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Pattern, the visual mathematics: A search for logical connections in design through mathematics, science, and multicultural arts

Seung-eun Lee

If it is merely defined that pattern is a repetition, it might be too simple. Patterns have been classified in the context of historical, cultural period. But there is more.

There appeared to be a mathematical system of pattern classification by crystallography in relation to group theory and symmetry operation. Furthermore, with the computer now we use and make unlimited digital patterns. Patterns also take us into a consideration of fractal geometry.

I created a series of two posters and an interactive application for my master thesis. This is the poster which refers to considering the visual elements, group theory and symmetry operation, and computer generated patterns such as fractals. The applications are created to help artists, designers, educating students, and general audiences understand pattern in a different way.

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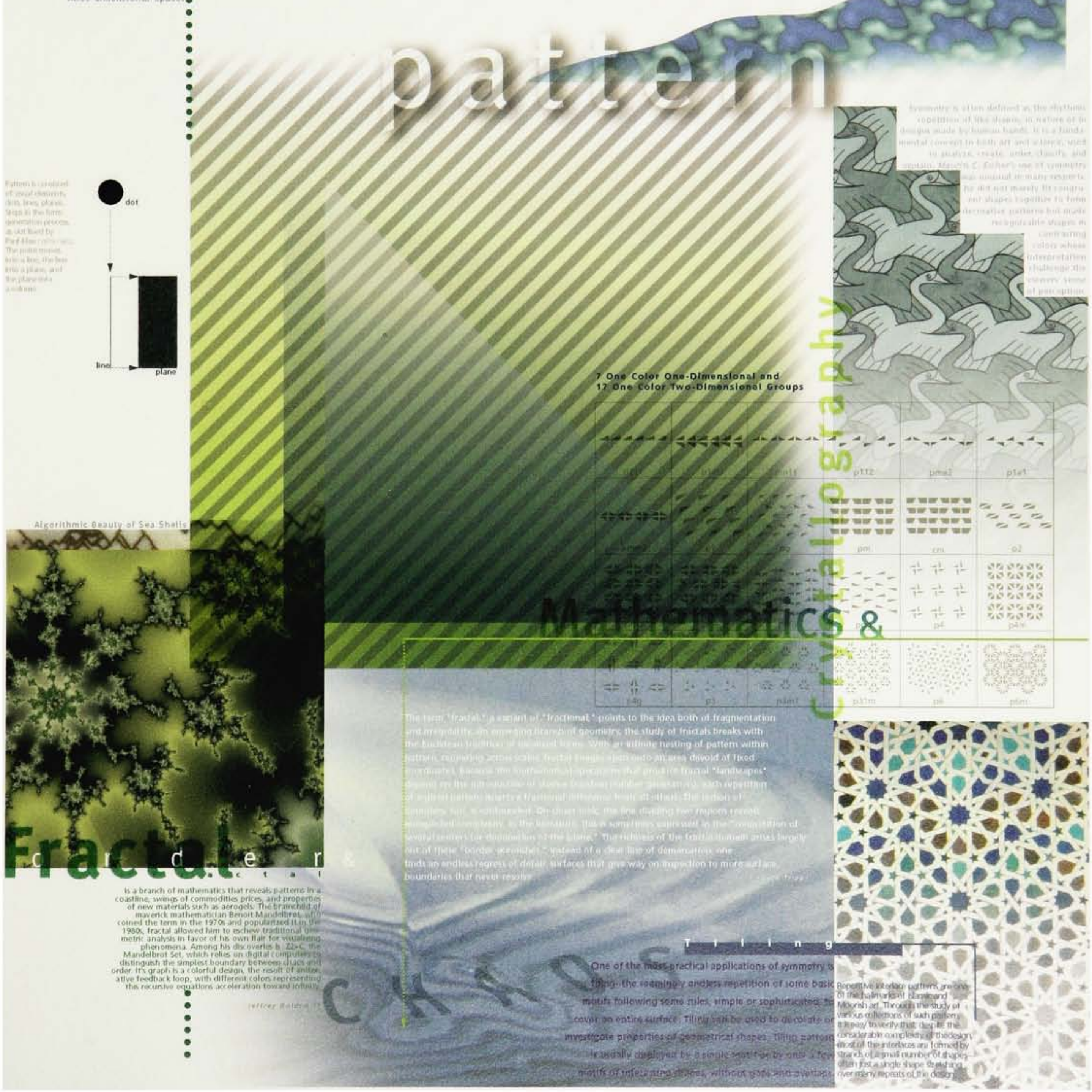
S y m m e t r y

The theoretical concepts of symmetry deal with group theory and figure transformations. Figure transformations, or symmetry operations refer to the movement and repetition of an one-, two-, and three-dimensional space.



A spiral and clouds!
The motif itself is not a pattern, but is used to create pattern. Although different cultures and religions share the same motifs, the name and meaning attached to each one varies.
I show two motifs, a spiral and a cloud having swirling shape, which are familiar to people. The arts of living in the West have been shaped by knowledge. The diversities of Eastern wisdom and Western knowledge seem to share the same basic pattern-forming processes that create the harmonies of nature and art.
Motifs are not only decorative and ornamental but also have symbolic meanings. I attempted to compare and analyze Eastern and Western patterns and motifs in terms of Semiotics. This poster was created to give people an opportunity to get a broader understanding about the motifs and patterns in the context of cross-cultural issue.
Seungyeun Lee
Semiotics
a term derive from the Greek
theory of how different signs are
constitute and classified according
to their uses and interpretations.
Mathematical patterns sometimes reflect visual patterns that the human eye finds particularly aesthetic. One famous example of such mathematical pattern is the golden ratio. According to the Greeks, the golden ratio is the ideal proportion for the sides of a rectangle that the eye finds the most pleasing. The golden ratio is found in nature: The chambered shell grows to form a logarithmic spiral, a mathematical curve that spirals out in a fashion dependent on the golden ratio.
The value of the golden ratio is (1+√5) /2, an irrational number approximately equal to 1.618. It is the when dividing a line into two pieces so that the ratio of the longer piece to the shorter.
x + 1
x
1
Poster
Semiotic Triad
Information Ideas
Audience
A theme, or ... element, form, or subject.
樣
Once ancient man began to live in communities, various taboos came into being regarding his way of life. Together with the concept of revering heaven, a totemist belief system came to control life. To Eastern cultures, clouds eventually came to symbolize longevity and immortality ... est desires of ... from the most ancient ... on. Man began the practice of sacrificial rites in order to ask the spirits to grant this wish, and he made the cloud image its symbol. Cloud shapes were carved on sacrificial utensils in the hopes that the desires they symbolized would reach heaven. The cloud motifs appear in descriptions of the realm of heaven that are scattered through ancient legends, and serve as symbolic representations of this ideal realm. These representations can be ... the depictions of heaven ... on tomb murals, in ... colorful designs of architectural decorations, on clothing, and on utensils.
Celtic Scroll
Sligo, Ireland, 2500B.C
By intuition or some ancient religion science, the inscribers of the marks seem to have grasped that the spiral pattern symbolizes activity in the life giving boundary between order and chaos.
CULTURE
Pattern arrangement appears to reflect culturally meaningful patterns of human behavior.
Apsara on the Temple Bell

Pattern, the Visual Mathematics

A search for logical connections in design through mathematics, science and multicultural arts

A Thesis Report Submitted to the Faculty of

The College of Imaging Arts and Sciences

In Candidacy for the Degree of

Master of Fine Arts

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June 1996

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INTRODUCTION

We see patterns everywhere around us that have a relationship with both the natural and man-made world. These patterns provide visual enrichment and enjoyment. It is also true that patterns are sometimes regarded as forms of decoration such as wallpaper or textile in the context of art history.

However, patterns are more than just a form of decoration. Through many eras, different cultures have developed patterns as a system of recognition, and based on mathematical system. Patterns are formed by repeating a motif as one of the fundamental regions. Some of the motifs have a symbolic meaning connected to culture and region. Living in the modern age, we are adapting to a multi-cultured society. Therefore, it is desired to examine how patterns have been developed by different and successive cultures. To help readers understand cross-cultural motifs and patterns, I also include Semiotics to support this topic.

There is no limitation to the study of patterns. I have done research on culture, history of art and craft, graphic theory, textiles, folk art, religion, cognitive studies, psychology, mathematics, crystallography and even music. As result, I believe that all of these fields are interrelated in analyzing patterns. No aspect is more important than another. Each discipline supports the other as they coexist.

