1971, p32). " I was interested in introducing the precise and exact aspect of science which had not often been done or at least had not been talked about" (Cabanne. 1971, p39). So his use of Non-Euclidean geometry should not be overlooked. In his essays on Duchamp, Bailly states "With the theoretical basis for these ideas we need not, in my view concern ourselves since they do not stand up well to close inspection." While perhaps Duchamp's use of Non-Euclidean geometry became quite unorthodox near the end, it is a mistake to reject this aspect of the Lerge Glass as so many people do. In one of his last interviews he stated "I wanted the album to go with the Glass and to be able to be consulted when seeing the glass because as I see it , it must be looked at in the arsthetic sense of the word." With this in mind it is hard not to deal with non-Euclidean geometry when addressing the Large Glass.

Yet as much as Duchamp speculated in his work, the only visual models available were geometry's conceptualisations of projections of 4D figures and he never attempted in the Large Glass to present the Bride in a complex geometrical term. Instead he went for a more personal view, "slightly extending the laws of physics and chemistry" (Cabanne. 1971, p39). In the end he would explain the Bride as a 2D projection or shadow of a 3D Bride who would have been the shadow of the ultimate 4D Bride.

Eroticism plays a large part in his work and can be found readily in the Lerge Glass. The sexual frustration of the Bachelors on the bottom panel is obvious. Through this sexual iconography he could shock his audience into paying attention, and then allow the double entanders to carry the important part of the meaning.

One of Duchamp's most famous use of sexuality was his adoption of the character, Rose Selavy in 1920 or 1921. Could this switch in sex have anything to do with the 4D? As we know a central aspect with geometry had to do with the results of rotating something through a higher plane. As Craig Amock suggessts in his essay entitled "Duchamp's Eroticism; a mathematical analysis" It is possible that Duchamp was thinking along these lines, while he chose a female alter ego. (ed. Kuenzli. 1984, p149-150). Just as shapes change in the 4D, perhaps Duchamp went through a change in the 4D, entering into it a man and coming out, a woman. It does seem reasonable to suppose that he was also concerned with what would happen to his own person if he were rotated through the 4D" (ed. Kuenzli, 1984 p149).

However the mathematics was serious, it gave Duchamp a way of underlying his humerous Dada superficiality, with deeper meaning, it allowed him to extend the dimensions of his Dada insight into the philosophical realms of art and aesthetics.

Research by art historian Lindu Dalrymple Henderson, proves conclusively with page after page of documentary evidence that the desire to create four-dimensional art was the motivation and philosophical support for the daring leaps of abstract art and modernism in general, of which Duchamp was a main contributer.

This new space developed in art at the turn of the century is in my view essential for understanding our visual experience in the 20th century. Television as a medium of communication has penetrated deep into the heart of our psyche. As Mc Luhan suggests it is television which has the potential to be connected to every other point in space without passing through the intervening space - the window to the fourth dimension. It is through this need to understand our new ability ro percieve things, that makes the Fourth Dimension a contemporary issue.

> there exists then, both the opportunity and the necessity to search for a structure of space that is multiple, simultaneous, paradoxical, impossibly convoluted, discontinous yet multiconnected, with mutually exclusive components. The opportunity exists because there are limitations of such a space all around us, the necessity, because we most make sense (in both meanings of the term) out of our experience of space.
> (Robbin. 1992,p53).

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