NATIONAL COLLEGE OF ART AND DESIGN

DEPARTMENT OF FINE ART PRINTMAKING

'THE PRINTS OF M.C. ESCHER AND THE FRACTAL BOUNDARIES WITHIN PRINT PROCESSES'

BY

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INTRODUCTION

> As if they felt too confined in the one soul, the mind of art and the mind of science have parted ... The divergence seems irreversible, and what both sides promoted together during the enlightenment is now out of balance.
> (Peitgen and Richter, 1986, p.1)

Being a print student, and becoming interested in the history of the medium, I came to realise that its history is almost absent from art history. This situation became an emotive force behind my choice to write about the unique properties of printmaking. Printmaking in all its forms exists as an extraordinarily diverse medium, I chose to select one artist's work, the Dutch printmaker M.C. Escher (1898-1952), the lithographer and woodblock printer. To be even more precise it was his post-1937 prints which caught my interest. These prints are like jigsaw puzzles with pieces that are all the same. The pieces, or figures, are starfish, shells, little men, fish, birds, or flowers and the list goes on ... They interlock, side-by-side, arm-in-arm, harmoniously together on the picture plane. Some are repeated patterns which could, in theory, be repeated until the end of time, if there were an end. Escher woodblock prints are all hand carved by the artist and printed by him also. They contain a quality which can only be attained by woodblock printing and this makes them beautiful. The structures on which Escher prints were built are mathematical in nature. The artist was a visual mathematician who could never understand the abstractions

of mathematical language.

In 1975 mathematician Benoit Mandelbrot computer generated an image, which he called the Mandelbrot Set. The Set was achieved by the iteration of a simple algorithm or set of rules, the resulting image proving to be simultaneously complex and beautiful. The nature of the Set includes scaling, self-similarity and randomness elements which are also evident in the works of M.C. Escher. John Briggs noticed a definite linkage between the work of Escher and Mandelbrot's fractals: 'Since a long time, I am interested in patterns with motifs getting smaller and smaller till they reach the limit of infinite smallness.' (Escher, Fractals: the Patterns of Chaos, 1992, p.166)

The book <u>Symmetry in Chaos</u>, by the two mathematicians quoted at the beginning of this introduction, shows computer generated images that have been formulated by Peitgen and Richter themselves. These symmetric fractals seemed to me to be structurally similar to Escher's <u>Circle Limit</u> prints and later prints of this sort. They were also beautiful and because of their stellating structures and bright colours could be described as psychedelic snowflakes. As mathematician, G.H. Hardy explains:

> The mathematician's patterns, like the painter's or the poet's, must be beautiful; the ideas like the colours or the words, must fit together in a harmonious way. Beauty is the first test: there is not permanent place in the world for ugly mathematics. (Hardy, 1940, p.84-5)

The visual linkage made between fractal computer images and Escher's later woodblock prints revealed itself to be in their similar morphology. They are both a result of the simultaneous application of both orderly and chaotic forces. Escher found orderliness within geometrical structures, platonic solids and crystals; he saw chaos in everyday life and it manifested itself within living bodies. Peitgen and Richter generated a chaotic or non-linear algorithm in conjunction with a linear, or ordered, algorithm to see what results they would derive from these experiments. Both the prints of Escher and the computer printouts of Peitgen and Richter exist somewhere in between art and science. Indeed, Escher's work in 1985 was the subject for an interdisciplinary congress and exhibition in Rome; this event proved to be an important link between art and science. (1) (Emmer, 1988, p.202)

This thesis is divided into four chapters. The first deals with the ancient tension of order and chaos, relating it to repetition and other aspects in the print processes. Chapter Two, entitled 'Infinity', deals with the concept that fascinated Escher - how to depict infiniteness, or a fragment of it, in print. Chapter Three, on Positives and Negatives within the process, is a technical and aesthetic account of Escher's prints. Chapter Four, on symmetry, relates symmetries as an integral aspect of the print medium, within Escher's work and within the nature of the world.

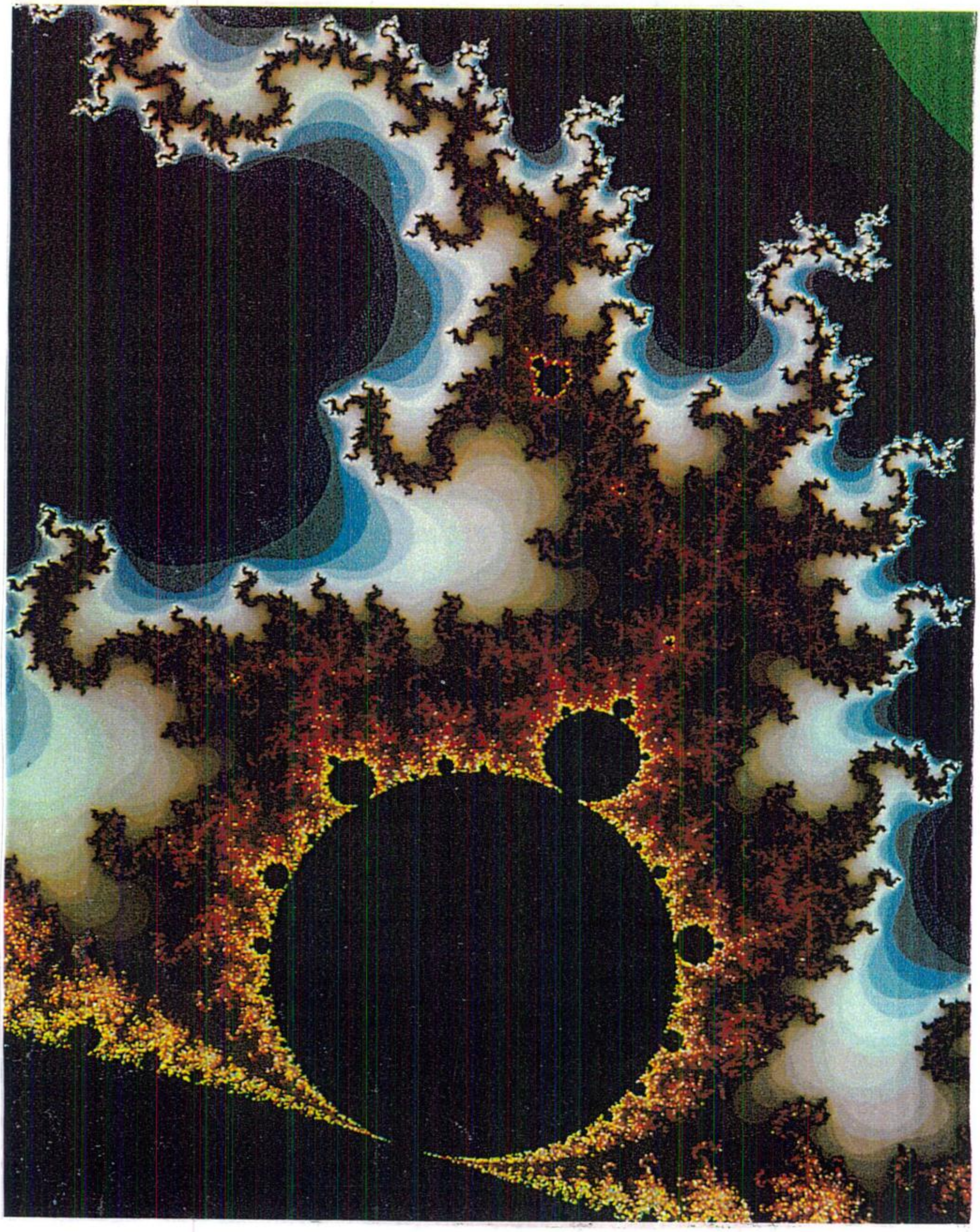
1. Art and Science in Italy: Recent Events, Leonardo, Vol.21, 1988, p.202

CHAPTER 1

NATURE OF PRINT PROCESSES: REPETITION, ORDER, CHAOS, FRACTALS

This chapter will outline the properties of print, such as the ability to state repeatedly a mark or image, the extreme of this being mechanical reproductive printmaking. The capacity to make a one-off spontaneous mark or image in print by changing or blending colours and using papers of various different weight or qualities also exists in print. The extreme of this is to make no two prints the same, thereby fetishising the 'originality' of each one. These aspects of printmaking can, and are, often seen as opposing rather than complementary properties. The uneasy relation between them has been the focus of many artists in their printwork, especially in the 1960s with artists like Roy Lichtenstein and Andy Warhol. This date coincides with the formal definition of the original print as a relatively new concept. In Vienna in 1960, The Third International Congress of Artists formed the basis of the regulations adopted in many countries. They decided that only the prints from a stone, plate or block, which the artists engraved themselves, could be considered as originals. These rules concerning the originality of prints varied from country to country. In France, for example, the National Committee of Engraving in 1965 excluded from their original print list any and all use of

mechanical or photomechanical processes. Nowadays, the concept of the original print is outmoded, as original prints and reproductions both have the same technology available to them. In this thesis I compare the concept of the 'original' and the 'reproductive' in print with the ancient tension between order and chaos, which is at once an ancient and a contemporary issue. Chaos theory, and the rise in the study of this area by chaologists, has led to the idea of a chaos revolution predicated on the many years of suppression suffered by chaotic concepts and systems. The prevalence of Euclidean geometry - the geometry of straight lines and shapes with a perfect symmetry - served to repress the irregularities present in everyday nature and concepts attached to them. Until now, any discoveries in mathematics or science of chaotic behaviour of diagrams were put aside and were considered aberrant. The rise of interest in chaos is linked to the work of the mathematician Benoit Mandelbrot. This Parisian mathematician was an IBM fellow, invited by the company to test their new equipment and discover its potential. Here he found academic freedom. He generated the set on a computer which was achieved by the iteration of a simple algorithim. It was called the Mandelbrot set and is fractal in nature. The fractal set was wholly unexpected to Mandelbrot; the images were intended as mathematical diagrams, drawn to make a scholarly point, but were also aesthetically beautiful in their own right. This set is a symbol for the chaos revolution and will be discussed in



1. Benoit Mandelbrot, The Mandelbrot Set (a detailed aspect) (1975).

more depth later in the chapter. The work on which I will focus will concern the printed images and their backup drawings by the Dutch artist M.C. Escher (1898-1972). His prints are non-Euclidean and deal with the themes of symbolic opposites, such as order and chaos. Escher's work provides an important link between science and art. In his periodic notebook of 1942, the artist had executed all of the possibilities of the polychromatic crystallographic groups before official crystallography had even thought of them, the official definition of which appeared in the scientific literature some fourteen years later. (MacGillavry, 1965, Introduction)

Dynamical systems can be simulated on computers, as in the Mandelbrot set. The resulting effect is a convoluted and intricate line representing the boundary line between two dynamic opposites, such as order and chaos. This line is, in theory, an infinite line as it is self-similar on all scales, and, in mathematical theory, a line has no thickness. This boundary represents a dynamic flux and has a sensitive dependence on initial conditions. Its results are, therefore, unpredictable. In studying a wide range of phenomena exhibiting a sensitive dependence on initial conditions, scientists across a range of disciplines describe chaos as a kind of order without periodicity or as apparently random behaviour in a simple deterministic (clockwork-like) system. An artist working his or her ideas through the printing process develops an

interdependent relationship with the process in order to achieve the outcome, a printed image. The resulting image is usually not predictable as the feedback from the medium influences the work's progress. It is usually a surprise to see the effect of the first proof of a stone, plate or block. In writing about the prints of M.C. Escher, I hope to illuminate some of the links between art and science. Escher's work was concerned with, for the large part, structures in nature, especially crystalline structures. The morphology of orderly systems interest Escher and to this effect a wide range of creatures inhabited his periodic drawings: starfish, crabs, fish, birds ... In his own words,

> No Moorish artist has, as far as I know, ever dared (nor did he hit on the idea?) to use as building components concrete, recognisable figures, borrowed from nature, such as fishes, birds, reptiles, or human beings. This is hardly believable because the recognisability of my own plane-filling elements not only makes them more fascinating, but this property is the very reason of my long and still continuing activity as a designer of periodic drawings. (Escher, 1983, p.9)

In the structure of his periodic prints Escher printed decidedly non-Euclidean forms. One reason this is so is there are the many specific points on the pictures' surface around which rotate Escher's motifs. These many points of attraction create a certain turbulence when viewing the print. This turbulence has been dubbed by modern mathematics as a strange attractor, but it has always interested great minds of the past. Leonardo's studies of turbulent motion are but one example. Water contains

vortices in which smaller and smaller vortices, subdivisions of the first, exist. Escher explains his attraction to this turbulence in the preface of the book Symmetry Aspects of M.C. Escher's Periodic Drawings:

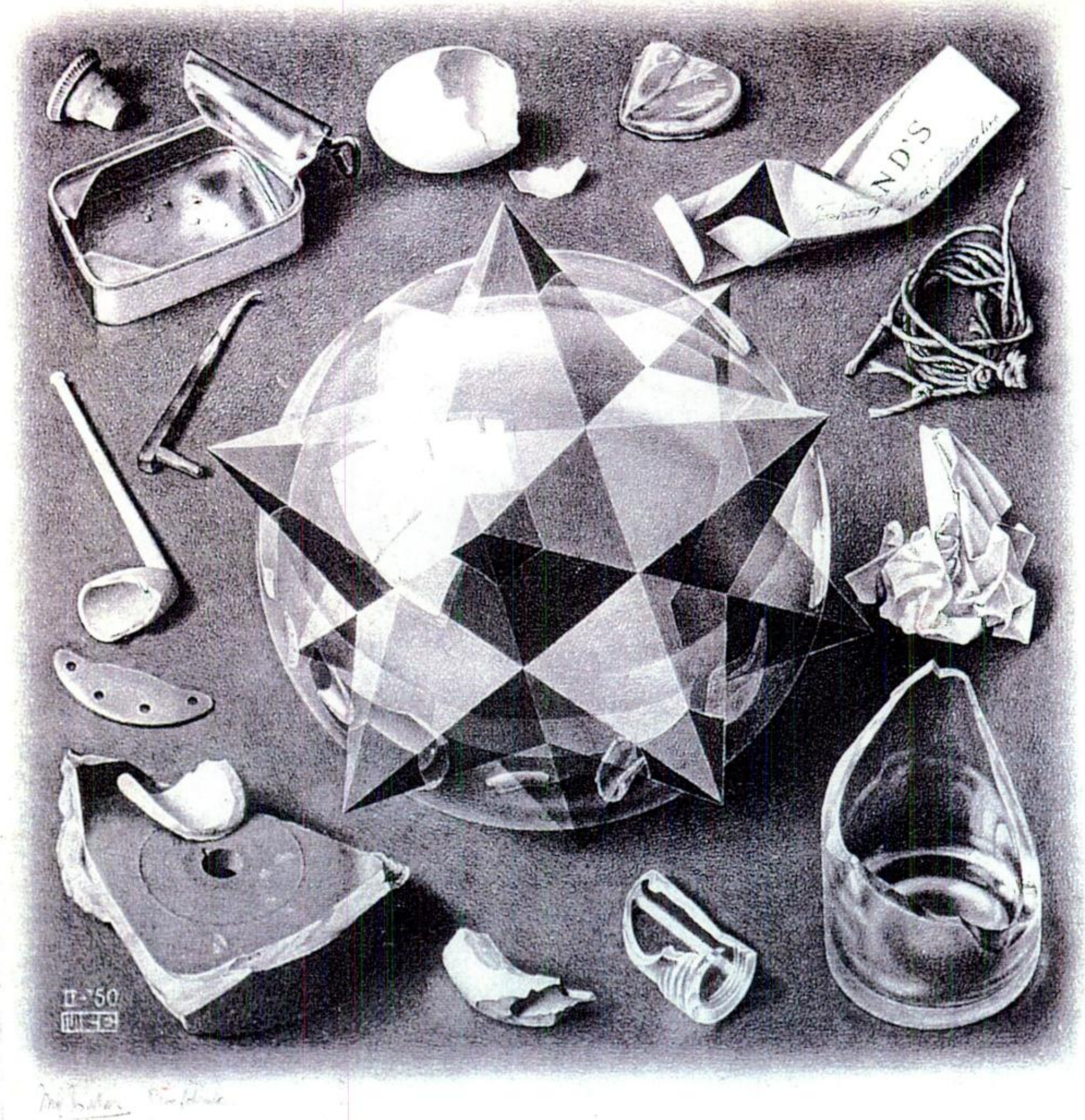
> The border line between two adjacent shapes having a double function, the act of tracing such a line is a complicated business. On either side of it, simultaneously, a recognisability takes shape. But the human eye and mind cannot be busy with two things at the same moment and so there must be a quick and continuous jumping from one side to the other. But this difficulty is perhaps the very moving spring of my perseverance. (Escher, 1965, Preface)