The goal of this thesis is to create images based on existing theories related to pattern and to use those images as an application. My intention is to explore many possible aspects of patterns and to set a reference for students, designers and others in the related field.

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Choosing a Topic

During the Summer of 1994, I started to consider my thesis topic. Anything could be a topic but I decided to choose patterns because it contains contemporary, multi-cultural and academic issues in which I have a strong interest. The topic also had to be on the view point of fundamental graphic theory and to be understood by both graphic professionals and non-professionals.

I remembered that while taking Theory and Methods (A major course in the first quarter of 1993) with Prof. Roger Remington, I was attracted to William Morris' pattern in Art & Craft Movement and decorative arts in the period of Art Nouveau. Since I had done research on the Art Nouveau period extensively at the time, I had an idea where to begin my research. With those questions in mind, I found it necessary to understand graphic theory and applications of pattern.

Since I had been interested in computers, I thought it would be an interesting new way to present the theory of pattern with printed media and interactive multimedia applications. I believed that showing the subject pattern with new interactive media would be a interesting way to satisfy all requirements for the thesis goals.

RESEARCH & ANALYSIS

Material Resources:

I started my research at the RIT Wallace Library. I printed a list of related articles from the word pattern using the Einstein search engine. Furthermore, I did my thesis research at the Rochester Public Library in downtown Rochester and the bookstores around the Rochester area. I tried to familiarize myself with words that describe pattern and gathered more information on books on how patterns have been studied in many ways and different fields of study. However, I found that most of those books talked just within art history. I was not satisfied because I couldn't find what I needed to know.

Prof. Roger Remington lent me Wucius Wong's *Principle of Two Dimensional Design* and *Principle of Three Dimensional Design.* Those two books were helpful for me to understand the idea of different structures in two and three dimensional composition. He also suggested the book *Basic Visual Concept and Principles* (Charles Wallschlaeger & Cynthia Busic-Snyder). It guided me to express my point of view on the graphic theory.

In order to get ideas about comparison of Eastern and Western Culture, I brought some books about Korean traditional and contemporary art from Korea. I was able to scan some images and quotes into the computer. I also gave a list of the books to my brother and friends that I needed for the research, so they sent me several books published in Korea.

During the research stage, I read *The Visual Mind* by L. Loreto, R. Farinato and M. Tonetti. The book talked about Interactive Multi-Window Computer Graphics in chapter 27. It showed illustrations of production and comparison of symmetry patterns in a multi-window arrangement. The chapter used the interactive computer program SYMPATI software as reference. SYMPATI is a MS-DOS application which works on IBM compatible PC's (see **Appendix 7. a**) I was interested to find the program and learn how it works.

I called a student who studies at Illinois Institute of Technology in Chicago to see if he could get any information on crystallography for me, especially SYMPATI. However, he sent me a demo version of a program LAZY, a software program which can create the structure of an atom, instead of the SYMPATI. That was a better program for me because the software was for Macintosh and I was able to use it on my Macintosh computer.

Research in Cambridge & Boston, Massachusetts

During the Fall/Winter Break, I went down to Boston to find more information. Since MIT and Harvard University are located in the Boston area, I thought they must have a great library system with good resources. On top of that, the Boston region is known as one of the biggest publication centers. When I got to Cambridge in Massachusetts, I tried to get into the Harvard University Library. However, the only way to get access to their library was to have a certificate that contains the list of the books issued by the RIT library. I experienced the same problem at MIT.

I had better luck with the Boston Public Library and the Cambridge Public Library. I found several good books. They were William Justema's *The Pleasure of Pattern* (1968), *Pattern The Historical Panorama* (1976), and M. Richard Proctor's *The Principle of Pattern* (1969). Nevertheless, those books can not be checked out of Massachusetts, so I had to spend a lot of time reading the books and making photo copies there.

The last day before coming back to Rochester, I stopped by the MIT Bookstore. The MIT Press always publishes good books, so I expected to find something useful. I was happy that I found three books related to pattern. They were: *The Visual Mind* (Michele Emmer, The MIT Press, 1993), *A Primer of Visual Literacy* (Dondis, Donis A.. The MIT Press, 1973), and *Strange Attractor: Signs of Chaos* (Allce Yang, The New Museum of Contemporary Art, 1989).

The Visual Mind is written by a group of mathematicians. The book introduced a new universe of mathematical images, forms, and shapes in media from drawings to computer graphics. It also analyzed the methods used to create these works. Inspired by this book, I found more possible research topics such as symmetry theory, fractals, mathematical analysis of Islamic patterns and computational patterns.

The Visual Literacy was another important source for my thesis development. It helped me to understand the basic elements of design and how to present meaningful synthesis of visual information.

Although spending just 4 short days for research, this trip to Boston was very helpful in terms of getting good materials. After I came back to Rochester, I could propel myself to go on to the next stage.

Figure 1 **Mind Mapping**

1. aids reading anddevelopment/expression of creativity.
2. makes advantageous use of visual memory for increased retention.
3. is a natural process. The brain has a natural tendency to cluster, or group ideas.
4. can be teamed easily.
   is adaptable to both groups and individuals.
5. is especially valuable for note-taking, speech making and planing, problem-solving, brain storming, planning session, and reviews exercises.
6. is an alternative to formal note-taking. Because of flexibility and adapt ability, new material can be easily added.
7. is a whole-brain activity.

Adapted from;
Use Both Sides of Your Brain by Tony Buzan.

Brain Storming and Mind Mapping

At the brain storm stage of my thesis development, I wrote down anything that related to the word pattern. It could be any simple words, dots, lines, shapes, and symbols that came from my mind or that I had seen. I was still brain storming even at the end of the research because I believe that brainstorming is the best way for idea expansion.

Besides brainstorming, there is another way to expand ideas. This is called mind mapping. Figure 1 Through the development process, I always reminded myself to get feedback through this method.

THESIS PROJECT PLANNING

Through the Fall quarter of 1994, I had been writing the thesis planning report. The thesis planning is the means of managing the design process, containing 10 items which are Project Title, Designer's Name and Address, Documentation of Needs, Problem Statement, Mission Statement, Methodology, Timeline, Evaluation Plan, Bibliography and Glossary of Terms.

Although I did not exactly follow the plan during the entire process, I was able to use it as a guide line of what was expected. With the guide line, I had freedom to add or change what I originally planned. Basically, I stepped ahead based on the planning report.

On the stage of doing research on methodologies, experimented with other fields such as anthropology, religion, culture, etc.. It also gave me an intuitive idea to have better perspective. (see **Appendix 2**)

Based on the research, which I had done during the phase of the thesis planning, I was seeking more possibilities in relation to new theories about pattern. Prof. Roger Remington emphasized and reminded me about the importance of methodology several times, constructing methodology was one of the most important processes for my thesis. In fact, from this methodology, I synthesized all materials and information on a diagram called the research map. (see **Appendix 3**)

Related to the categories on the diagrams, the research of the methodology had to support my ideas for the final design. For this I spent lot of time setting up the appropriate methodology. Within the limited time, I rushed myself to cover other unfamiliar fields of study. Topics such as crystallography, mathematical theories and the perception theory were studied. I tried to understand the essential ideas of the theories first, and then I made the research map to connect these methodology topics.

My Study became more extensive than I anticipated, so I spent a lot of time deciding which category to focus on for my thesis.

Collecting Definitions of Pattern

First of all, it was necessary to have the definition of the subject. There are many interpretations of the word pattern, so I wrote down the meanings as I went along with the research.

The richness of pattern is based on order, and represents a blend of the organic and geometric. It is a sort of design that consists of a number of similar compositional figures. Most composition of pattern is a structure that governs position and arrangement of figures and forms to bring about visual order and harmony. Pattern results from the repetition of a shape size, color, texture, value, direction, position, and orientation, either by itself or in combination.

[The term pattern necessarily implies a design composed of one or more devices, multiplied and arranged in orderly sequence. A single device, however, complicated or complete in itself it may be, is not a pattern, but a unit with which the designer, working according to some definite plan of action, may compose a pattern.] *Christie, Archibald H. Pattern Design (1969)*

Once I gathered the definitions of pattern, I organized and interpreted them into my own words. Therefore, it helped me decide on the main topic and theme for my thesis.

Reading Peter Steven's the *Handbook of Regular Patterns (1980)*, I began to have more questions. The book is full of illustrations such as classes of finite one-dimensional (line), two-dimensional (plane) pattern classes. It is helpful for artists and designers to understand the understructure of repeated pattern. Although the book has good information, it does not have the explanation of what symmetry group theory or X-Ray crystallography is about.

I really wanted to know what the notations such as mt, pg, or c2mm meant. I asked a student majoring in mathematics, but he didn't seem to know. I was disappointed. I asked a professor in the Department of Imaging Science at RIT. He said that he knows the theory but I did not get any helpful knowledge about the symmetry group theory.

I looked for some books about X-Ray crystallography at the RIT library. It was not easy to learn a new field of study depending on only books. Fortunately, I found *Elements of x-ray Crystallography* written by Azaroff, Leonid V. (1968) and *Symmetry in Science and Art by* Shubnikov, A. V., and V.A, Kopstic (1974). These two books introduced the basic theory of crystallography. Although it took a long time to understand the mathematical theory, I had a great time studying it. I will explain the general idea of crystallography on page 13.

Mathematical Concept

Nature likes to repeat designs. Recall the structure of snowflakes, the hexagonal shape of honeycombs, and molecular structure patterns. With these examples in mind, it comes as no surprise that mathematicians have attempted to classify these repeating patterns.

There are many types of patterns, visual pattern, human behavior pattern, mathematical pattern... and so on. Visual pattern is associated with point, line, shapes, and geometry. Human behavior can act as a pattern, such as the sleep pattern of an average adult is at night. Mathematics is a form of pattern derived from number, logic, and spatial forms. Mathematics is not only about numbers and only useful for buying or selling. Western cultures usually refers to mathematics as just arithmetic (as the public thinks), or the study of number and space. However, mathematics is not just as the dictionary defines, it has evolved into the "science of patterns".

Numerical systems are also part of pattern. We don't recognize numbers as pattern because humans are not born with the knowledge of mathematics but acquire this through education. The infant learn numbers as an abstract entity which can not be seen, heard, felt, smelled, or tasted, but remembered and utilized for the rest of his or her life. Once they learn how to identify numbers, they are able to use the knowledge of counting to recognize mathematic patterns rather than just seeing them as shapes.

Mathematical patterns sometimes reflect visual patterns that the human eye finds particularly aesthetic. One good example is the golden-ratio. The Greeks found the golden ratio as the ideal proportion for the sides of a rectangle that are most pleasing to the human eye. The rectangular face of the front of the Parthenon has sides whose ratio is in this proportion, and it may be observed elsewhere in Greek architecture. The golden ratio is also found in nature: The chambered shell of the Nautilus mollusk grown to form a logarithmic spiral, a mathematical curve that spirals based on the golden ratio.

Figure 2 Fibonacci Sequence

Fabonacci sequence is produced by starting with 1 and adding the previous two numbers to arrive at the next, continuing to infinity. The first twelve Fibonacci numbers are 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, and 144. These numbers have interesting properties and are often evident in nature and art.

The golden ratio crops up in various parts of mathematics. One well-known example is in connection with the Fibonacci sequence.Figure 2 This is the sequence of number at each stage found by adding together the two previous ones (except at step 2 where you only have one previous number). Thus, the sequence begins.

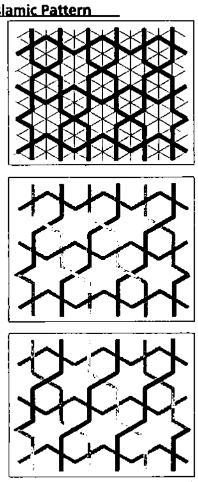
What is Crystallography?

Crystallography is the study of the external form of the crystals and their internal structures (i.e. the arrangement of atoms in them). Crystals are solid matter in which atoms are essentially arranged according to an underlying crystal lattice. The symmetry possible in a crystal is traditionally called crystallographic symmetry. Although Crystallography originated with minerals, it includes more general topics-- undergoing development into a broad area of pure applied research. Crystallography is an interdisciplinary field that has close contacts with many branches of other sciences such as chemistry, mathematics and biology.

Islamic Pattern

The vision of Islamic pattern is the knowledge of the cultural order of an ordered universe. The Islam lands were the crossroads of East and West, the nexus of the great trade routes, so the people were great navigators of the desert as they were later to be of the oceans of the world. They held all natural phenomena in great respect and noted the structure of star and plant formations. Their land of desert developed in the people a cosmic sense of scale and distance in relation to topography and the heavens combined with a minute order and geometry.

Figure 3 | Interlaced Islamic Pattern



Repeated pattern and interlaced patterns are often characterized in Islamic art. Symmetric tiling of one form or another have been used as decoration on buildings in the Islamic world. We frequently obtain or symbolize meaning by the use of symmetry. This is found in the religious icons, the exquisite mosaic and patterns used in Islamic art. The Islamic pattern is based upon an ingenious application of geometry and the structure as an instrument to unify the diversity encompassing all in one reflects Islamic cosmology. The pattern is drawn next ending to infinity, exploiting ambiguity, illusion and flux.

The largest published collections of interlace patterns are by author J. Bourgoin. Therefore, we will observe most of the interlaced patterns in three areas. First, interlaced patterns consist either of identical strands or of two shapes of strands. Second, these measures are related to the symmetry properties of the pattern. Third, an explanation of the frequent appearance of interlace patterns consists of strands of a single shape or just two different shape in Islamic art. Figure 3

Branko Grunbaum and G. C. Shephard, The Visual Mind (1993)

Tiling

Tiling is one of the practical applications of symmetry. The repetition of some basic motifs following some rules to cover an entire surface makes a two-dimensional space group. Tiling can be used as decorative wallpapers or textiles or to investigate properties of geometrical shape. (see Appendix 7. b)

[A tiling is covering of the plane by closed shapes without gaps or overlaps; two other synonymous terms are tessellation and parquetry. Mathematically, the space is treated as a heavy outline of tiles that fit perfectly together. The fitting together of shapes to fill an area is a pleasurable challenge--play with colored polygon shapes or the completion of a jigsaw puzzle are examples in which the shapes are given, and we expect them to fit together in many different ways.] *Doris Schattschneider, The Visual Mind (1993)*

Islamic and Moorish pattern have attracted people to their intricate pattern. Dutch graphic artist Mauritz Conelis Escher is the most famous artist displayed tiling a surface by a single motif or a few motifs of interesting shapes.

Mauritz Conelis Escher

Figure 4 Mauritz Conelis Escher

Maurits Cornelis Escher was born in Leeuwarden in 1898. His graphic art bursts with cunningly planned visual surprises.

At the first meeting with Dr. Richard Zakia he suggested that I do some research on Mauritz Conelis Escher (1898-1972). Figure 4 I found two books about M. C. Escher at Border's Bookstore and I scanned over his bibliography and chronological artworks, but I didn't pay attention to his works upon the regular division of the plane that were derived from mathematics and crystallography.

It wasn't until after winter break when I found the *Vision of Symmetry*, the *Symmetries in Culture*, and the *Symmetry*. I now had a better clue to understand the formation of pattern in relation to symmetry theory. I resumed researching M. C. Escher. The most fancy application of the laws of crystallography can be seen in the work of M. C. Escher, who arranged people, animals, and insects in two-dimensional one-, two- and multi-colored symmetrical patterns.

One of the practical applications of symmetry is tiling-repetition of some basic motif to cover an entire available surface, making a two-dimensional space group. Tiling can be used as decorative wallpapers or textiles or to investigate properties of geometrical shape.

Crystallographers use the symmetry group of a pattern in their classification scheme; it is based on the identification of an underlying geometric lattice of the pattern related to its translation symmetries and their location, in relation to this lattice, of centers of rotation, axis of reflection and axis of glide-reflection. The crystallographers' and mathematicians' quest is for a logical analysis of a given structure; Escher's quest was to discover the various ways in which to create original periodic patterns in the plane. (see **Appendix 7. c**)

Tiling & Symmetry Group

The mathematical model for internal structure of crystals is one in which atoms are aligned in a periodic lattice, so almost all mathematical investigations of tiling have been restricted to those that are periodic. In a periodic tiling, there is always a minimal patch of the tiling that fills the whole tiling by translating it again and again in two different directions. One can first fill out an infinite strip with the patch, then translate the strip to fill out the plane.