Escher, while being aware of living in a beautiful, ordered cosmos, felt a certain hopelessness and uncertainty in the face of human existence. For Escher, order was the preferred state and he related it to the repetition of units, in print and in time. Chaos, however, pervaded his life and he relates this to a multiplicity without rhythm. He felt alone in his garden of regular division and repetition. In 1948 he wrote a book about the regular division of the plane. 'What fascinates me and what I experience as beauty others evidently often judge to be dull and dry.' (Escher, 1986, p.141) Later in his life, after 1954, he acquired many admirers who became fascinated by his work. He tried to compensate in his work for the disappointments of his youth. The young Escher was a poor student with a tendency to illness; he had to repeat a grade twice and just barely passed school. He became a modern hermit, spending hours in his studio, not allowing any of his family to see a work until it was complete and he was satisfied with it. A shy, sensitive young man, he

was the son of a highly critical mother and a dominating father who once told Mauritis that his son produced wallpaper. While Escher strove towards order, asserting in his pocket calendar, 4 December 1958, 'We adore chaos because we love to produce order'. (Escher, 1988, p.141) In Escher on Escher, J.W. Vermeulen observed that Escher experienced a contradiction in life, between nature and the order on which it is based, and his personal feelings about the hopelessness of the human condition. Escher had many reasons for feeling this way; the fact that the Escher family had to move from Italy and the beautiful landscape which he loved because of the fascist dictatorship and the capturing of de Mesquita and his family, Escher's close friend and ex-tutor, by Nazi Germans are two examples of this. In January 1967, he wrote to Gerd Arntz, artist and colleague:

> The world we live in is a hopeless case. I myself prefer to abide in abstractions that have nothing to do with reality. (Escher, 1986, p.143)

The chaotic aspects of reality confused Escher. His first attempts to represent chaos are evident in a series of prints made around the 1950s, in which he opposes the dynamics of order and chaos. The print entitled Order and Chaos (1955) is a heavily symbolic rendering of this opposition in the lithographic medium. Order is represented by a large crystal shape in the centre of various discarded man-made refuse. Order takes a central, more prominent role in the composition of the print, whereas chaos encircles order and is scattered about the



2. M.C.Escher, Contrast (Order and Chaos), Lithograph (1950).

crystal towards the edges of the drawing on the lithographic stone. The title of the print, pulled from a lithography stone could also be seen as a reflection on the essence of lithography as this process uses the antipathy of matter, in this case oil and water, to achieve the end result, an edition of prints.

The theme order and chaos has historical resonance in many cultures, in which ancient peoples thought of order and chaos as an uneasy tension held in the balance. Chaos was, they believed, immense and creative, while order was produced in chaotic conditions. Cosmologies, commonly envisioned a primordial state where chaos pervaded, an abyss from which beings and forms burst forth. In one Chinese creation story Yin, a ray of pure light, jumps out of chaos and builds the sky, while the remaining Chinese, Yang, forms the earth. The principles of Yin and Yang are said to retain the chaos from which they sprang, too much Yin or Yang will bring it back.

The Biblical universe begins without form and void until God (order) comes along and begins to give structure to it in the form of creation. There ensues a continual struggle between chaos and order as Satan (a manifestation of the hydra-like chaos) continually raises his head. The belief that an order and chaos balance leads to cosmic creativity is not a new idea. The artist, William Blake 'deeply etched' into the notion of reciprocity between

order and chaos in his illustrated manuscript of 1790, The Marriage of Heaven and Hell. Carried out in the Etching medium, it comprises episodes, from one to six plates per episode. Its content deals with ethical and theological 'contraries'. Blake, in this study mocks the categorical techniques which seek to make the contraries appear as 'negations'. The marriage is a dialectical union and serves as a model for the dialectics of order and chaos.

Reductionist science changed the notion of a reciprocity between order and chaos by the suppression of chaos and the labelling of it as a formless, unimportant mess. Reductionist science is also called Euclidean science, named after Euclid the most prominent mathematician of antiquity. He was best known for his book Elements. Its influence has prevailed almost from the time of its writing to the present. Euclid flourished c.300 BC. He wrote many works in mathematics and it is said that, next to the Bible, the Elements may be the most translated, published and studied of all the books produced in the Western World. Reductionist science stored away chaos and chaotic concepts and focused on Euclidean geometry, the geometry of straight lines and shapes inherently containing symmetry. The old scientific concept of the balance of nature) is inexorably replaced by the new concept of the dynamic, creative and marvellously diversified chaos of nature. The new science is closely related to a new geometry, named fractal geometry by its founder, Benoit

Mandelbrot. This mathematician generated, on the computer screen a set which is the most famous object in modern mathematics. The Mandelbrot Set is a symbol for the chaos revolution and is a fertile testing ground for the science of non-linear dynamics. Fractal geometry's symbols are convoluted surfaces, folded non-linear shapes which mimic what is found in nature and in the world around us. Mandelbrot coined the term 'fractal' in 1975 in order to be able to give a title to his first essay on the topic. The shapes which he labelled as fractals in his mind all shared the property of being 'rough but self-similar'. These shapes could be also called non-Euclidean forms.

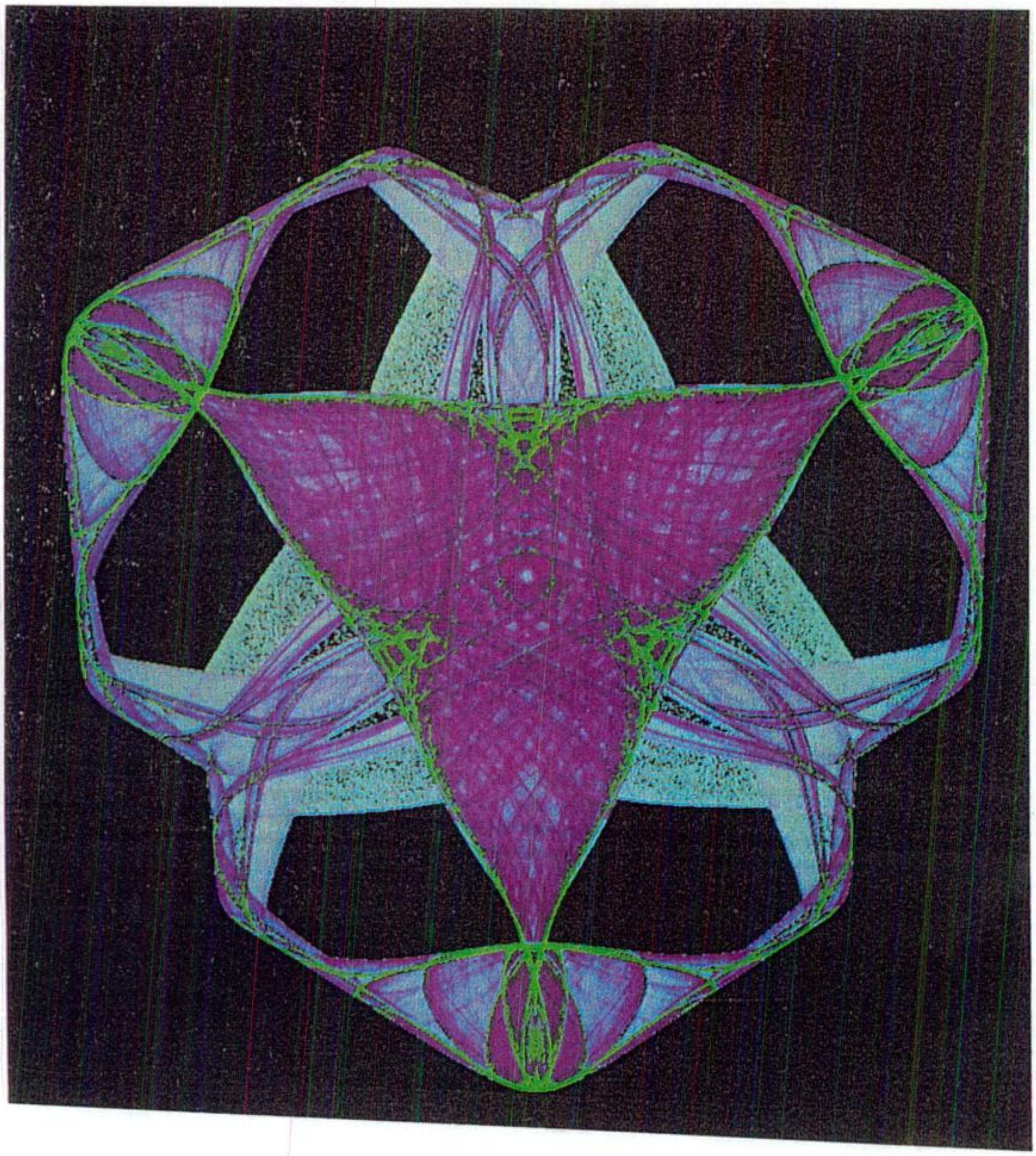
Escher was inspired to create his work, in response to the complex structures within the world around him. Escher was fascinated with the morphology of crystals. Mixing symmetry and chaos is nature, and art's common strategy in the creation of forms. This tension is the fuel which fires into existence forms such as snowflakes, starfish and even our own bodies, and it engenders a world that contains marvellous variety and self-similarity on many scales.

> Using simple mathematical rules chaologists can now model complex dynamical systems, formulating rules to mimic, on a computer, such natural phenomena as the flocking pattern of birds to a roosting spot and the growing branch and leaf forms of specific flowers and trees. Chaos theory and fractal geometry have opened up undreamed of correspondences between the abstract mental realm of mathematics and the movement and shapes of our planet's myriad organisms. (Briggs, 1992, p.39)

In <u>Symmetry in Chaos</u>, the two mathematicians, Martin

Golubitsky and Mike Field, collaborated on a study which included a number of diagrams that illustrate what happens on a computer screen when both a non-linear equation and symmetric instructions are entered simultaneously and iterated. By introducing a slightly different equation each time, the result will vary considerably. These pictures, or computer print-outs, show what might happen when a fluid is poured onto a solid container. The dynamical motion, a turbulence, is mimicked by lines on the screen a simulation of what the fluid might look like at a specific moment in time. All chaotic systems are sensitively dependent on their initial conditions. 'Our pictures mixing symmetry with complicated dynamics impose a regularity that was hard to imagine in advance.' (Briggs, 1992, p.95)

The popularity of fractals among scientists, artists and the general public is reflected in an independent research company called Art Matrix. This was set up in 1983 by mathematicians, John Hubbard and Homer Smith. It grew out of a collaborative venture between the two, and was based at Cornell University, New York. John Hubbard proved one very important theorem about the Mandelbrot Set. It was a whollistic theorem and claimed that all the mini Mandelbrot figures folded into the boundary are mathematically connected. This research group consequently sold half a million postcards and countless videos of the Mandelbrot Set in motion. The cover of the Scientific



3. Field and Golubitsky, An Image of Symmetric Chaos (1992).

American magazine 1985 narrated the collaboration between Benoit Mandelbrot, Heinz-Otto Peitgen and John Hubbard. The response to this article was phenomenal - thousands of readers requested to have the set on their walls. Friendly rivalry resulted to see who could come up with the most interesting and aesthetically pleasing. The set had become a magnet for artists, scientists, mathematicians, even school children were interested. I believe this is because fractal geometry moves away from quantitative measurement and embraces the qualities of things such as texture, complexity and wholistic patterning (that is, patterning at various scales). This is a new way of appreciating, a revived way of looking and processing what we see.

Strange Attractors; Patterns of Chaos (1989), an exhibition organised by Klaus Ottoman explored the fractal revolution taking place in art which manifests itself in fractalist 'activity' rather than any particular style or movement. He believes fractalist art is a mirror of the psychological and social state of society, concerned with the experience of fractalisation. To 'spot' signs of fractalist art, Ottoman says to watch for three, or one of three, attributes of fractals: scaling, self-similarity and randomness. While fractal printouts from computers will never replace the individual artist's intention and expression, fractal qualities of self-similarity and simultaneous order/chaos seem to reveal something important about the nature of art. Perhaps they serve to link art

and science in a new way. The fractal qualities are important to printmaking in particular. Because a fractal is a simulated boundary between two forces, it is the all-important or fundamental link between them. It is a fertile and constantly fluctuating dividing line, but a boundary nonetheless. The two extremes in printmaking - mechanical reproductive printing and the original or fine art print - were once seen as being part of a whole system, until the invention of photography. This, happening in the middle of the nineteenth century split print into distinctive and somewhat hostile camps, one 'fine art' and the other 'commercial'. This is because photography, combined with screenprint or offset lithography, enabled the image to be mechanically reproduced an indefinite number of times. Engravers who wished to sustain the status of artist had long-standing reasons for wishing to disassociate their work from reproductive work, which was then held in low regard. Printers' relatively low standing had been highlighted in England by the attitude of the Royal Academy. On its foundation in 1768, it admitted all but one engraver, Francesco Bartolozzi and labelled him as a painter. In 1812 a committee was set up to investigate the inferior position held by engravers in the Academy. It concluded that engraving was wholly devoid of those intellectual qualities of invention and composition which painting, sculpture and architecture so eminently possess, its greatest praise consisting in translating, with as little loss as possible, the original arts of design. It

was not until 1928 that the Academy eventually accepted engravers on an equal basis as painters and sculptors. The effects of this bifurcation of print are still evident. Fractal geometry teaches us, with imagery, something our ancestors once knew instinctively, that order and chaos exist as a holistic fluctuating system. Print and its many applications, fine art and otherwise, are linked and cannot exist any other way. The embracing of this link, which is fractal, and therefore complex, will lead to a greater comprehension of the diversity of print concepts in the future.