Mathematicians use geometric transformations of the plane that preserve shape to describe the order. These transformations are translation, rotation, reflection and glide reflection. Each such geometric transformation is called a symmetry of the tiling; the collection of all symmetries of a tiling is called the symmetry group of tiling. Symmetry groups are not just collections of geometric transformations but also have algebraic structure. Periodicity of a tiling severely limits the possibilities for symmetries other than translations; there are only 171 different types of symmetry groups of periodic tiling.

Symmetry

During my research, I was surprised to find that many subjects such as crystallography, fractal, Islamic patterns, music and many more all relate to symmetry. This leads me to question myself; Why are humans attracted to symmetry? Why did it make people feel comfortable? Did it happen naturally? Did God create it this way? As for the theology field, it covers the studies on theory of perception, cognitive theory, group theory, etc.. At this point, I need to talk more about the definition of symmetry and why I had to study symmetry and how symmetry theory supports the explanation of pattern .

Symmetry is a very simple concept, but it also means more than just a pleasing visual response. Symmetry appeals to our visual sense, and thereby plays a role in our sense of beauty. Symmetry has enjoyed a special place in both philosophy and theology. Symmetry is a mathematical property which generates repeated patterns, as well as a feature used in the perception and categorization of form. Symmetry plays a role in a wide range of decorative designs and textiles. Symmetry is based on superposition. Elements which are regularly superpositioned along an axis are thus regularly repeated. The resulting pattern is symmetrical. In both everyday usage and mathematics, symmetry has the sense of repetition, such as a wallpaper repeating one design over a number of times.

The perfect symmetry is repetitive and predictable, but sometimes people consider imperfect symmetry to be more beautiful than exact mathematical symmetry. Man seems to like visual symmetry, balance or comfort so that is why man usually makes objects with symmetrical shape. Symmetry is a mathematical as well as an aesthetic concept, and it allows classification of different types of regular pattern and distinguishes between them. The symmetry concept provides perspective from our world as an integrated whole.

The collection of all such symmetry patterns, based on tilings in the plane, have been classified by their symmetries; These symmetries are called either the wallpaper groups or the two-dimensional crystallographic groups. Symmetries restrict the kinds of pattern arrangements possible forming a sort of grammar. All patterns are produced by the same rules. Pattern structures can change, but the rules cannot. There are limited possibilities to build patterns based on group theory. I'm not a mathematician and I don't know the specific details beyond the basics, so I am going to introduce the theories on the following pages and appendixes to help interested readers understand.

Humans have the ability to discern patterns. Symmetry relates harmony and proportion and it provides perspective form. Symmetry is divided into two large classes; *point group* and *space group*. The symmetry groups have algebraic structure and provide a way of generating periodic tilings as I talked about on the previous pages.

Author Dorothy K. Washburn and Donald W. Crowe pointed out the differences in cross-cultural preferences for all the plane pattern symmetries associated with culturally meaningful stimuli, and investigated the significance of different geometries in different cultural contexts.

Point Groups are when at least one special point in the object or pattern differs from all the others. This special point has an important distinguishing feature: it remains unchanged no matter what type of symmetry operation is performed. Such symmetries belong to the point-group category. For an example, a system of concentric rings resemble the pattern when a stone is thrown into still water. The pattern remains unchanged if it is rotated around its center regardless of its position. Those are often called finite patterns and there are group 1 and m, group2 and 2mm, group3 and 3m, group4 and 4mm, group5 and 5m, group6 and 6mm, group7 and 7m, group8 and 8mm, 10mm, 12mm, 16mm, 24mm, ..., and higher. (see **Appendix 7. d**)

Space groups are another form of symmetries. However, there is no point in the object or pattern that is different from all the others. For example, patterns of hexagons like a beehive are considered a space group. In general, space groups can be one-dimensional, two-dimensional or three dimensional-according to whether the repetition extends in the X, Y, or Z axis.

If a design admits translations in only one direction the design is called a band, strip, frieze, or **one-dimensional** pattern. In the beehive example, the hexagons in the pattern extend in two directions-length and width. The corresponding symmetry is called a **two-dimensional** space group. If a plane figure admits translations in two or more directions, it is a two-dimensional pattern. Two-dimensional patterns are commonly found on wallpaper, tile, textiles, and other media where broad areas are covered by motif repetition.

A pattern can be generated simply by a repeating motif. This symmetry operation is repeating the same objector motif simply by shifting it a consistent distance and the resulting pattern is periodic created by infinite repetition of the same motif. From any one-dimensional pattern with periodicity, it is easy to generate a planar pattern by repetition, extending the periodicity in two directions.

Symmetry Operation

Symmetry operation and its combinations provided 7 possibilities for creating border decoration with one color and 17 possibilities for two color one-dimensional groups. There are another 17 possibilities with one color for creating planar two-dimensional space group and 46 possibilities for two color, two-dimensional groups. For three-dimensional periodicity, there are altogether 230 possibilities.

One-color	finite
	one-dimensional 7
	two-dimensional 17
Two-color	finite
	one-dimensional 17
	two-dimensional 46

No matter how complicated, every rigid motion of the plane is one of four basic rigid motions. They are translation, rotation, reflection, and glide reflection. The term "operation" implies action or movement.

Translation	the motif moves up or down, left or right or diagonally while keeping the same operation in translation, the resulting pattern is periodic.
Reflection	the figure across a vertical axis or across a horizontal axis
Glide-reflection	the motif turns in rotation
Rotation	the motif both translate and reflects

(see Appendix 7. e and 7. f for the full explanation of the symmetry operation)

Symmetry in Culture

Pattern arrangement reflects culturally meaningful patterns and human behavior. Since the discovery and explanation of human behavior is the essence of anthropology, it would seem that an analytical technique which can isolate behavior consistently and objectively would be a great asset for the study of certain kinds of cultural activities. Practically every culture in the world is known to decorate at least some portions of its material possessions with repeated patterns. *Dorothy K. Washburn and Donald W. Crowe (1988)*

Incidentally, I was studying Dorothy K. Washburn and Donald W. Crowe's *Symmetries of Culture (1988)*. They talked about patterns occurring on decorated objects from culture. They also showed one-and two-color, one-and two-dimensional, and the common finite design. I borrowed the idea pattern of triangles from the symmetry group classification for my thesis. While I was studying with this book, I explored many structurally similar patterns which are from different cultures and

Symmetry relates to harmony, proportion, and beauty.

historical periods. (see Appendix 7. g and 7. h)

Chaos Theory and Fractal

Fractal is a geometrical figure in which an identical motif keeps repeating itself on infinite scale. Originally the geometry of nature is fractal to the extent that when looking at shapes in nature-clouds, trees and coastline-small parts are the same as big parts.

Traditional dynamics deals with regular patterns, where as chaos is the science of the irregular. It aims to extract new kinds of pattern from apparent randomness, pattern that would not be recognized as such in a traditional approach. Chaos is a kind of randomness of which origins are entirely deterministic. It also involves shapes which are almost invariably fractal.

Chaos theory has resulted from a synthesis of imaginative mathematics and readily accessible computer power. It presents a universe that is deterministic, obeying fundamental physical laws, but with a predisposition for disorder, complexity and unpredictability.

It is the beautiful graphics associated with chaotic systems that make it appealing to people who see them. They show how a simple equation, when input into a computer, can produce breathtaking patterns of ever increasing complexity. (see QuickTime Movies on CD-ROM)

While playing around with HSC Software Kai's Power Tool 2.1, a plug-in for the Photoshop, I appreciated the beautiful fractal pattern. To me, fractal is an absolutely revolutionary approach that applies the theory of pattern. After discovering the fact that fractal is related to symmetry theory, I used fractal as a part of my thesis. The fact that fractal is related to symmetry theory was not surprising any more since I was beginning to understand that all research topics are interrelated.

Mandelbrot Set

The fractal geometry was invented by Benoit B. Mandelbrot,Figure 5 and has become known as the Mandelbrot set. The fractal geometry is between the excessive geometric order of Euclid and the geometric order of general mathematics. It is based on a form of symmetry that is infinite self-similarity. The pattern that Mandelbrot and others discovered in one region of the complex plane was a long proboscidean insect shape of stable points--the mandelbrot set itself, usually in black--surrounded by a flaming boundary of filigreed detail that includes miniature, slightly distorted replicas of the insect shape, and layer upon layer of self-similar forms.

Figure 5 Benoit B. Mandelbrot

In the 1960 and 1907s an IBM researcher, Benoit Mandelbrot, invented a new geometry, which he called "fractal" geometry. He coined the term "fractal" to suggest "fractured" and "fractional" –a geometry that focuses on broken, wrinkled, and uneven shapes.

The boundary area of the set is infinitely complex, therefore fractal, because it is possible to bring out finer and finer detail. Computer graphics artists call the process of unfolding the detail "zooming in" on the set's boundary or "magnifying" it. (see also **QuickTime Movies** on **CD-ROM**)

Icons of Chaos and Strange Attractor

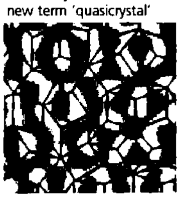
Points symmetrically related have symmetrically related images. This condition is used for the mathematical form of the equation; and once a symmetric equation is found, we can use it to do dynamics. This symmetry--creation is called chaotic icons. The "icons" for fluid flow are called attractor, and they are in an imaginary mathematical space of which points correspond to all possible flow-patterns. People do not normally think that chaos is a means for creating pattern, but the strange attractor is another kind of fractal pattern made by a dynamical exhibiting chaos. (see **Appendix 7. i**)

Quasicrystal Pattern

Lattices in the plane or three-dimensional space can have rotational symmetries of orders 2,3,4, and 6 but can not achieve five-fold rotational symmetry. It wasn't until the early 1970's, when a mathematician, Roger Penrose, discovered a way to tile the plane with figures that exhibit local fivefold symmetry as recreation investigation. The significance of the discovery was added to in 1984 when crystallographers identified it as Quasicrystals. Figure 6 A quasicrystal is a material without the regular lattice structure of ordinary crystals, but has its atoms arranged in a highly ordered fashion that exhibits local symmetry. Quasicrystals are somewhere between amorphous bodies (like glass) and perfect crystals (like diamonds). The study of Quasicrystals is still at its infancy, but it demonstrated the possibility of a mathematical framework that can serve as a basis for understanding these newly discovered materials.

Figure 6 | Quasicrystal

A crystal lattice can have two-, three-, four-, five-, and six-fold symmetry. These alloys can not be crystals in the usual sense, hence the new term 'quasicrystal'



3D-Stereo Random Dot Pattern

Not many people know that the 3D-Stereo random dot pattern is based on the symmetry theory. Bela Julez devised the stereogram made up of randomly distributed dots. (see **Appendix 7. j**) The image seen by the right eye is identical to that seen by the left in all but a central square region, which has been cut out, shifted a little to one side and stuck down again onto the background. The white gap left behind was then filled with a random pattern of dots. If the two images are viewed through a stereoscope, the square that was cut out appears to float in front of the background. Such stereograms contain spatial data which are processed automatically by the visual system. *Bruno Ernst, The Eye Beguiled-Optical illusions (1986)*

Human Sense of Order

The search for pattern is part of human nature. Human mind and culture have developed a formal system of thought for recognizing, classifying, and exploiting patterns. As in human behavior, pattern lies at the heart of cultural systems, allowing both participants and observers to anticipate the future. The creation and perception of pattern has a logical as well as aesthetic component.

Humans are endowed from birth with the capacity to judge experiences by such prior categories as similarly or contrast. We distinguish the familiar from the unfamiliar and the simple from the complex. Moreover, there is a relationship between our reactions to remembered sights and to simple shapes. For example, if we see something familiar, it becomes the expected and thus taken as normal, unless an unfamiliar context arouses attention. Geometrical simplicity can also become monotonous and fail to register except where it contrasts with less ordered surroundings.

If the aim of history, archaeology, and anthropology to describe and study the products of human behavior which consistently reoccur and thus form non-random patterns, and if we treat these patterns as manifestations of ideas held in common by makers and users of the artifacts, then we must, first of all, give our attention to classificatory aspects of those phenomena which relate to those non-random ideas and patterns of behavior. We offer here one way of more rigorously defining the units of analysis for a whole class of phenomena--repeated design--in a way which enables us to address important problems relating to group formation, maintenance, and interaction. The problem of why people do things similarly is pervasive, profound, and not trivial. It deserves our best systematic efforts.

[Order and complexity are antagonistic, in that order tends to reduce complexity while complexity tends to reduce order. To create order requires not only rearrangement but in most cases also the elimination of what does not fit the principles determining the order. On the other hand, when one increase the complexity of an object, order will be harder to achieve. Order and complexity, however cannot exist without each other. Complexity without order produces confusion; order without complexity produces boredom. Although order is needed to cope with both the inner and outer world, man cannot reduce his experience to a network of neatly predictable connections without losing the stimulating riches and surprises of life. Being complexily designed, man must function complexily if he is to be fully himself; and to this end the setting in which he operates must be complex also. It has long been recognized that the great works of man combine high order with high complexity.]

Rudolf Arnheim, Psychology of Art (1972)

Gestalt Theory and the Law of Prägnanz

Patterns can be considered in terms of perception theory. Patterns are composed from a basic list of visual elements; dot, line, shape, direction, tone, color, texture, scale, dimension, orientation and movement. The interaction and effect of human perception on visual meaning is from the research and experimentation in Gestalt psychology. However, Gestalt thinking has more to offer than just the relationship between psychological phenomena and visual expression. Its theoretical base is the belief that an approach to understanding and analyzing all systems requires recognizing that the system as a whole is made up of interacting parts, which can be isolated and viewed as completely independent and then resembled in the whole.

Gestalt theory was one principle that contributed to order and structure in a pattern; that is, symmetry contributed to the "goodness" of the pattern. Gestalt theory of perception, the Law of Prägnanz defines psychological organization as "good" (regular, symmetrical, simple) as prevailing conditions allow. It would be defined emotionally least provoking, simplest, least complicated, all of which describe the state arrived at visually through bilateral symmetry. Axial balance designs are not only easy to understand, they are easy to do, employing the least complicated formulation of counterpoise. *Dondis, Donis A.. A Primer of Visual Literacy (1973)*

Visual Literacy

Visual literacy is the analysis of points, lines and shapes in space, while art is often concerned with aesthetic appreciation or with the use of space to evoke an emotional response. The figures and forms involve the use of basic visual elements; point, line and plane. They are part of the attributes of form that create tone, texture, or pattern. The mathematician may think about and define words such as point, line, plane, and volume in abstract terms.

Point used repetitively in a regular configuration can be used to create various patterns. Patterns can be created by a simple shape or configuration called a cell of fundamental region.

Line can be used for representation of shapes, to form objects, and structures. Line can bring meaning, symbolism, and expression to visual forms and their message. Like points or dots, lines can be used to produce tone. Patterns can be organized from a set of lines into a configuration that can be repeated an infinite number of times.

Plane is defined in Euclidian geometry as formless, representing an infinite expanse of flat surface area that stretches two-dimensionally in all directions. Like points and lines, planes can be used to create images with tone, texture, and pattern.

Paul Klee's Form Generation theory

Prof. Robert Keough suggested that I read Paul Klee's *Pedagogical Sketchbook* (Sibyl Moholy-Nagy, 1953) when I talked with him about starting to design the application of graphic elements such as dot, line, plane, and color. (see **Appendix 7. k**)

Paul Klee(1879-1940), artist and master teacher at the Bauhaus, developed his theory regarding pictorial dimension of form generation starting with point as the generating agent. In his writing in conceptual terms: "the point moves off and the line comes into being--the first dimension. If the line shifts to form a plane, we obtain a two-dimensional element. In the movement from planes gives rise to a body. Summary of the kinetic energies which move the point into line, the line into a plane, and the plane into a spatial dimension." *Paul Klee, The Thinking Eye (1961)*

William Morris and The Arts and Craft Movement, 19C.

Sometimes the Arts and Craft Movement, 19C is criticized for its lack of practical tendency. However, anyone will appreciate Sir William Morris (1834-1881) if they viewed his patterns. Sir Morris revolutionized the art of pattern-making and altered the course of Western design. His patterns display the value of form, function and beauty.

Morris himself wrote: *'The special limitations of the material should be a pleasure to you, not a hindrance; a designer, therefore, should always thoroughly understand the process of the special manufacture he is dealing with or the result still be a more "tour de force".'* *William Morris, Textiles (1893)*

Geometry and Pattern

The human visual-cognitive system looks for geometric shapes. Geometry is the mathematical study of shape. It enables mankind to recognize a triangle as a triangle, a circle as a circle, but not size nor color, rather its shape. Whenever we see three straight lines joined at their ends to form a closed figure, we recognize it as a triangle. Geometry is the concept of proportion, which is related to the Pythagorean axiom that everything is arranged according to number. It is a property of numbers, harmony, proportion and has been used in aesthetics.