CHAPTER 2

INFINITY

This chapter will discuss the historical concept of infiniteness and its essential links with time and dimensions in the universe; secondly, it will focus on Escher's approaches to infinity through the medium of printmaking. The concept of infinity is intangible; it is contained in, and mirrored from, our minds. As human beings we can never experience infinity. We can only attempt to imagine it. Our imagination is inimical to the idea of nothing, that is why we clutch at chimeric ideas of an afterlife and a rebirth, all of which would be endless in time or eternal in space. Escher philosophised about a putative experience of 'infiniteness': "Deep, deep infinity! Rest, dreaming removed from the nervous tensions of daily life; sailing over a calm sea on the bow of a ship, toward a horizon that always recedes." (Escher, 1986) There have been many attempts by artists, philosophers and scientists to understand and to use the concept of infinity on the basis that it is woven into the structure of the universe. In A Brief History of Time, the scientist Stephen Hawking highlights some important longstanding questions about the universe. They are simple questions to which we still, as yet, do not have the answers. What we do know about the universe and how do we know it? Did it have a beginning and, if so, what happened

before then? What is the nature of time and will it ever come to an end? These questions, although apparently simple, are intrinsically linked to the human never-ending quest for knowledge and explanation. As a graphic artist, it was Escher's desire to depict an infinite universe through his work; he ultimately wanted to capture infinity on the two-dimensional plane. To this effect, Escher presented his periodic drawings as a fragment of an infinite periodic tessellation, a three-dimensional reality. One cannot, however, have an infinitely extended surface on which to print this fragment in its entirety. During the war years, when Escher found it difficult to concentrate on the conceptual side of his work, he carved some wooden spheres covered with periodic repetitions, Carved Beachball with Fish, where interlocking fish motifs are carved into the surface of the ball is one example, Angels and Devils is another. If the wooden sphere is turned repeatedly in one's hands it will give the impression of never-endingness. Escher considered this solution as cheating because the same fish arise again and again. To achieve the impossible task of capturing infinity on the two dimensional plane Escher then used motifs which diminished in size toward the centre, called "o" in mathematical terms, giving the illusion of a three dimensional space on a two dimensional plane. The notion of a two dimensional space is also an illusion as no surface is completely flat in our three dimensional world. The print Path of Life I gives the impression of looking

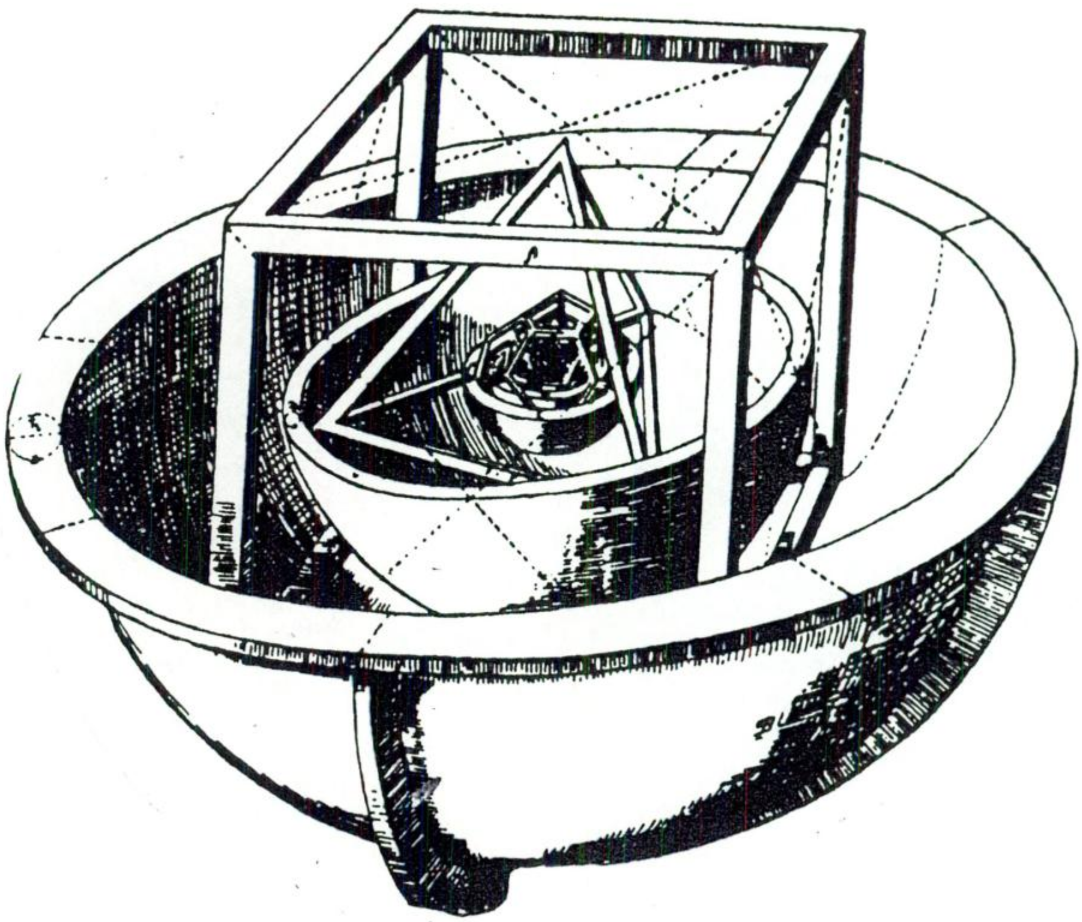
4. M.C. Escher, <u>Carved Stained Beachball with Fish Motifs</u> (1940).

5. M.C. Escher, Path of Life I, Woodcut (1958).

down an infinitely long cylinder coated inside with a periodic repetition of fish motifs. Escher combines non-Euclidean geometry with woodblock printing to achieve a depiction of the concept of infiniteness. The fish alternate from black to red to white and red and swirl, following concentric rings, which evoke a mandala effect. This tunnel, or passage, is particularly effective in its depiction of infiniteness, as if it were a time tunnel or vortex into which we are drawn.

In 340 BC, the Greek philosopher Aristotle, in his book <u>On the Heavens</u>, put two arguments forward to prove that the earth was round. First, he realised that eclipses of the moon were a result of the casting of earth's shadow on it, as this shadow was always round, it followed that so too must the earth be. Secondly, the Greeks knew from their travels that the North Star appeared lower in the sky when viewed in the South that it did in more northerly regions. The Greeks also had a third argument, for why else do you see the sails of a ship coming over the horizon before the hull? Aristotle believed for mystical reasons that the earth was the centre of the universe and all other planets followed a circular path around it. This idea was elaborated upon in the second century AD by Ptolemy who formed a complete cosmological model. The earth stood at the centre surrounded by eight spheres that carried the moon, the sun, the stars and the five planets known at the time, Mercury, Venus, Mars, Jupiter and Saturn. His model was generally, although not universally accepted. It was

adopted by the Christian Church for it had the great advantage of leaving room outside the sphere of fixed stars for Heaven and Hell. In 1514, Nicholas Copernicus, a Polish priest, produced a simpler model which he circulated anonymously for fear of being branded a heretic by his church. This model proposed that the sun was stationary at the centre and that all the planets moved around it in circular motion. This idea was not taken seriously until nearly a century later. Two astronomers, the Italian, Galileo Galilei, and the German, Johannes Kepler, publicly supported the Copernicus theory. Sir Isaac Newton's Philosophiae Naturalis Principia Mathematica (1687) is probably the most important single work ever published in the physical sciences. The work posited a theory of how bodies move in space and time, developed the mathematics needed to analyse these motions and postulated a low of universal gravitation. Newton then showed according to his law how gravity causes the moon to follow in an elliptical orbit around the earth, and the planets to follow elliptical orbits around the sun. He also realised that since the stars attract each other, they could not remain motionless, and they may one day all fall together or collapse. According to Hawking, in a letter in 1961 to Richard Bentley, "Newton argued that this would indeed happen if there were only a finite number of stars distributed over a finite region of space. But he reasoned that if, on the other hand, there were an infinite number of stars distributed more or less uniformly over infinite



6. Kepler, Johannes, Kepler's Universe (1601)

space, this would not happen because there would not be any central point for them to fall to." (Hawking, 1988, p.5).

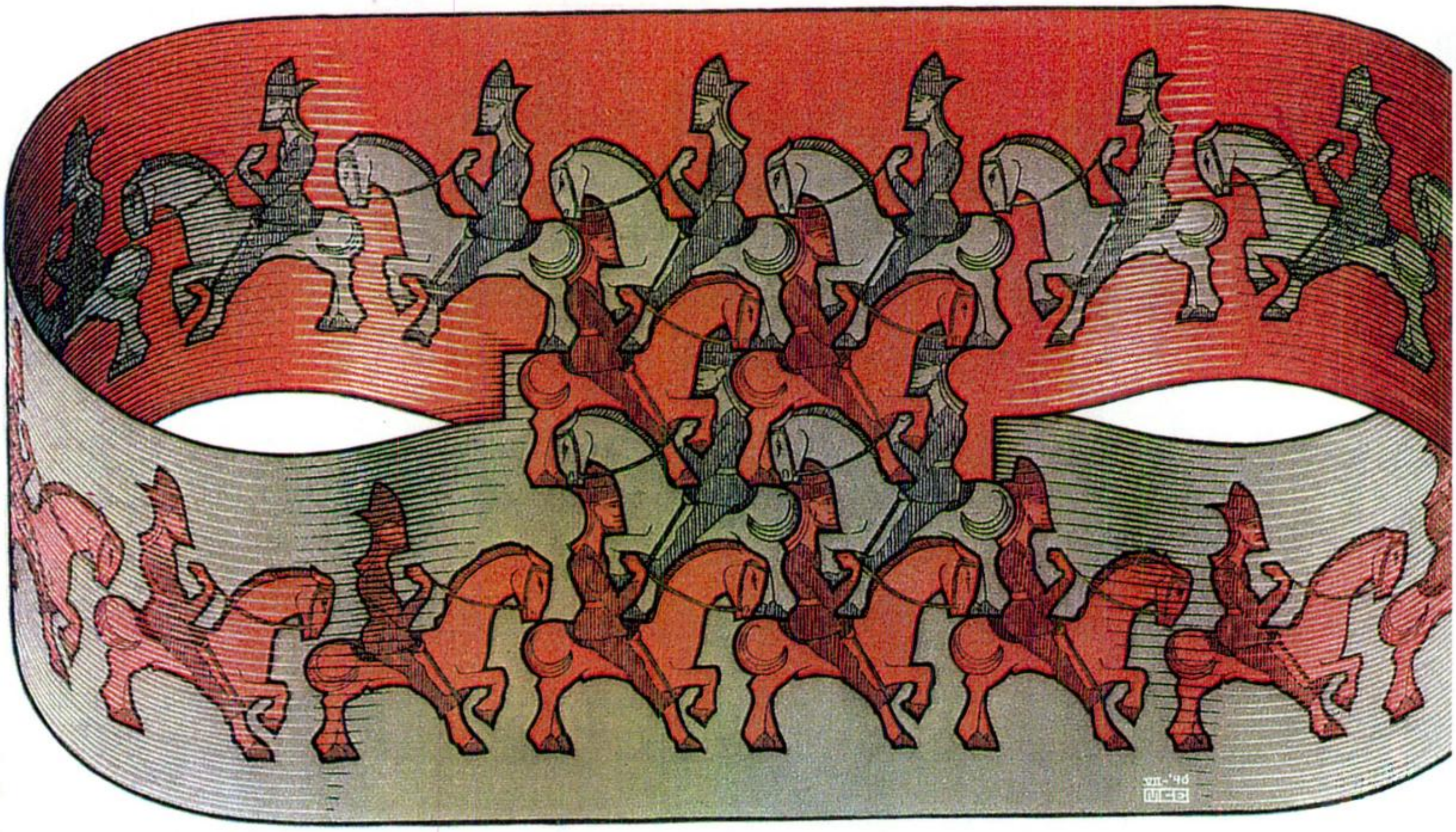
In an infinite universe every point can be described as the centre, because every point has an infinite number of stars on each side of it. Today, however, scientists know that it is impossible to have an infinite static model of the universe. Perhaps Escher makes a more resolved depiction of what he believes to be an intrinsically infinite universe by taking the conceptual approach and communicating infiniteness through the repetition of a figure. If infiniteness is something humans can only imagine, then it is an intangible concept which can probably only be approximated through the medium of the concept.

There have been various arguments objecting to the notion of an infinite static universe, leading to a recent belief that the universe is slowly expanding with time. According to a number of early cosmologies (Christian, Jewish, Muslim ...) the universe began as a finite, not too distant time in the past. St. Augustine accepted a date of about five hundred BC for the creation of the universe, according to the Book of Genesis. Aristotle and other Greek philosophers repudiated the idea of creation, believing instead that the human race and world had existed, and would exist, forever. In 1929, when Edwin Hubble discovered that the universe was expanding, the

question of whether or not it had a beginning shifted its concerns away from the metaphysical or theological realm to the scientific. Did the universe have a beginning, and through time, will it eventually end?