On the other hand, symmetry is also regarded as a kind of geometry. The name of geometrical proportion a:b=c:d is harmoniously ordered or rhythmically repeated proportions introduced in a logical recurrences in all consciously composed plans. Either Euclidean geometry or non-Euclidean geometry is based on distance and angles, but the transformations that preserve distances and angles are precisely the rigid motions in Euclidean geometry.

Moorish or Islamic decorative art, Chinese lattice, and Greek and Celtic canon is famous for the geometric ornamentation and patterns. Those are structured with numerical and geometrical relationships progressing through the dimensions.

The use of the geometric principle of symmetry for the description and understanding of forms represents the union of mathematics and design. The only limitation is they must consist of regularly repeated patterns. The geometric principles of crystallography is to develop a descriptive classification of pattern design.

Golden Section, Golden rectangle, Fibonacci Numbers and Symmetry

In nature, this mathematical relationship appears repeatedly in growth pattern. The golden section is that a certain length is divided in such a way that the ratio of the longer part to the whole is the same as the ratio of the shorter part to the longer part.

Mathematical relationships between the features of the golden rectangle and the spiral show the connection between the spiral and the golden section. The golden section was said by Kepler to be "one of the two treasures of geometry," and was considered by Plato as the key to the physics of the cosmos. This mathematical relationship appears repeatedly in growth patterns in nature and has fascinated mathematicians and artists for centuries.

There is also a connection between the spiral and Fibonacci series. The construction of the golden rectangle has a connection among the golden section, spirals and the Fibonacci numbers. They are related to each other since the golden ratio is obtained. The golden ratio is a symmetry because when patterns are generated by simple rules the definition of symmetry includes harmony and proportion. The fundamental property of the logarithmic spiral corresponds precisely to the principle that governs the growth of shells. The principle is the simplest possible; the size increases, but the shape remains the same. The only mathematical curve which follows this pattern of growth is the logarithmic spiral. (see **Appendix 7. l**)

The essence of shell shape is captured by the logarithmic spiral, characterized mathematically by Decartes[Figure 7] in 1638. The logarithmic spiral was observed in many man-made and organic forms.

Figure 7 René Descartes (1596-1650)

French mathematician and philosopher. He introduced the idea of coordinate geometry. In coordinate geometry, figures can be described by means of algebraic equations.

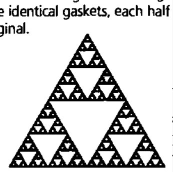
Algorithmic Beauty of Seashells

Shells are one of the most interesting creations of God. The shell is a metaphor of geometrical proportion, symbolic, and a pattern formation of biology. The fundamental property of the logarithmic spiral corresponds precisely to the principle that governs the growth of shells. The mathematical curve that follows this pattern of growth is once again the logarithmic spiral. (see **Appendix 7. m** and **7. n**)

The logarithmic spiral shape also reveals various colors and patterns on the surfaces effected by flowing water. Like a tree's annual ring, most shell patterns are historical records of what happens at the growing edge. Each kind of shell has millions of various patterns with lines, dots, ripples, regularity, irregularity, symmetry and so on. Several shells display triangles as their basic pattern element, and the patterns are similar to the famous Sierpinsky triangles[Figure 8] with their fractal geometry.

Figure 8 Sierpinski Triangles

The Sierpinski gasket is the simplest example with which we can make the point. This is obtained by repeatedly deleting the middle quarter of a triangle, removing smaller and smaller pieces, forever. It was invented by Waclaw Sierpinski and named after. The Sierpinski gasket can be thought of as being composed of three identical gaskets, each half the size of the original.



Equiangular, proportional spiral, logarithmic spiral.

Multi-cultural Mathematics

The connection between geometry and art lies in their common interest in space. In some cases art can be thought of as a creative application of geometry. The geometry involved in art and design can be much more accessible and enjoyable to most of us, and the development of geometrical concepts and skills can be applied to help people enjoy creative art.

The multi-cultural connection lies in the naturally multi-cultural context of art. By looking at the geometry of two-dimensional patterns and designs, art of this kind can be found all over the world in brickwork, woodwork, tiles, weaving, carpets, and other works of art. The Arabic geometrical designs have perhaps the most developed and sophisticated tradition in this respect, but many of these designs are found in ancient India, China, and Africa and, of course, have been integrated into modern Western culture.

The artistic and mathematical beauty of these designs, whether or not they are part of culture, are examples of multi-cultural mathematics. The pattern of the number bonds is reflected in the pattern of lines which it generates, thus giving strong visual support to an important numerical relationship. The act of drawing may itself be pleasurable, and provide a contrast to the repetitive recall of number bonds. An example of the link between mathematics and the art of multi-cultures is Arabic patterns and designs that provide an ideal context for work in geometry and art.

The analysis of the design by synthesis into a generating algorithm or algorithms can be exciting. Mathematics can be abstracted from certain patterns and designs in an attempt to describe the patterns more or less formally. As I described in the previous page, the group theory has been used to prove that only seven or seventeen of such patterns can exist. The formal deduction of the results on symmetry groups and their subgroups would complete the development of the third stage of geometric thinking, recognizing mathematics in the design, or analyzing and describing the design mathematically.

Semiotics

Semiotics, a term derive from the Greek, is the theory of how different signs are constituted and classified according to their use and interpretation. The sharing generates a uniform response to the symbol and tendency to define its integrity in interpretation. Semiotics is the study and application of signs. Signs are anything and everything that convey meaning. For example, words are signs, pictures are signs, colors are signs. Graphic designers use signs to represent information and ideas.

In my thesis I attempted to convey this information;

1. Patterns can be created using mathematics and crystallography.
2. Patterns use repetitive motifs and symbols.

3. Patterns are aesthetic.
4. Patterns are used in many ways...
   arts and crafts, graphic design, textiles, etc.
5. Patterns are culturally defined.

Motif

A motif itself is not a pattern, but the basic unit of a pattern with an arbitrary or abstract shape, or derived object. Also it can also be a unit cell or fundamental region, mostly consisting of symmetry. Although different cultures and religions share the same motifs, the name and meaning attached to each one varies.

I showed two motifs as a main subject to explain how motif reflects different cultures. These were a spiral and a cloud having swirling shape, which are familiar to people and have been studied in symmetry theory. The arts of living in the West have been shaped by knowledge. The diversities of Eastern wisdom and Western knowledge seem to share the same basic pattern-forming processes that create the harmonies of nature and art.

In general, decorative motifs are signs that have symbolic meaning, most of which were originally conceived as symbols.

Computer Generated Pattern

The consequences of computer techniques cannot yet be estimated, but we learn a great deal from almost any sequence of order and styling of its effect. The ability of the computer not only to organize but also to introduce an exactly calculated dose of randomness results in giving latitude to chance. Within a fixed framework of predetermined moves not only exhibit features of aesthetic interest, they also offer unrivaled insights into the operation of our sense of order in the perception of complex patterns. (see **Appendix 7. o** and **QuickTime Movies** on **CD-ROM**)

Motion Pattern

Like any other pattern, motion pattern is worthy of consideration. It is used for virtual games or screen design and animation as well. I found some CD-ROMs, such as Head Candy and GrooveThing that provided good examples of motion patterns at several computer stores: Lechmere, Compu U.S.A, and Computer City. With parts of animation from the CD-ROMs mixed with some other animation from online service, I created an animation as an example of motion pattern on my digital book. (see also **Appendix 7. o** and **QuickTime Movies** on **CD-ROM**)

Video Feedback Pattern

Video feedback creates an electronic light show that produces an endless variety of chaotic fractal patterns. Video chaos results from the iteration that takes place when a TV camera is pointed at its own monitor. We can replicate this setup by placing a mirror at right angles to the screen, and pointing an 8mm video camcorder at the seam where mirror and TV screen meet. The imperfections in the seam were blown up by the positive feedback to chaotic (or fractal) forms made to look like a kaleidoscope. (see **Appendix 7. p**)

Music

The first time when I considered music, I recalled the musical notes and the sound of patterned structure. I was excited since music has also been studied in context with mathematical symmetry theory. The extension of the regular periodic repetition of parts of the musical composition; the regular repetition of identical parts in the whole constitutes the essence of symmetry. We are more justified in applying the concept of symmetry to a musical composition in view of the fact that it is written in terms of notes, i.e. it takes a spatial geometry, so that we can inspect its constitute parts. (see **Appendix 7. q**)

Symmetries and self-similarities abound in the world of geometry, and a great deal of music also shares these properties. Music is an ordered pattern of sounds and it can be analyzed in terms of three primary musical structures-melody, harmony and rhythm. **Melodic patterns** represent the tune that enables a listener to recognize a familiar piece. **Harmonic patterns** are simultaneously sounded notes, but also involve temporal order. **Rhythmic pattern** comprise the timing aspect of music.
Wendy S., Sabrina S., and Golden L. Shaw, "Mathematics and Music: A Search for Insight into Higher Brain Function" (1994)

Each of these structures possesses its own type of patterns. Music occurs in time, and the inherently temporal aspect of musical patterns is of particular interest with respect to the trion model in relating music to other higher brain functions. Melodic patterns, or patterns of successive tones, represent the "tune" that enables a listener to recognize a familiar piece even when it is played with a variety of distortions. Harmonic patterns involve the vertical dimension of music, or simultaneously sounded notes, but harmonic patterns may also involve temporal order. Rhythmic patterns comprise the timing aspect of music;the pattern of long and short that accompanies the melody and yet may be separated from it.

Different cultures and even different styles within a musical culture may have different musical organizations or emphasize these three structures to different degrees, but structure of some kind is common to all music.

THE FIRST THESIS COMMITTEE MEETING

At the first thesis committee, we discussed what I had done and how I was going to narrow down the information. All members of the committee showed up at the Graduate Graphic Design Studio on Dec 13, 1994. I prepared several handouts (see Appendix 9. a, 9. b, and 9. c) and explained my thesis development to them.

Concerning the primary question for the final pieces, Prof. Robert Keough and Prof. Roger Remington had different opinions. While Prof. Remington told me that I didn't have to make my own patterns, Prof. Keough suggested that I create my own patterns using some of the computer softwares such as Adobe Illustrator, MacroMedia FreeHand, Specular TextureScape and other texture stock CD-ROMs. (see CD-ROM) My final applications would eventually be informative in the researcher's point of view, so I decided not to create new patterns.

Dr. Richard Zakia, another member of my thesis committee, promised that he would help me study Semiotic theory He was especially interested in my idea about combining pattern and semiotics in the cultural context. He is very knowledgeable of Semiotics and he suggested that we have regular meetings to have discussions.

The results of the committee meeting were as follows:

1. The final applications are presented by a series of 2 posters and interactive multimedia.
2. Those applications are primarily aimed to be informative references.
3. The viewers should be given information about how patterns are studied in various fields.

PRELIMINARY THESIS PRESENTATION MARCH, 14

The second year students were scheduled to have presentations on March, 14. It was required of each student to present their thesis content with visual information by handouts, a overhead projector or a computer.

Although I had done the research and visualized information, I needed to prepare a speech for my audience to understand my thesis concepts such as crystallographical notation of patterns, M. C. Escher's art work, and category diagram. As usual, I was shy to speak in front of people, but I got used to it by this time.

Prof. Roger Remington, Prof. Deborah Beardslee and the first year students were at the presentation. Each second student was allocated about half an hour for the speaking. Overall, the students' presentations were positive and helpful to every student. Before the presentation, the students didn't know about their peers' work and how much they had done. It was a good time not only to know each student's work, but also to get feedback from each other.

The question by Prof. Deborah Beardslee, one of the professors of the graduate program, "What is Crystallography?" was shocking to me. Although I prepared a lot of materials, I was not able to answer the question. I realized that I missed a topic at the very core. I concentrated too much on digging widely and deeply but I forgot to set up the basic content. It was important feedback which reminded me to keep the direction without missing anything.

Through the presentation, my chief advisor Prof. Roger Remington's positive feedback encouraged me. I respect the way he teaches and treats his students. I was taught not only theoretical knowledge but also the teaching method. After the presentation, the second year students agreed that we did a good job and we established a friendship among us.

DIAGRAM

The diagram was an organized chart that helped me map out what I was going to do. This was a process that guided me to construct my thesis. It was also helpful in the sense that it was easier to present my ideas to the committee using a handout at the thesis presentation. (see **Appendix 3**)

IDEATION

Sketches

Before closing the Winter quarter of 1995, I showed some rough idea sketches for the poster to the committee. Those were B/W 600 dpi laser printer output on legal size paper. (see **Appendix 9. d 1, 2**) However, I was not satisfied with the preliminary concept as much as the images. Talking with Prof. Roger Remington about my feeling, I was ready to improve the sketches.

The Spring quarter of 1995 was practically important because I had achieved something visually. At the beginning of the quarter, I showed the revamped sketches to Prof. Remington. He seemed to be more interested in the new draft than the old one. Satisfied by the new design and good feedback from him, I was confident to move onto the development stage.

FINAL THESIS PRESENTATION METHOD

Why Posters and Interactive Application?

In order to present the best visual concept for my thesis, I believed that posters would be the best medium, particularly if there is a lot of information with a web-like structure and text. Poster is a proper means for making the viewers stay on to observe. Once I had decided that I was going to present in a poster format, print size and printing medium became a concern. Since I had already known the quality of the IRIS print, I chose this printing medium without hesitation. Furthermore, the interactive multimedia application would certainly assist the posters as a part of the thesis.

Recently, the computer graphic applications have increased interest in many ways. Therefore, it is the designer's responsibility to provide good graphics and aesthetics. My interactive multimedia application; so-called digital book was one of the goals which I was really eager to make. However, to make the multimedia application appropriately, immense time and advanced skill are required. It just so happened that for the past one and half years, I have learned sufficient computer skills as well as graphic theory. The thesis show was a great opportunity for me to exhibit my graphic design ability through those digital applications.

In order for the viewer to understand both posters and interactive application, the two must remain consistent. They should have the same visual presentation and content of the theory. Therefore, I chose the two kinds of media for my thesis show. It was great to have both medium for my thesis. For example, The posters allow the viewers to explore the image in full resolution while maintaining the freedom to move up closer or further back. The interactive application will further enhance the viewers understanding of the poster. Since the software MacroMedia Director is capable of showing slides and QuickTime movies, it made a perfect application to explain the content of my thesis.

Refinement of Thesis Content

Before the Winter break, I had a meeting with Prof. Roger Remington and I presented idea sketches of two posters that came visually. He was pleased with the sketches and suggested that I talk with Pro. Robert Keough to get additional comments. After the meeting with Prof. Keough, I valued his suggestion about Paul Klee's Form Generation Theory. He also lent me his Pedagogical Sketchbook, so I could study about Klee's theory. I was pleased to get more good information without changing much of the layout.

Developing Posters

I started work on the implementing stage using materials I studied thus far into the application at the beginning of the Spring quarter of 1995. I decided at this time that I would make two posters at the size of 18"x 23". My intent was that I would break-out the traditional proportion for my posters and make them into a manageable size.

To keep the two posters with the same theme, I passed on the layout of the first poster to the second poster. This process allowed me to use the same grid system and implement the elements for the second poster.

Production

Prof. Roger Remington and I talked many times on developing layout. Working with the computer, I could manipulate the layout more easily than on the paper. However, when I tried to print out the document, I encountered some difficulties. My first option for output of my first draft was ETC (Educational Technology Center), image service under RIT Wallace Library. The Canon color laser printer CLC 500 at the ETC was not able to handle the Adobe Illustrator document which contains over 100MB of EPS files; The file was just too big for the Mac CXII, an outdated computer, to handle the task. The next option was to go to a service bureau outside of school. Experience lead me to choose UFO Systems because they have better equipment. However, even with the more advanced Xerox 5775 color laser printer, it failed to print. The operator suggested that I change the application from Illustrator to QuarkXpress because the QuarkXpress and the printer handle large EPS files much better. After I recreated the document, I saved it as postscript file and readied for round two. Eventually, the printer printed my first draft after four hours of waiting.

Working with that file size, I found myself starring at the computer progress bar for a long time, not to mention that it crashed several times during the making of the first poster. If anyone has worked with the Adobe Photoshop, one would know how long it takes to wait for the next command. Learning from the first poster, I reduced the resolution to 180 dpi so it will be easier to make without sacrificing much of the image quality that's needed to exhibit the poster.