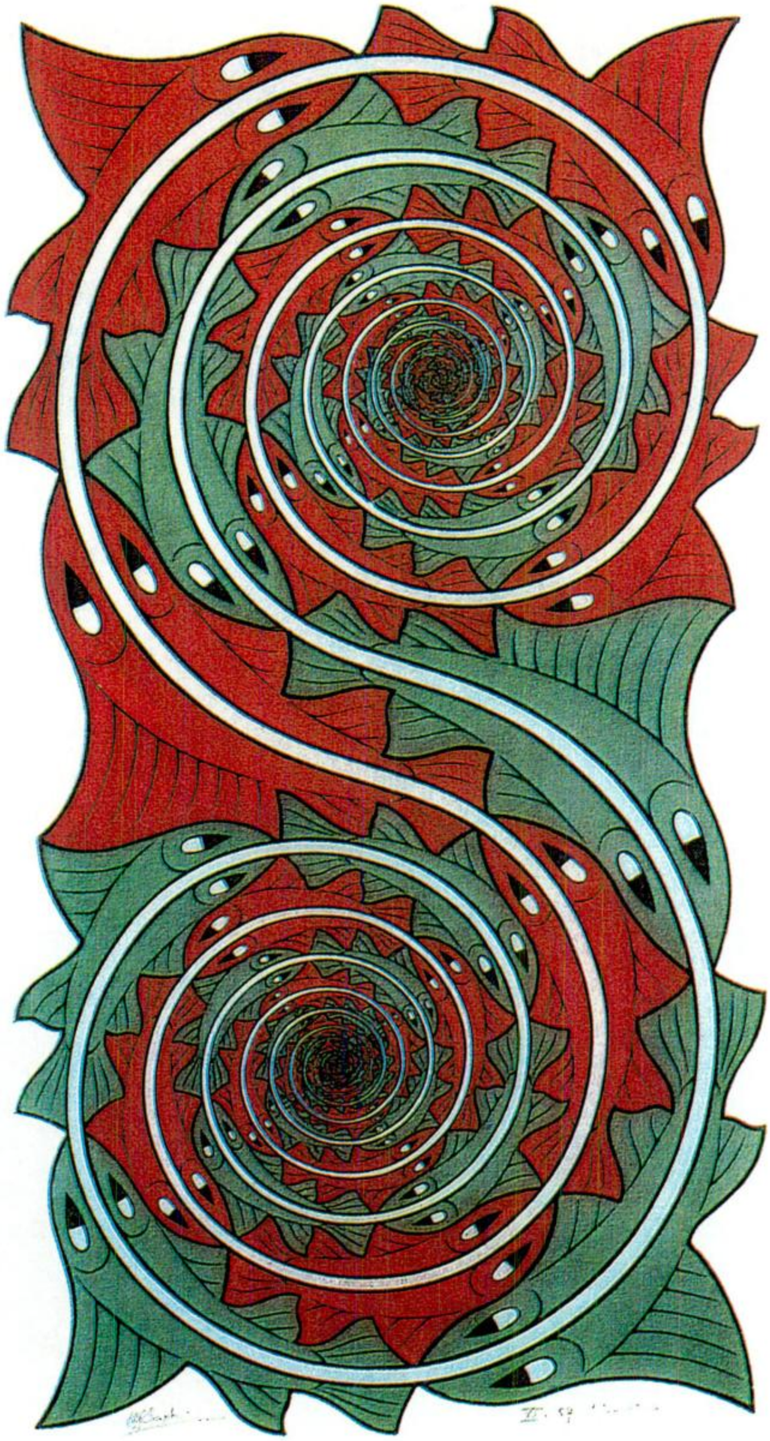
In a three colour woodcut of 1946 entitled Horseman, Escher successfully captures a sense of the continual flowing of time. By taking his regular division drawing of the same name as a starting point, the artist printed on the surface of the paper the illusion of a closed circuit. Within this twisted circuit the horsemen move in procession on both sides of what is seemingly a fabric or bendable plastic. Each side is the opposite, colourwise, to the other; red and grey are interwoven. The horsemen, in the print, break out of their initial central periodic drawing to begin their procession in which there is only one direction. This notion of time passing continually recurs in Escher's work, some examples being Development I, Path of Life I, and Whirlpools. Ever conscious of the preciousness of his own time, Escher wrote of his own work in his essay 'Approaches to Infinity', "He [the artist] must divide his universe into distances of specific length, in compartments that repeat themselves in endless series at every border crossing between compartment and the next, his clock ticks." (Escher, 1986, p.123)

Escher, thus, presented time as having circular or cyclic qualities, one could say iterative qualities. In



7. M.C. Escher, Horseman, Woodcut (1946).

the structuring of his infinity prints, he used geometric spirals and arcs, and rotated a figure around a central point in the plane. A geometric transformation in the plane which simply scales the figure is called a similarity. Spiral paths of similar figures can be obtained by rotating a motif around a pivot while simultaneously shrinking it, then repeating the transformation again and again, this is called spiral similarity. Even though Escher did not get to grips with the abstractions of mathematics, he instinctively used this method in his work. Escher also used central similarity, as in the print <u>Path of Life I</u>. In this work fish motifs shrink in size along lines which radiate from the centre. In 1957 he made a pair of designs for a mural with the theme of life passage. It was around the same time that he made the print <u>Whirlpools</u>. This print is a double spiral containing fish motifs. Each fish is born in the eye of the whirlpool and follows a coiled path outwards increasing in size, then follows a spiral path in the opposite direction towards the vortex of the second whirlpool. This while conveying on illusion of infiniteness in the presentation of an interdependent system in motion also alludes to initial and final states of life; birth in the eye of one whirlpool follows with death in the eye of another. There is a rotational technique employed in the printing of the woodcut whereby Escher skilfully carved one block to print the two colours. Simply by rotating the block 180 degrees and reprinting it, the two impressions



8. M.C. Escher, Whirlpools, Woodcut (1957).

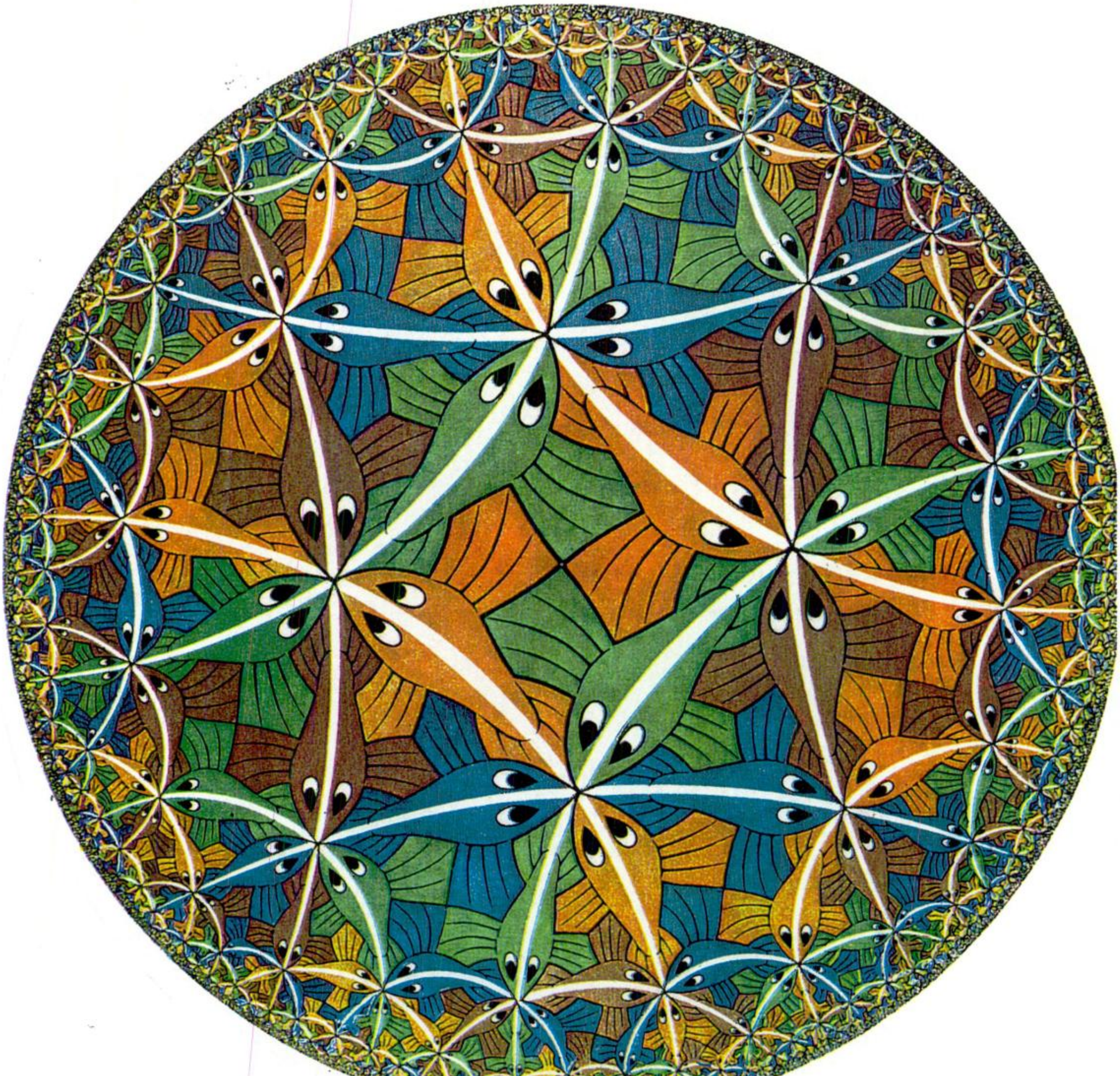
neatly interlocked to form the print. This, I think gives the effect of a turbulent, yet predetermined, system in motion. Scientists and mathematicians have realised that turbulence, an integral part of nature is an aspect in the formation of and in the workings of most dynamical systems. These systems range from the weather system, to the motion of water, to the way an organism evolves. In the book Turbulent Mirror scientists David F. Peat and John Briggs, illuminate on Chaos theory and the emerging science of wholeness. They talk about Leonardo da Vinci's early studies of turbulent motion of water and how, in doing so, he noticed how vortices tend to fragment into smaller and smaller vortices. They assign a new scientific name to turbulence, that is, strange attractor, and this is, simply put, a broken-up attractor.

> The notion of vortices within vortices ad-infinitum suggests that systems close to turbulence will look similar to themselves at smaller and smaller scales - suggesting again, that strange attractor of turbulence is a mirror world.
> (Briggs and Peat, 1989, p.49)

Briggs and Peat assert that there is evidence to show that in a system this is a sign of that system's infinitely deep interconnectedness or of its wholeness. In Whirlpools where Escher represents an interlocking system which visually expresses this strange attractor, which has been subject of a great interest to many leading thinkers of their day in the past.

All of Escher's life-passage prints employed a compositional structure of whirling a motif, which follows

a path and diminishes in size. Escher sought to depict an opposite progression, to depict motifs increasing endlessly in number from the centre outward while decreasing in size to approach an infinite number of points on the boundary of an enclosed region. In 1957, about the same time as Escher's life-passage prints, the artist came across a mathematical article by H.S.M. Coxeter. (Visions of Symmetry, p.25) This article was on the topic of periodic tessellation of a hyperbolic plane and it included diagrams to illustrate the various points. The diagram was a tiling of black and white triangles on a hyperbolic plane. Escher, by studying these diagrams, took in the visual information he needed to construct his own hyperbolic tessellation. He learned how to construct the various arcs within the circle which would function as the scaffolding for his images. In the next two years he produced a series of prints which were his own approach to infinity through hyperbolic tessellation. These prints include four separate prints, entitled, Circle Limit I, II, III,and IV. Coxeter later sent Escher a copy of the article to thank him for giving him permission to reproduce two of his prints to illustrate the article. Two articles written by Coxeter are devoted to Escher's work: Angels and Devils and The Non-Euclidean Symmetry of Escher's Picture 'Circle Limit III' (Visions of Symmetry, p.251) These articles tell a story of their correspondence and include a mathematical analysis of them. The Circle-limit prints allude to an infiniteness composed of interdependence as



9. M.C. Escher, Circle Limit III, Woodcut (1959).

figures of contrasting shades interlock and move together. They are kaleidoscopic images in which invisible mirrors refract and crystallise the figures into a harmonious union. This notion of something being self-similar on all scales is a key fractal idea. 'Mandelbrot argued that in order to appreciate how the points, lines, planes and solids of the real world fill space, the Euclidean idea of distance (and measure) must be abandoned.' (Briggs, 1992, p.64) Escher used non-Euclidean methods such as scaling, self-similarity and non-linearity in his prints in the 1950s before Mandelbrot coined the term fractal or even wrote about it, and Escher, to my knowledge, was not even aware of Mandelbrot's work. Mandelbrot was inspired toward this area in mathematics and computers by the work of mathematicians, including the German, Karl Weierstrass; the Italian, Guiseppe Peans; and the German, Helge von Koch. These men shocked their colleagues by creating curved lines that convoluted in such a way that they could entirely cover the surface of a plane. To clarify the term, curved lines, I should explain that mathematicians call any line with a bend in it, a curve. These curved lines were called monster curves as they generated confusion as to whether they were to remain lines or be classified as a two-dimensional place. In effect, they occupied the space between dimensions. One monster curve entitled the Hilbert Curve is generated by starting with a simple figure. Next, the same figure is applied to its own three sides. Then one iterates the figure several more times, applying it to

itself, as above, and watches the space fill. The iteration of the Hilbert curve can theoretically be carried out indefinitely until the curve crosses every point on the place without crossing itself; remember a line has no breadth in mathematical theory. Hence the ambiguity. Does this curve remain a line or become a plane? The problem was put aside along with other monsters, such as the Cantor set, until the 1960s when Mandelbrot realised their potential. He saw that these shapes broke the traditional view of dimension by elegantly existing somewhere in between. Escher too, was uncomfortable with traditional views on dimension. He believed that in our world of three dimensions neither a reality of two or four could exist. He continually tried to give the illusion of three dimensional space in his works on paper while all the time realising that there can be no reality of a two dimensional space. This is something that made him continue working as an artist.

To conclude this chapter I stress the inseparability of art and science, the work of M.C. Escher is an prime example of how an artist can work conceptually in tandem with a scientific question, such as the depiction or description of the infinite universe. Stephen Hawking says that the eventual goal of science is to invent a theory that describes the whole universe. Today scientists describe the universe in terms of two basic partial theories: the general theory of relativity and quantum

mechanics. These two theories are known to be inconsistent with one another, hence the continuing search. Escher too wanted to, in a visual printed image, resolve the concept of an infinite universe. According to Hawking, 'Since the dawn of civilisation, people have not been content to see events as unconnected and inexplicable. They have craved an understanding of the underlying order of the world. Today we still yearn to know why we are here and where we came from.' (Hawking, 1998, p.13)

CHAPTER 3

POSITIVE, NEGATIVE; A TECHNICAL AND AESTHETIC DISCUSSION OF PRINTMAKING

This chapter comprises two parts: a selectively brief, historical, technical and aesthetic survey of the art of the print beginning in China, where paper was invented, leading to the development of a surface ready to accept a printed impression; and an examination of the prints of M.C. Escher, whose predilection for contrast of black and white is paralleled by his high regard for dual concepts in thought. According to Escher:

> Good cannot exist without evil, and if one accepts the notion of God then, on the other hand, one must postulate a devil likewise. This is a balance. This duality is my life. Yet I am told that this cannot be so. People promptly start waxing obtuse over this sort of thing, and pretty soon I can't follow them any further. Yet it really is very simple: white and black, day and night - the graphic lives on these. (Escher, 1986, p.17)

Escher here uses the term 'graphic artist' to describe the printmaker. In his acceptance speech upon receiving the Culture Prize of the City of Hilversum on 5 March 1965, Escher said, 'I am a graphic artist with heart and soul, but the rating "artist" makes me feel a little embarrassed'. Perhaps this is because Escher felt he had little in common with his contemporaries. The reason for Escher's understanding of the importance of contrasts could be a result of his working mainly in the print medium.

In The Art of the Print, Fritz Eichenberg, the printmaker and writer, stresses the great importance of woodblock printing throughout history:

> The woodcut deserves perhaps the most honoured place in the history of the print, since it is the most ancient, the most direct and, by virtue of its great simplicity, easily the most democratic medium of graphic multiplication and artistic expression. The woodblock print is the descendant of the earliest graven images. The process of cutting into a piece of stone, or carving a relief into a temple wall practised thousands of years ago, required essentially the same skill necessary for the cutting of a wood block. (Eichenberg, 1978, p.68)

In AD 105, paper was apparently invented in China. It was not long before the first prints on paper came about. Before this, however, there were proto-signs of dualistic properties at play produced in the form of seals, rubbings or stencil processes. The word 'yin', Chinese for seal, can also stand for any impression on any surface from clay to paper.

It was in the Buddhist cave colony of Tun-huang in Chinese Turkistan (founded AD. 366) that the greatest printed treasures were found by Sir Aurel Stein in 1907. The treasures included some thousands of well-preserved printed scrolls, printed mostly for devotional purposes. One of the most famous of these is the Diamond Sutra which was dedicated for universal distribution by Wang Chieh to perpetuate the memory of his parents. Others had printed on them thousands of images of Buddha. One seventeen-foot long scroll, which is now preserved in the British Museum, had four hundred and eighty impressions of the same image

of the Buddha. These images would have been stamped by hand until a more effective technique was employed. By placing the inked block on a flat surface with the paper on top, and rubbing the back of the paper, a better quality print was pulled from the block.

In fact, China subsequently became the home of the largest printing and publishing ventures in the world. The first known cutting of images into wood for the purpose of printing took place during the T'ang Dynasty (AD 618-906). T'ang Dynasty's early Emperors were enlightened patrons of the arts and literature. During this timespan, books on magic, religious tracts and a gazette, The Kai-Yuan, were published.

Woodcuts entered the homes of simple everyday people in the middle ages, facilitated by the availability of paper in the West. The prints which were widely distributed among their houses, were carved anonymously and printed on single sheets of paper. Most of them had been designed to serve the purpose of warding off disease, death, fire or robbery, and depicted images of popular patron saints. These prints would be pasted on the insides of suitcases, cabinet doors, trunks, travelling chests or wardrobes (Eichenberg, 1976, p.76). In this instance the print served as a protector or comforter of people's fears and anxieties about the unknown, what might happen in the future to them or their families. It is interesting to

note at this point that playing cards and tarot cards, commonly used to divine the future, were then printed from woodblocks and hand coloured, using stencils. Early prints expressed a growing excitement over expanding technical possibilities within the medium. Various unusual methods were employed in early Japanese prints. Experimental approaches in print media have been employed throughout history up to the present day. The adaption of an experimental approach to print, or simply being open to trying out something different, can result in the adaption and development of new techniques, for the benefit of the process.

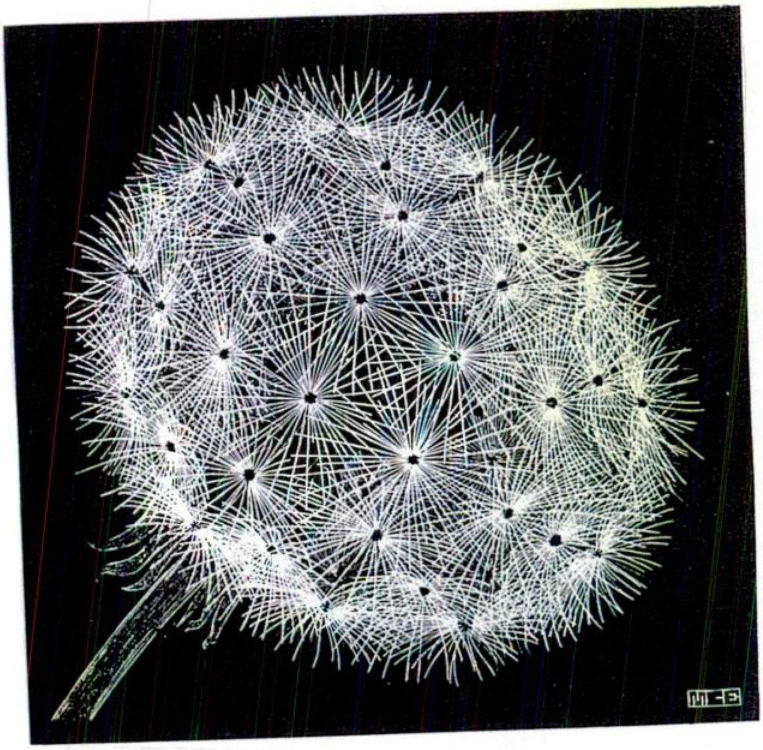
Some of the early Japanese techniques include: *Kirasuri*, printing or stamping with powdered mica instead of ink; *Gofunzuri*, printing with white opaque ink on paper coated with mica; *Karaguri* or *Gauffrage*, printing with uninked woodblocks to achieve an embossed surface, today commonly referred to as blind emboss; and *Fuki-e*, a process by which ink was sprayed through stencils. These methods express the basic properties of printmaking at an embryonic stage. Stamping with powdered mica on white paper, for example, produces a positive print, mica being dark in colour. In contrast, printing white opaque ink on mica-covered paper or *Gofunzuri* prints an image in the negative. Contrasts are the fundamental properties of print. An interesting method employed by early Japanese printmakers is *Gyotaku*, which translates as fish-print. It is a

variation of the rubbing technique and can be applied to any deep relief object's surface. The indirect method of this technique involves laying the wet paper onto the surface of the object, allowing it to indent around its contours, and rubbing a crayon onto the raised areas. The direct method would result in a mirror image of the indirect method; it involves inking the surface of the object and laying down paper on top, and rubbing the back to achieve a lasting impression. The third type of *Gyotaku* is an extension of the direct method. When the print is pulled in the direct version of the technique it is then transferred, or offset, onto a second piece of paper with the use of contact, then pressure. This offset print is again a mirror image of the original print from the inked surface. These methods embody the primitive, but essential, aspects of printmaking, a constantly expanding medium that continually branches to reveal itself in new ways.

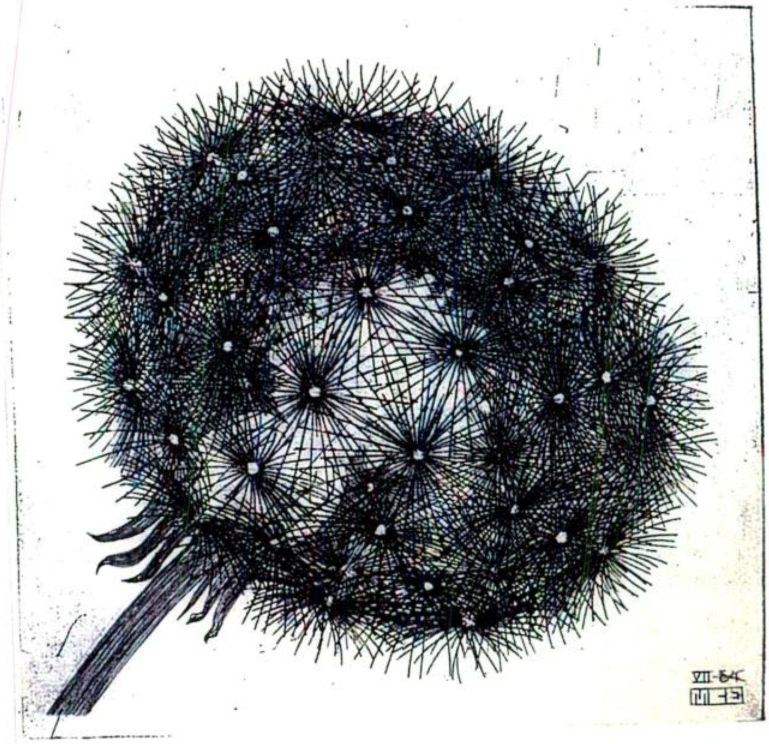
From the explanations given of these simple printmaking techniques, it should be evident that print mediums are primarily concerning surfaces. 'To handle a beautiful piece of wood is sheer sensual delight, to cut into its surface a never ending adventure, to search for its hidden qualities always exciting.' (Eichenberg, 1976, p.130) Different surfaces result in varying results. The ink must be transferred from the woodblock's surface to the paper's. Should the ink sit on the peaks of the

woodblock's plane, resulting in a relief print, or should it bleed only into the wood's crevices and knots, and then be printed in the intaglio method? Escher's woodblock Blowball has been printed in these two versions, both intaglio and relief. The resulting impressions, laid side by side, resemble exact opposites - one is white where there is black on the other. A surface is a record of events that have happened at a specific time or events that are in progress. Paper's surface is the result of a process whereby pulp from plants or trees is laid out in a particular fashion to dry. When dry, it can then be treated or bleached to make it white. This paper is ready to be used in whatever way a person wishes to use it. It is a surface which can take an impression from another surface. It will then record this particular action by keeping a trace, or an impression of, this unique moment of contact. When this detail is recorded on the page, the surface will never be exactly the same again. A surface is a fractal, because it is a boundary between what is inside and what is outside, what one hides and what one reveals.

During his time studying at the Haarlem School of Architecture, Escher was greatly influenced by his print teacher, Samuel Jesserun de Mesquita. When he left the college, as a mark of respect, he always kept a photo of his old tutor pinned to a cupboard door in his studio. Escher, when he tried out a new print or new concept and was pleased with the result, would send de Mesquita a print



10. M.C. Escher, <u>Blowball</u>, Wood engraving (1959).



10(b)M.C. Escher, <u>Blowball</u>, Printed in intaglio method (1959)

from the block. They respected each other's work. De Mesquita was enchanted by the technical possibilities of printmaking and passed on his knowledge to interested students. One basic possibility was, of course, the print and its offset, or mirror, image and the yin/yang relationship between block and print. In The Magic Mirror of M.C. Escher, Bruno Ernst concludes that a certain duality underlies the whole of Escher's character:

> Over against the intellectuality of his work and the meticulous care that goes into the planning of it, there is the great spontaneity of his enjoyment of nature's beauty, of the most ordinary events of life, and of music and literature. He was very sensitive and his reactions were emotional rather than intellectual. (Ernst, 1985, p.17)

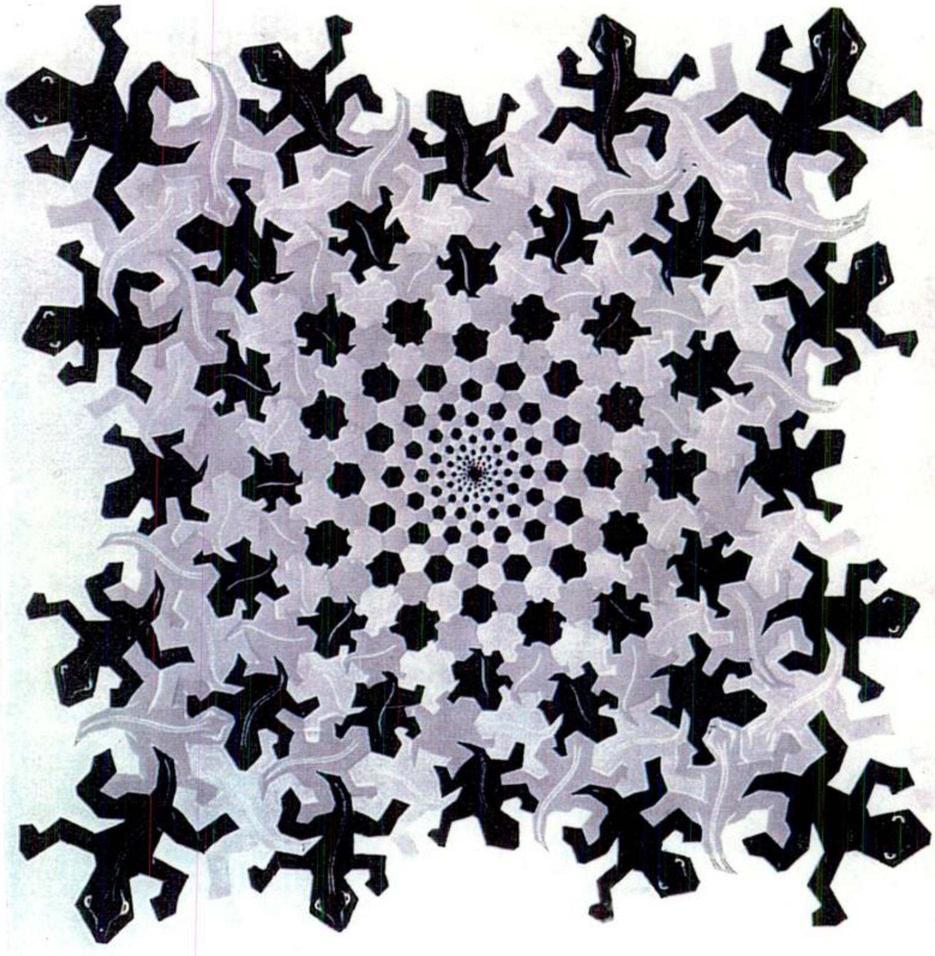
In the book Escher on Escher Exploring the Infinite, Escher writes about the importance of contrasts in life: 'We human beings are always after contrast, and without contrast in a more general sense, life is impossible on our solid ball of earth, which revolving around its axis, floats so happily through infinite space in spite of all human blunders' (Escher, 1986, p.16). He realises that no image, form, shade or colour can exist alone, and that among everything that is visually observable, we can refer only to relationships and contrasts. When observing a print hanging on the wall our eyes take in the visual information lights, darks and colours on the picture's plane. The interplay of complementary and contrasting colour and tone keeps our eyes interested and keeps us looking. This experience is akin to that turbulent motion or strange attractor mentioned in Chapter 1.

The significance of dualistic concepts have puzzled great minds throughout history. The beauty and strangeness of nature provided chief inspiration for Charles Darwin, as he struggled to develop a coherent theory of evolution. According to psychologist, Howard Gruber, who studied Darwin's methods at length, 'The meaning of his whole creative life work is saturated with ... duality'. He postulated that, on the one hand, Darwin wanted to face squarely, nature's entire panorama in its amazing variety of colour and form by embracing its irregularities and imperfections. On the other hand, Darwin was 'imbued' with the spirit of Newtonian science and hoped that within nature's shimmering network of life forms he would discover a few simple laws in which to explain it (Briggs, 1992, p.38). It was within the nature of the world around him that Escher found his inspiration. Escher's periodic tessellations, symmetrically packed, with similar figures, structurally reflected the morphology of crystals. His use of rotation around a point in the plane, mimicked the whorls in certain flowers and several of his prints are based on the structure of the double helix. The DNA molecule, a double helix structure, was discovered in 1953 by scientists Watson, Crick, Franklin and Williams (Anne Griswold Tyne, 1978, p.89).

Development II (1939) is an example of one woodblock print structured around the bands of a double helix. The format of this print is square and its colours include

green-grey, brown, black and the white paper. It was printed from three wood blocks, one for each colour, that interlocked exactly when printed. The print is a periodic tessellation of frog motifs with rotational symmetry and scaling. The darkest frogs spiral upwards and outwards toward us from the centre of the whorl. The lighter frogs glide in a rotational fashion downward and toward the centre of the whorl; they spiral at a more acute angle and seem, therefore, to do so at an increased velocity. There are also brown frogs which could also be classed as 'grey' as they are 'between' lightest and darkest. The double spiral structure of this print is polemical. I call it a double spiral, although there are three paths of frogs, because it has an imaginary top and bottom; the vanishing point or point of rotation and the boundary of the edges of the print. It is loosely reminiscent of the DNA structure: one band coiling upward and inversely one band coiling downward, both intertwined. It is interesting to recollect at this point that Escher described his interlocking motifs as building blocks for life: '... concrete, recognisable figures, borrowed from nature, such as fishes, birds, reptiles or human beings.' (Escher, 1965, Preface). A Double-helix structure was used by Leonardo da Vinci in his notebooks. One of these sketches included a design for a double-helix staircase - the stairs would intertwine but never meet.

> It was Leonardo, whose sketch of a double helix stairs inspired the Chambord stairs. It is particularly fascinating in light of Leonardo's profound interest and research in natural forms and human anatomy, that

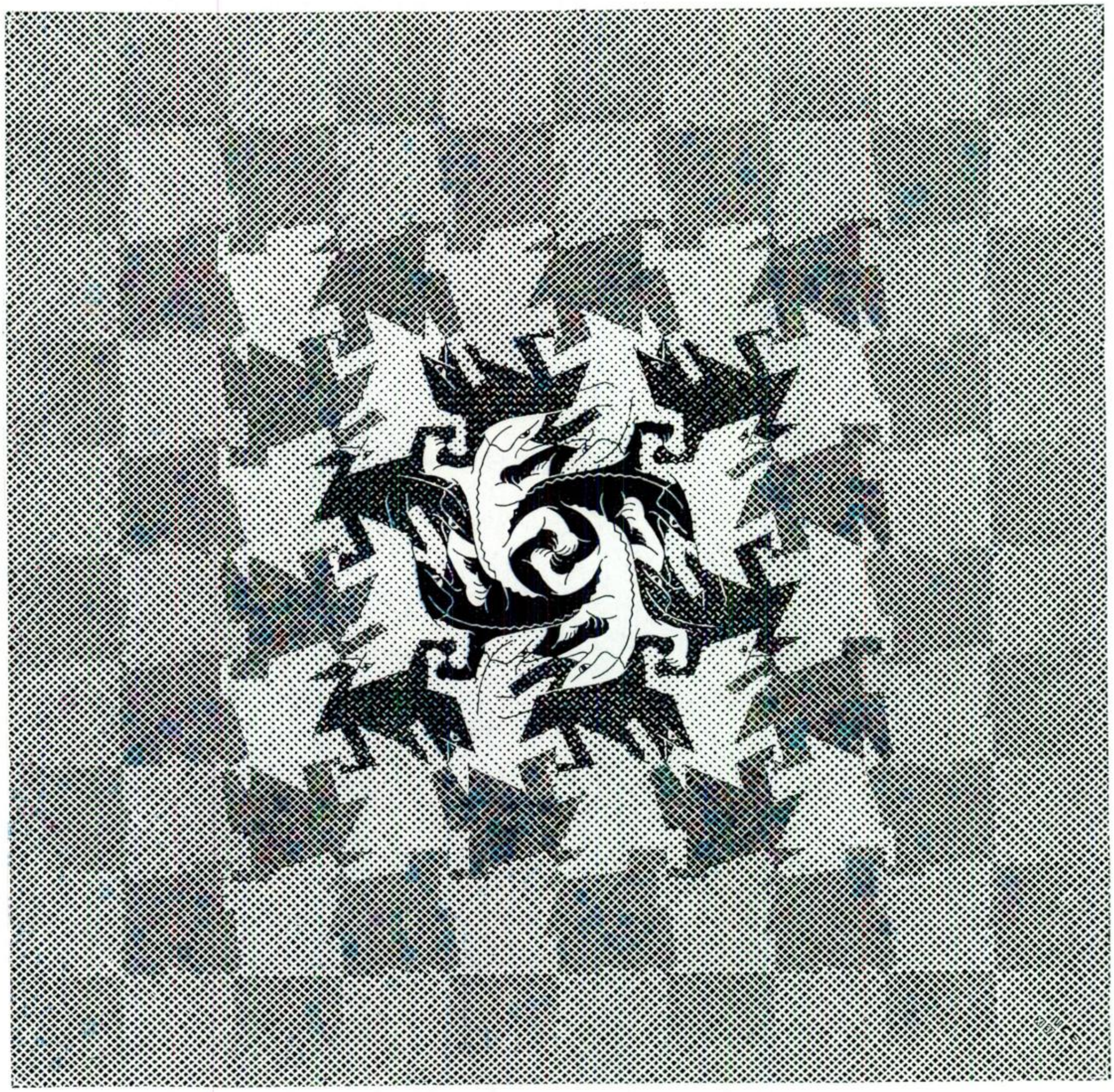


11. M.C. Escher, Development II, Woodcut (1939).

> his intuitive leap into the geometry of the double helix prefigures the discovery of the double helix structure of the DNA molecule in 1953.
> (Anne Griswold Tyne, 1978, p.89)

Like Leonardo's staircase, Escher's frog motifs never meet because they are harmoniously interwoven just like the order of the double-helix. The effect this print gives is of looking through a squared-off eyepiece into a vortex or whirling mass. It is reminiscent of the ariel phenomena of creature storms which have been continually recorded from AD 200-1973. These storms consist of various creatures, frogs and toads being most common, falling from the sky. The common theory for these reported, strange phenomena is that a whirlwind sucked them up and deposited them elsewhere (Hitching, 1978, p.195-6). We are not sure if these creature storms are accurate descriptions of something that really happened. They do, at least, exist in people's minds and have been recorded in writing. To imagine looking up through a swirling mass of these creatures, I feel, is akin to thoughts evoked by reading Escher's print <u>Development II</u>.

The woodblock print <u>Development I</u> (1937) by Escher clearly visually expresses his predilection for contrast. Its square-format has grey checks all around the edges. These become more distinct, as creatures with arms, legs and a tail as they progress toward the centre, where shapeless ground has totally vanished and figures replace it. The figures are four lizards, interlocked, two white, two black. The fact that the lizards take a central role



12. M.C. Escher, Development I, Woodcut (1937).

emphasises their importance in the overall picture. They have been born from the greyness and, therefore, contain fundamental aspects of it, black and white, in equal amounts. At the time when Escher made this print, he was aware of an experimental study by psychologist, Molly R. Harrower. In April of 1936 she published an article entitled 'Some Factors Determining Figure Ground Articulation' in The British Journal of Psychology. According to Marrianne L. Teuber, in her article in Scientific American (1974), Escher was influenced by Harrower's work. In his essay White-Grey-Black, Escher relates the creation of a print to the creation story in the Book of Genesis in which creation begins with the separation of emptiness and substance. If you exchange these two opposites with the words black and white, you have the creation of a printed image - without colour of course. 'Isn't it really an utterly illogical way of acting to start from the one extreme at our disposal: the white paper? Wouldn't it be more valid, at least theoretically, to take the average between the two extremes as starting point: that is, paper in a shade of grey?' (Escher, 1986, p.17). In this chapter I have sought to establish the inseparability of medium and concept.

CHAPTER 4

ON SYMMETRY

> The dynamic action of making symmetric tessellation is done more or less unconsciously. While drawing I sometimes feel as if I were a spiritual medium controlled by the creatures which I am conjuring up. It is as if they themselves decide on the shape in which they choose to appear. They take little account of my critical opinion during their birth and I cannot much influence on the measure of their development. They usually are very difficult and obstinate creatures. (Escher, 1965, Preface)

There has been a considerable amount of theory written about symmetry, some of it in overtly mathematical language. Much has been published in order to explain the term itself. The broad usage of the word symmetry, connotes a sense of harmonious balance in individual figures or sets of figures. Geometrical symmetry in individual figures or sets of figures is the narrowly defined usage of the word. There are so many different kinds of symmetry, in fact, that it is almost impossible to give an all-inclusive definition of the word. For this reason, care must be taken when trying to make the notion precise. It is quite natural for a printmaker to be fascinated by symmetrical arrangements of images, as symmetry is integral to print media. Almost all print forms embody the ability to be repeatedly printed while also allowing for the position of the image to be altered and overprinted. This may be done sequentially, resulting in a pattern or rotationally, around a point in the plane.

There is also the ability to offset in printmaking; meaning an image can be transferred, using ink, to a second surface before being stamped onto the paper. In commercial printing, this technique is widely used. The first roller picks up the reverse image and the second transfers it to the paper. The result is a print in the same, rather than in the reverse, direction as the plate. The most basic symmetry is concerned with an object on a plane, and its mirror image translated through a line on the plane. All symmetries of the 2D plane require an axis, point or plane in which to translate through, rotate around or spiral tirelessly about in helical motion. Escher frequently used symmetries in his work. Symmetry is a phenomenon of space and time, therefore, relating to Escher's concepts of infinity. This urge to capture the infinite led him toward the mapping of periodic tessellations and ever closer to the field of crystallography. In 1935, Escher came into contact with crystallographic theories and then realised that his periodic drawings were based on rules that had been scientifically investigated. This scientific text, being almost incomprehensible to Escher led him to form his own layman's theory in 1942 on the subject.

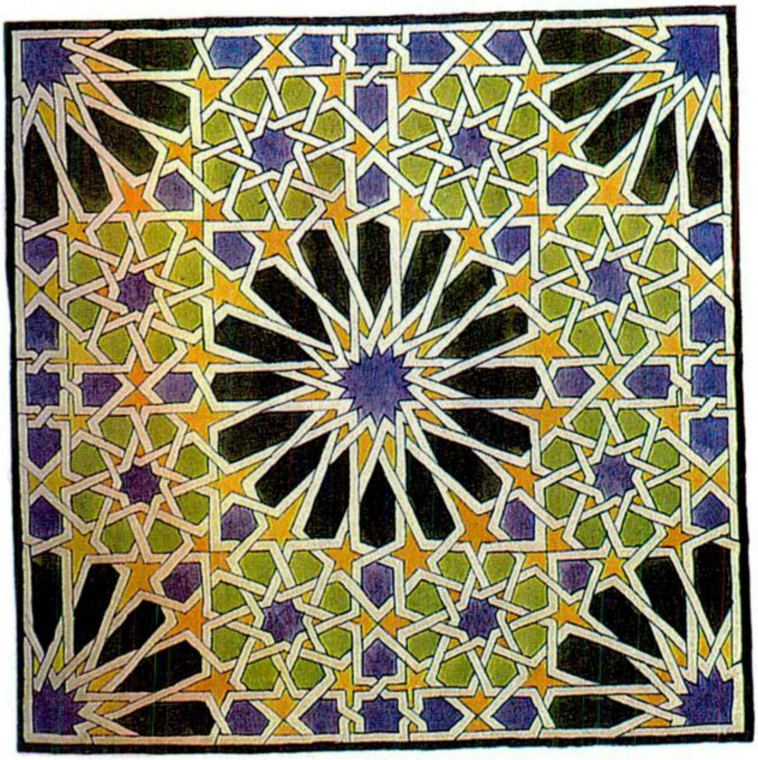
In 1922, Escher made his first visit to the Alhambra in Spain. This is where he came into contact with the Moorish mosaic patterns that were to have great impact on his work. Escher was intrigued by these mosaics, especially because there were no gaps between the abstract

figures of the tiles. In 1936, he made a second visit to the Alhambra and, on this occasion, he made many watercolour and pencil sketches of the mosaics on graph paper. By studying these designs he gained increased insight into how to construct his own symmetric tessellations. The abstract figures in the Moorish plane fillings evoked in Escher's mind figures with animated features. They reminded him of people, starfish, birds. The visit to the Alhambra, coupled with Escher's departure from Italy, resulted in a change of direction in the artist's work dated about 1936. When speaking about his post-1936 prints, he says that they were created with a view to communicating a specific line of thought.

> The ideas that are basic to them often bear witness to amazement and wonder at the laws of nature which operate in the world around us. He who wonders discovers that this is in itself a wonder. By keenly confronting the enigmas that surround us, and by considering and analysing the observations that I had made, I ended up in the domain of mathematics. (Escher, 1959, p.55)

The Moors were strictly forbidden by their religion to depict living forms. Their Second Commandment prohibited the use of any likeness of anything that is in the heaven above or the water under the earth. This restriction enabled the depiction of many symmetry groups without the added confusion of figurative shapes. In art, as in science, this laying down of restriction often creates a possibility of new and unexpected discoveries.

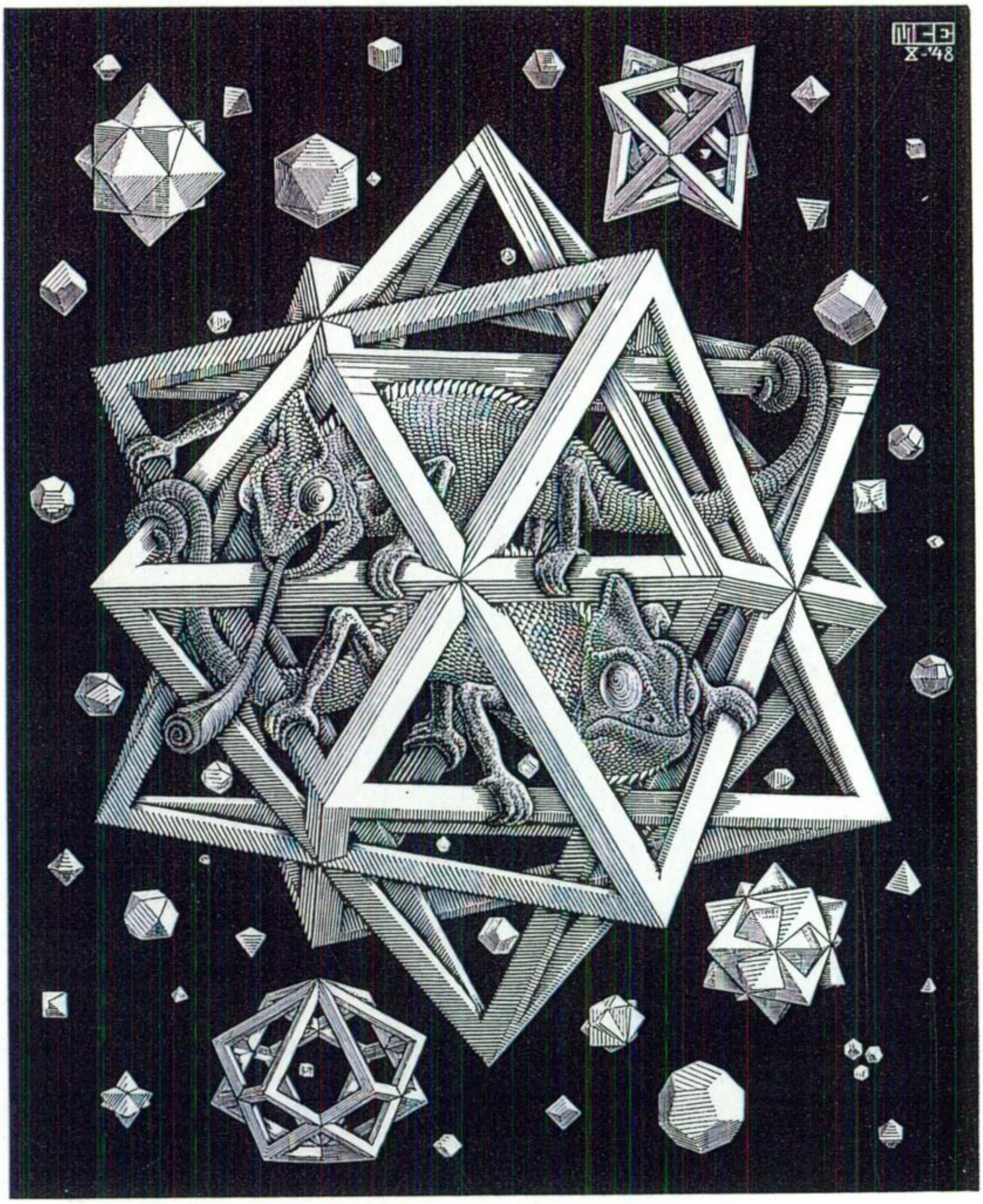
There are certain three dimensional shapes, in our



13. M.C. Escher, Mural Mosaic in the Alhambra, Pencil and watercolour on graph paper (1922).

world that fit together, closely packed without any space between them. They are called regular polyhedrons in mathematical language - regular, because they fit exactly together, while polyhedron simply means a solid with many sides. There are five of these regular polyhedra: a regular tetrahedron, a cube, a regular octahedron, a regular dodecahedron and a regular icosahedron. These regular polyhedra abound in geometrical symmetry. It is thought that Pythagoras was the first to discover these solids. He kept one, the regular dodecahedron with its twelve pentagonal faces, a secret. The pentagons that make up the regular dodecahedron are embellished with the mystique of the golden ratio. Plato, a pupil of the Pythagorean school, believed this shape was the shape of the external shape of the Universe. He figured that the four other solids were symbols of the four elements: fire - the tetrahedron, earth - the cube, air - the octahedron, and water - the icosahedron. Kepler, an astronomer of early modern times, admired Plato's theories. He constructed his own model of the Universe, in which the six planets known at the time were determined by the circumscribed and inscribed spheres of the five regular polyhedron. This image of Kepler's Universe is a prime example of a Euclidean vision of a clockwork-like universe.

In Escher's print from a woodblock entitled Stars, 1948, the artist gives visual expression to the concept of an underlying order in the universe. The print's plane is

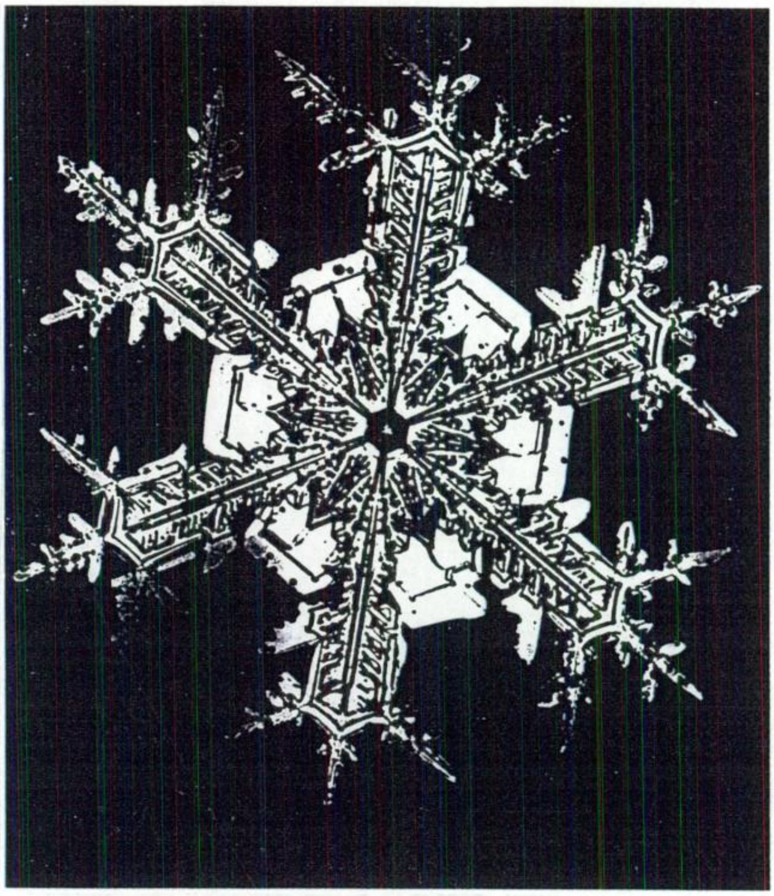


14. M.C. Escher, Stars, Woodcut (1948).

black, signifying emptiness or infinite space. Suspended between the nothingness are crystalline shapes, peeping in and out, made up of regular polyhedra. The largest, and closest, is a framework made up of three octahedron. The cage is inhabited by two chameleon-type creatures, one facing left, the other right, floating through imaginary space. The print Stars is a more chaotic and scattered picture of the Universe than Kepler's Universe. In it Escher combines organic chameleons with geometrical Platonic solids. This combination, organic and inorganic, was frequently used by the artist as a driving force in his work. The idea of mixing symmetry and chaos has been explored by mathematicians, Mike Field and Martin Golubitsky in their book, Symmetry in Chaos (1992). The book was published following their research into the generation of computer images which were a combination of symmetry and chaos.

> In our mathematics research we study how symmetry and dynamics co-exist. This study has led to the pictures of symmetric chaos that we present throughout this book; indeed we have two purposes in writing this book: to present these pictures and to present the idea of symmetry and chaos - as they are used by mathematicians - that are needed to understand how these pictures are formed ... One of our goals of this book is to present these pictures of symmetric chaos because we find them beautiful. (Field and Golubitsky, 1992, p.vii)

The construction or morphology of these computer images is in accordance with the formation of a snow crystal. The hexagonal structure of the single ice molecule grows at its unstable boundary by attracting other water molecules. Its erratic flight path and its encounter



15. W. Bentley, A Snowflake, (1962)

with temperature and humidity effect its pattern as it begins to develop with one tip or another picking up molecules from the air. A competition between instability at the crystal's boundary and the stability of the surface tension across its growing mass amplifies the crystal's microscopic preference to grow symmetrically in six directions at once. Constantly changing conditions result in no two snowflakes being the same, while each one retains its essential hexagonal structure. Crystallographic structure and morphology greatly intrigued Escher, who once said:

> Long before there were men on this globe all the crystals grew within the earth's crust ... There is something breathtaking about the basic laws of crystals. They are in no sense a discovery of the human mind; they just 'are' - they exist quite independently of us. The most that man can do is to become aware in a moment of clarity, that they are there, and take cognizance of them. (Escher, 1959, p.93)

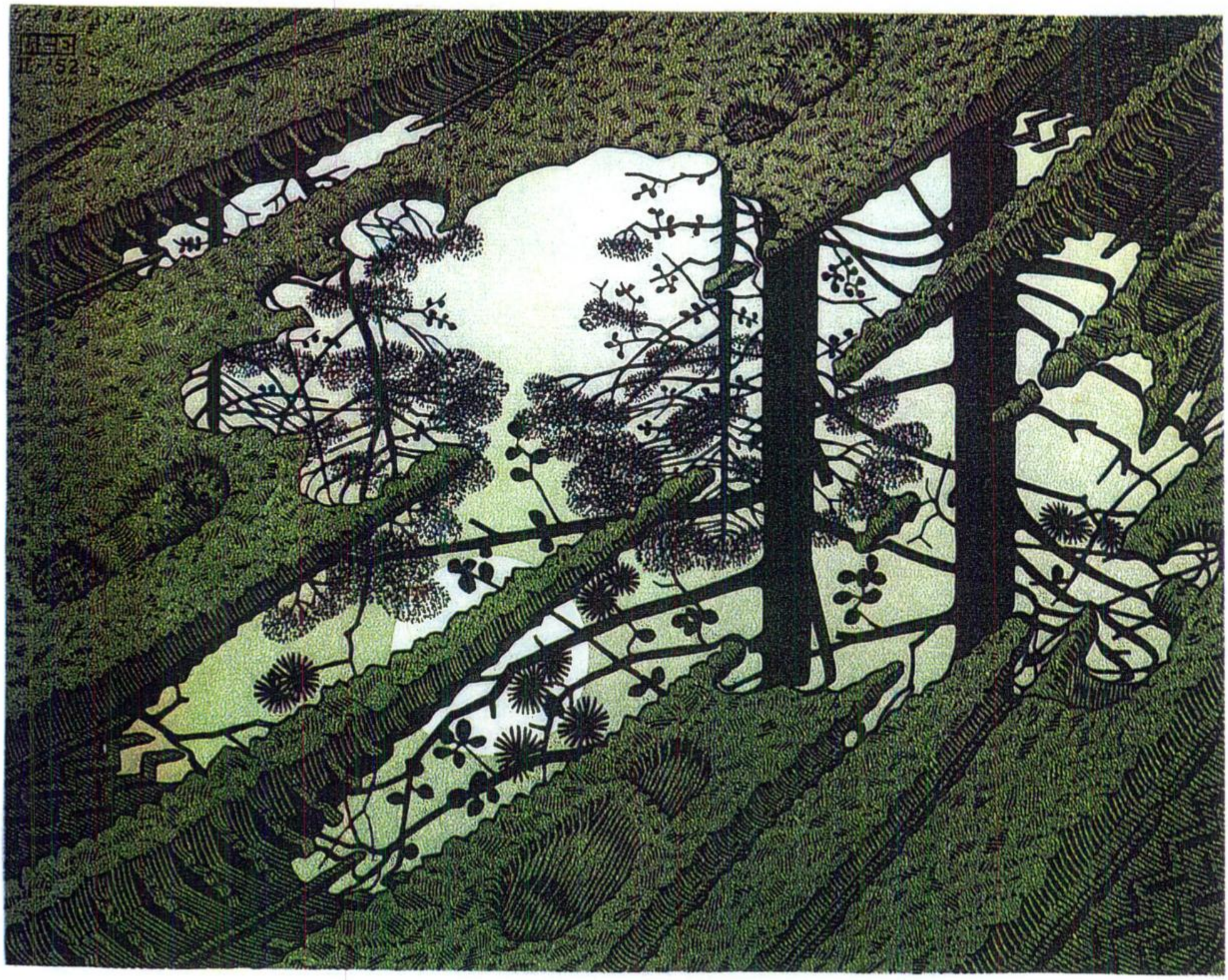
Close-packing is an underlying aspect of crystallography and is similar to the regular division of the plane. A crystal is made up of identical congruent figures, or atoms. A symmetric tessellation is made of alike or congruent figures; it is a jigsaw with identical pieces. These identical pieces can be turned back to front or flipped over. The transformation that relates to two congruent figures is called an isometry. There are two types of isometry. A direct isometry is either a translation or a rotation. An opposite isometry is either a reflection or a glide-reflection. The isometries that transform a whole pattern into itself are called the

symmetry operations of the pattern. A glide reflection is similar to the relation between two successive footprints on a straight snowy path. In Escher's print Puddle (1952) he depicts, in the woodcut medium, footprints on a muddy ground through a puddle. These footprints are glide-reflections.

Within the cosmos and in nature, all around us symmetry's laws are in operation. In life forms and their complex variations in pattern, colour, motions and mysterious habitats, symmetry is less sharply defined. In living forms symmetry is manifested in four different ways: bilateral symmetry, rotational symmetry, spiral symmetry and helical symmetry. These are combined in different ways to form cycles, resulting in variations in life. One example is the early development of human form by Anne Griswold Tyng in her essay Seeing Order.

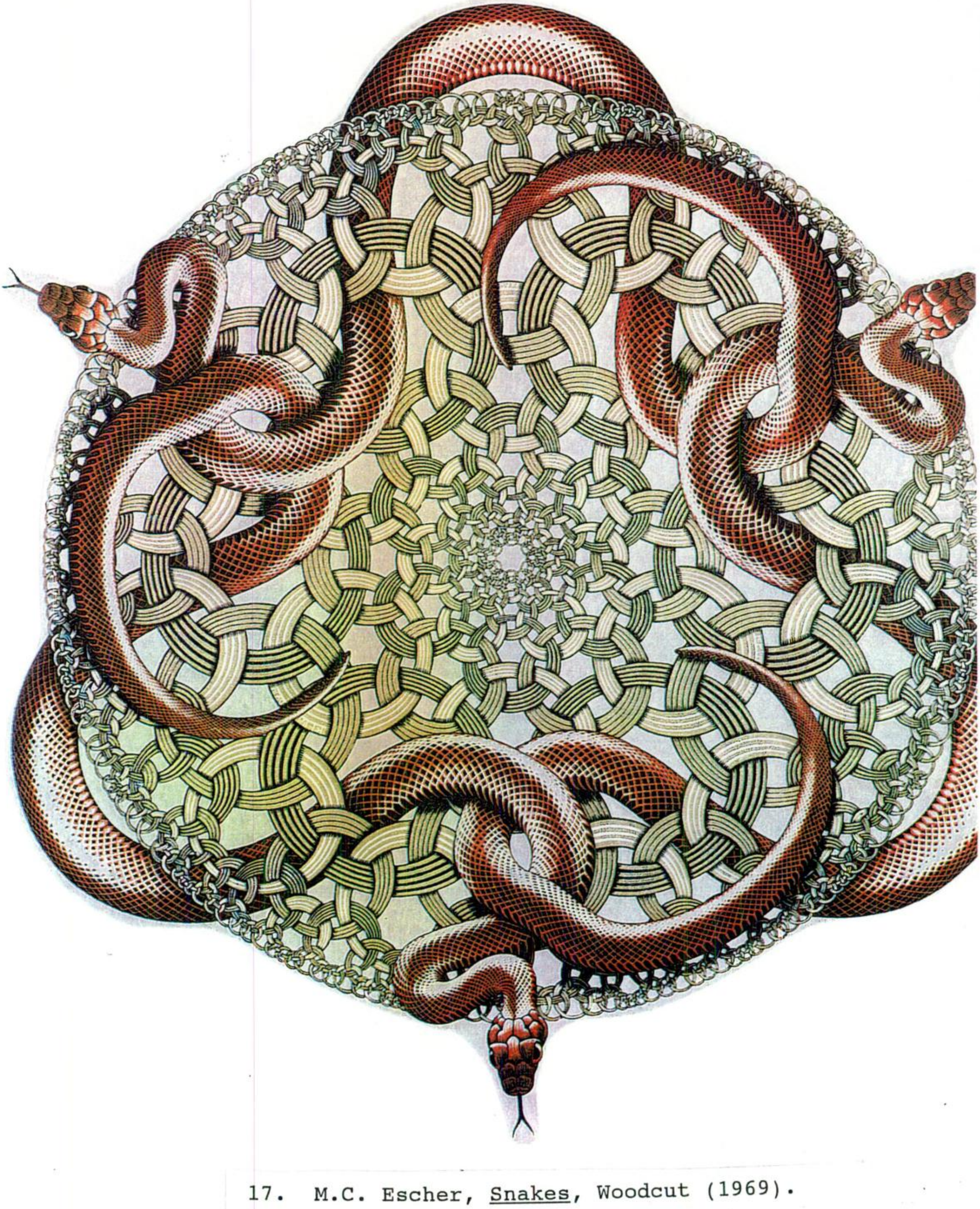
> Bilateral man evolved from numberless hierarchies of cycles of form, from the primordial ordering of atoms and molecules, goes through the cycle again in the early stages of embryonic development from the bilateral, then rotational cleavages of the ovum, to the helical bodystalk of 18 or 19 days to the spiral embryo of about 4 weeks to the miniature complexity integrated into his ultimate bilateral form as a ten week two inch embryo of potential human being. (Anne Griswold Tyng, 1978, p.103)

Leonardo de Vinci has been mentioned in stages throughout this thesis. The related works being his double helix sketch for a staircase and his studies of turbulent motion. In a letter to a close friend, Escher enthused about da Vinci's work: 'When you read his short notes, it's just as though he's sitting next to you and you can hear him



16. M.C. Escher, Puddle, Woodcut (1952).

speaking like a lonely, wise and melancholy old man from fifteenth-century Italy'. (Escher, BAARN, 22 April 1959) It is no surprise that Escher was interested in Leonardo's work. He was also a man whose work effectively embraced and entangled art and science. Escher's last published print was Snakes (1969). He did this print just before moving to a home for retired artists at the Rosa Spier house in Laren. Even at the age of sixty seven, though his health was deteriorating, he was determined to print this woodblock. With the help of a neon strip, a steady hand and magnifying glass, the print became possible. Escher admitted that working on the wood engraving Snakes was a struggle and that, when finished, it would not be a masterpiece. However, he was pleased with the results. In March 1972, Escher died at the home in Laren. This last print was skilfully carved, printed from three blocks, one for brown, one for black and another for green. Three snakes' bodies entwine around each other and through the chain-mail, which forms a circular pattern. The snakes rotate about a vacant central point. In this print Escher effectively uses rotational symmetry. There is a tension, not only because of this threefold symmetry, but because of the combination of subject matter. This being man-manufactured metal chain-mail with organic twisting bodies. The serpent symbolically depicted by man emphasises the geometric polarity of the helix form, especially when coiled around a tree or cross. It is a symbol of good and evil. Michelangelo depicts the serpent entwined on the

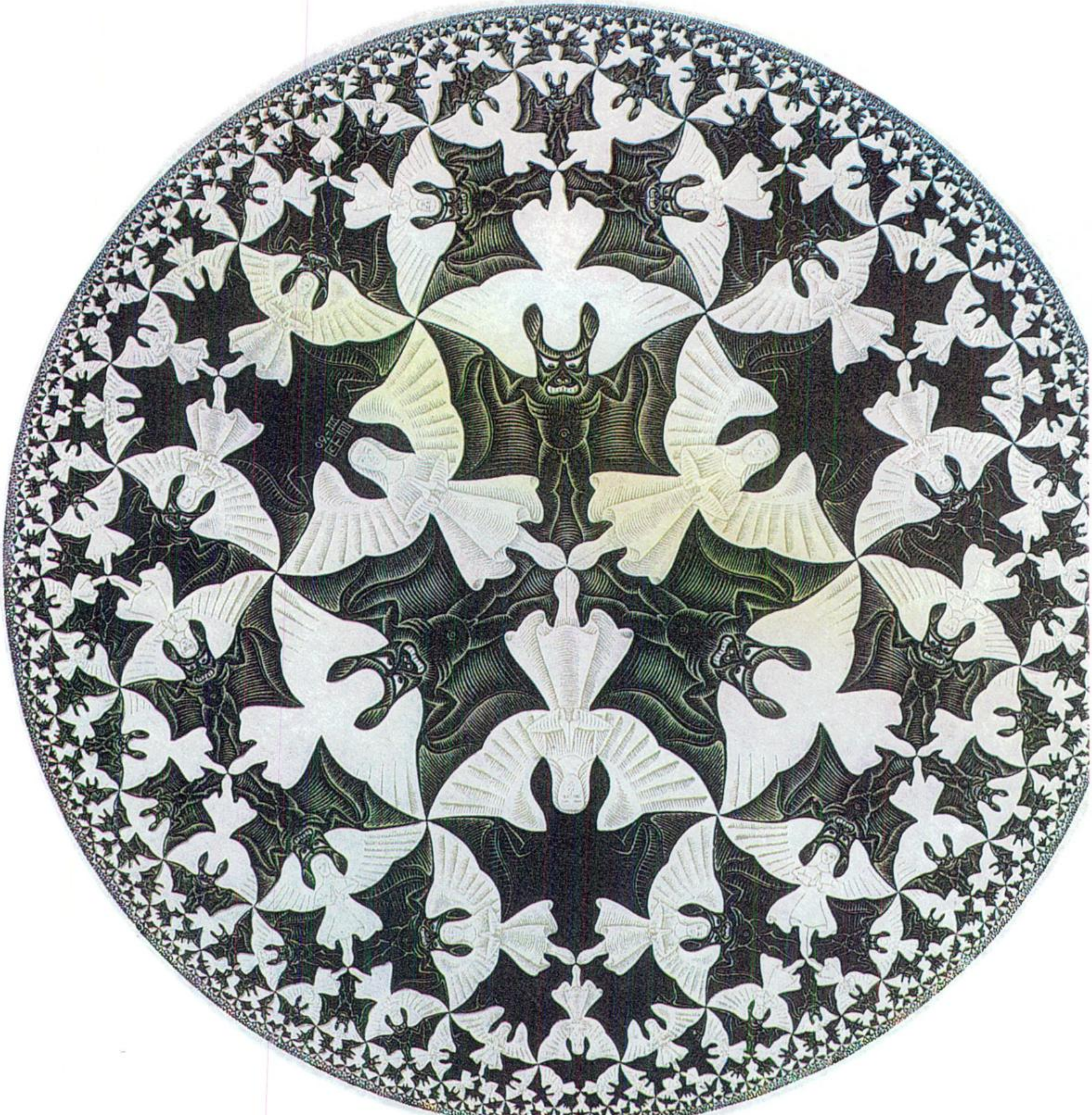


17. M.C. Escher, Snakes, Woodcut (1969).

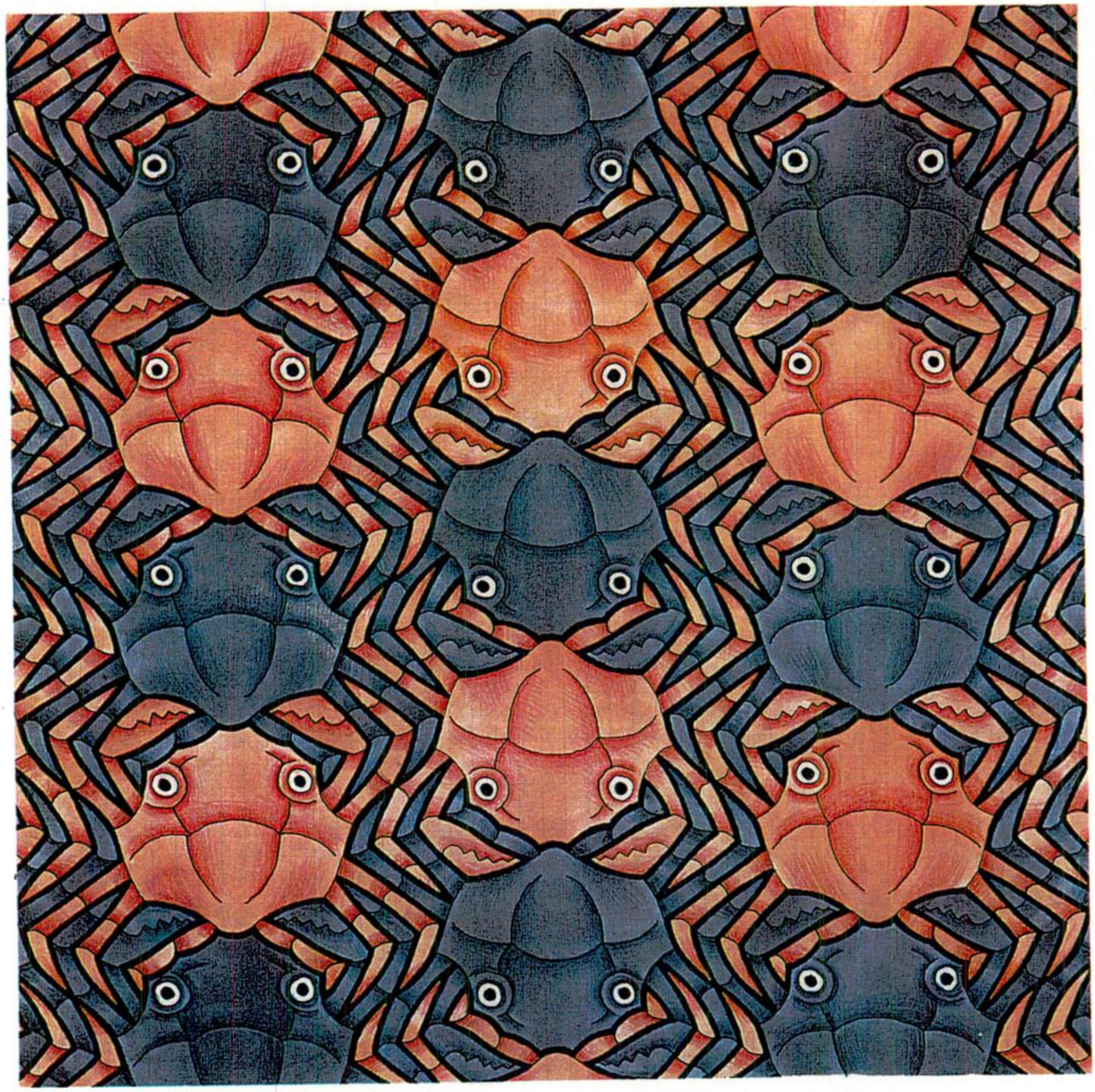
Tree of Knowledge of Good and Evil in his Sistine Chapel painting of the _Expulsion of Adam and Eve from the Garden of Eden_. As the connector between instinct and spirit, the serpent is the symbol of healing. The print _Snakes_ has a mandala-like format which draws our gaze inward while the snakes are being charmed rhythmically to the same tune outward. This print is, I believe, to be one of Escher's more beautiful and subtle renderings.

CONCLUSION

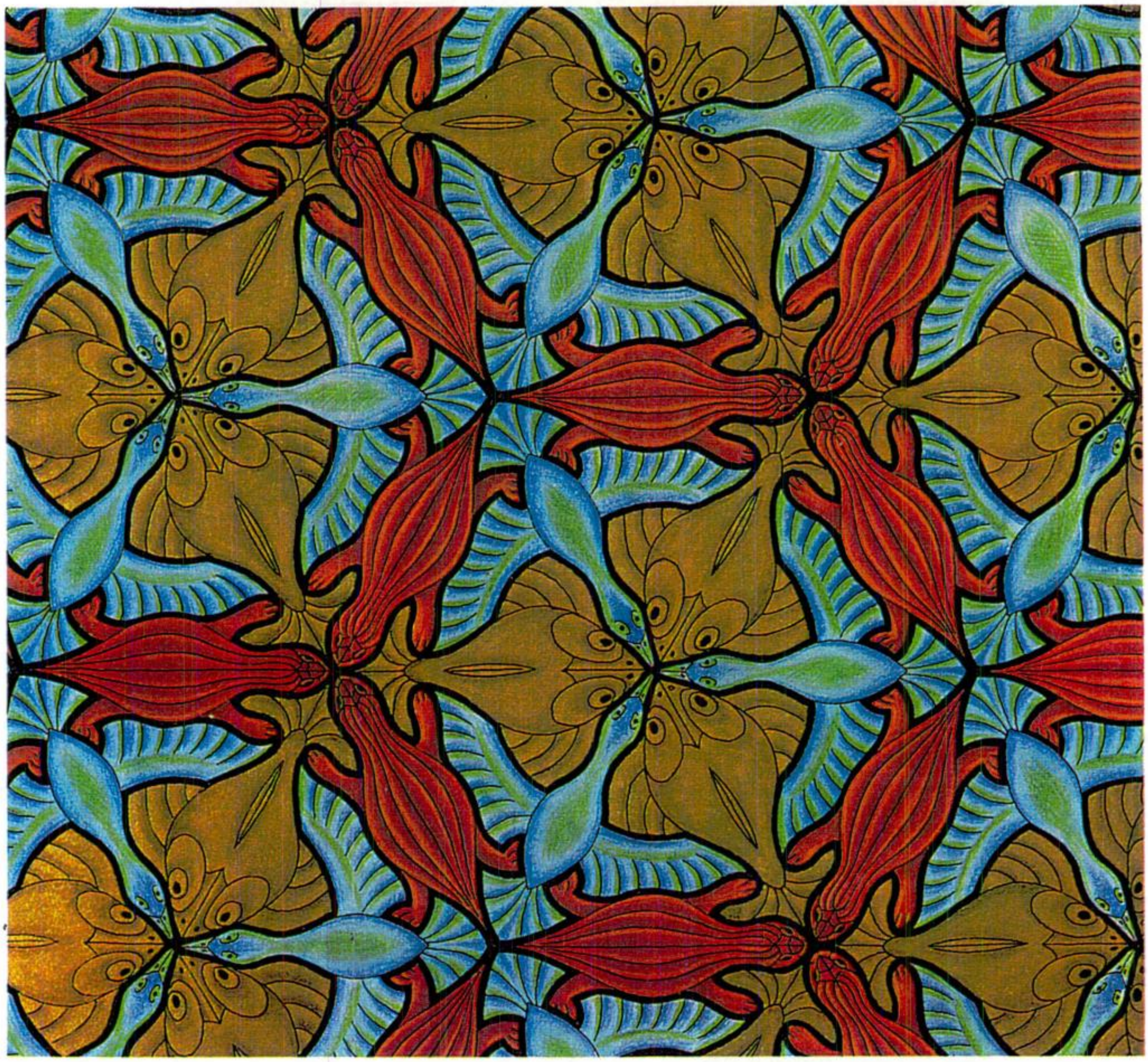
This thesis discusses the unique properties of printmaking, beginning with the mechanical reproductive aspect of print in relation to the fine art or original print, and following on with an outline of the dualistic properties that are the roots of the process. One theme that especially intrigued Escher was the depiction of the concept of infinity on the two dimensional plane. He was also inspired by the notion of endless repetition within the printmaking process, hence his periodic tessellations. This basic human desire, to capture an intangible concept such as infinity, is linked to our urge to discover an underlying order in the universe. The figures in Escher's periodic drawings are rotated around varying points in the plane. In our minds, however, they spiral, like the many planets in our galaxy, in perpetual motion. Escher's interlocking motifs also depict a fragment of infinity as they are designed to exactly fit together in a repeatable fashion. The print <u>Circle Limit IV</u> depicts a sphere with rotated angel and devil motifs which diminish in size until they reach the boundary line. These angels and devils are symbolic opposites of good and evil, heaven and hell, and, in this piece, are inscribed on the sphere as an interlocking whole. I will now conclude this paper, combined with this print as it encompasses with Escher's complex visual language, the four themes of repetition, infinity, positive/negative, and symmetry.



18. M.C. Escher, Circle Limit IV, Woodcut (1960).



19. M.C. Escher, Periodic Tessellation with Crab Motifs (196



20. M.C. Escher, Periodic Tessellation (1948)

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