Grid System

In order for the viewer to understand the images better, I organized the graphic work with the same layout. Therefore, I devised a grid system as part of the design element.

Layers

Working with the new version of Adobe Photoshop 3.0, I was really happy to find that layering function was much easier to create than the previous 2.5 version. I had the ability to generate complex multi-layering effects and change the layout whenever I wanted. It also allowed me to unleash my creativity easier than before. With the new feature, I was able to create 20 layers for the first poster and 14 layers for the second poster. I had to make each of the images in layers. When an image was completed, the layers were flattened. The next image was then constructed on top of the previous image and the process was repeated. During the making of these images, I upgraded my computer to 58 MB to enable the layering function to process faster.

Drop Shadow Effect Using Channels for the Chinese and English Character as the Main Text

I used both English and Chinese character for the second poster title. I believed that it might be helpful to make viewers understand what I intended at once. Without the Chinese operation system on my computer, I had to scan the characters meaning "motif" as a TIFF file. To make it as a dominant theme, a Photoshop technique called drop shadow effect was used to make the motif stand out.

Scanning and Images Manipulation

After I finished sketches in my mind and on the paper, I gathered images that I considered useful from the books and some Photo CD-ROMs. The main images such as the blue waves, M. C. Escher's work, the big nautilus shell and the carved cloud were scanned from books. I used a flatbed scanner scanning at 300 dpi, millions of color as TIFF file format, brought them into Photoshop, and then fixed each image pixel by pixel for better quality. I tweaked the image on the color saturation, brightness and contrast level, and got rid of the artifacts generated through the scanning process using the stamp tool.

Typefaces

Choosing the right typeface was as important as any other factor. They all have to work together to achieve harmony. Through Prof. Heinz Klinkon's class, Imagery and Typography, I learned how to manage both successfully. I cautiously examined many kinds of fonts from different design font shops. I used Goudy, ITC OfficinaSans, Meta Plus Family, Rotis Family, Frutiger Family, MatrixBook, OCRB, Veljovic, and Letter Gothic 12 BT Those fonts are classical, trendy, and easily readable. Each of them I used go along with the images and the content of my thesis.

Color

Color is unquestionably important for posters. I chose green and blue for the first poster, violet and brown for the second poster. I also tried to avoid very saturated colors. As intended, the soft pastelish tone and colors agree with the multi layered, half-transparent images.

Pragmatics

Last year, I saw the work of Gedeon and Talos, former RIT graduate students. Their work was output from IRIS print. Figure 9 I knew that the print gave the best color fidelity right from the screen. Even though the cost of IRIS prints are very high, I knew that it was the best solution for this project. There were two paper options for the print; one was glossy paper with laminated coating, the other one was watercolor paper. Personally, I preferred watercolor paper, but I was worried about the water-based ink. It gets fuzzy with moisture, so special handling was necessary.

Figure 9 IRIS Print
uses watercolor based ink
with virtual resolution 1200dpi
actual resolution 300 dpi

Prof. Roger Remington also liked the watercolor paper and he agreed that the paper gives a delicate pastelish look. On the other hand, the glossy paper strongly reflects under the spot lights. Framing was another important process to be considered for the thesis presentation. After the decisions were made, I put off the poster and started on the interactive application.

Developing Interactive Multimedia Application

While working on my thesis, I took independent study with Prof. Nancy A. Ciolek for Graphic Theory. I also took the Communication Design course in the winter quarter and the Animation course with Prof. James Ver Hague in the Spring quarter. Both professors were very helpful and provided feedback on my design. Through these courses, I was introduced to ideas, concepts, applications, and general principles of interactive media on computers. We also explored logic and aesthetic considerations for the end users.

My objectives in terms of the interactive multimedia were as follows;
1. Applying Graphic Design in the new age of computers
2. User Friendly Interface Design (Considering Computer Semiotics)
3. Creativity
4. Effective Interactive Technology
5. Organizational Structure and Navigation
6. Ethics in Computer Design

Navigation

To move around without getting lost or confused, the user needs to know the means of travel, available destinations, and the current location. Navigation consists of elements such as buttons. Screen location of those buttons play an important role in letting the user know how to navigate. There are five common ways to structure: for instance, linear, tree, network, single-frame, and combination structures. I chose a jump-linear structure, a variation of the linear structure, because it is useful when I want users to have primarily one path but also the ability to jump to any given point. (see **Appendix 9. f**)

Figure 10 Human Interface Design

Based on some assumptions about people, good interface design allows the user to accomplish tasks. People tend to be curious and they want to learn. They often learn the best by active self-directed exploration of their environment. A sense of control of what they are doing is important. They work most effectively when the environment is enjoyable and challenging.

Nancy Ciolek, Communication Design

Images and GUI (Graphic User Interface) for Page Spreads

The screen resolution for most monitors are able to display 640 x 480 pixels. I used 832 x 624 screen size because my monitor can only display at that resolution. To make the interface user friendly, I included graphics, text, sound and other elements to make information easy to understand. After I had finished the interface design, images and text started to fall into place according to what I had planned. All imported images were saved as PICT file with 16-bit color instead of index color with system palette as thousands of color.

Cast Members

After the images were completed from the Photoshop, I saved each image at 72 dpi resolution as PICT file format for the cast members. Although I knew the quality of texts created on MMDirector were not as good a solution as on Photoshop, I created the paragraphs with text tool on the MMDirector. I had no choice because I had a lot of text to put in the movie. As far as creating text, Photoshop is well known for lacking the capability to handle lots of text. There were a total 444 cast members but not all of them were used as the sprites for the movie.

Score

The MMDirector movies are controlled by the "score". The score contains the notation that describe the movie and is the tool for animation. The score is strung together with scripts so it provides the user locations and directions. My MMdrector movie consists of four main buttons to allow the user to go to previous page, nextpage, mainmenu, and quit. All pages contain the other additional buttons, which also help the user to go to other pages by short-cut, animations, sound and QuickTime movies.

Using Lingo

I had a hard time understanding "Lingo", a scripting language used by MM Director that executes complex commands and animations. Fortunately, I had a friend who is more experienced in scripting help me overcome the difficulties. During this time, I met the committees regularly to get their thoughtful suggestions.

Sound

Music and sound effects provide the end user an atmosphere and audio feedback such as the click of buttons. I used Øystein Sevåg's music CD for the introduction and sound samples from SoundSation CD-ROM for button click sound. By using SoundEdit Pro 16, I changed the pitch and length of a sound and fade-in and fade-out effect. Every sound was saved as 11 kHz in audio AIFF format, then imported into MMDirector and placed into the movie score as a sprite.

QuickTime Movies

For my MMDirector interactive application, I included QuickTime movies to show pattern in motion application. My friend Andy helped me create them using transition effects from the Adobe Premiere 4.0 and Adobe After Effects 3.0. I edited several small QuickTime movies from the Specular TextureScape CD, which is a software that is able to create patterns, textures, and animations and from the part of a virtual reality game, HeadCandy to show an example of moving pattern. Many virtual reality games have appeared with faster PC's, so we can enjoy watching various moving patterns on computers in real time. Andy also downloaded several fractal movies from the net service to illustrate moving patterns, but the resolution was very low. He suggested and helped me compress the movies as CINEPAK format for playback. The CINEPAK format is the best balance between speed and quality. This format allows playback smoothly without loosing any image quality.

Personal WorkStation

system	Apple Macintosh OS, System 7.5
hard Drive	1250MB Internal Hard Drive with 56MB RAM
monitor	Apple Macintosh 16 inch display
scanner	HEWLETTE PACKARD ScanJet IIcx
printer	Apple Macintosh LaserWriter Pro 630
devices	730MB Lacie Joule External Hard Drive 1050MB Lacie Joule External Hard Drive 44MB SyQuest Drive and Cartridges 230MB Optical Drive and Cartridges
Software	Abobe Photoshop 3.0 Abobe Illustrator 5.5 Adobe Streamline 3.0 Adobe Premiere 4.0 Adobe After Effects 3.0 QuarkXpress 3.31 HSC Kai's Power Tool 2.1 Adobe GalleryEffect Vol. 1, 2, 3 Andromeda Series Filters 1, 3 XAOS Terazzo XAOS Paint Alchemy 1.0 XAOS Fresco Texture CD Macromedia Director 4.0, 5.0 Macromedia Projector Macromedia SoundEdit Pro 16 Specular TextureScape Spigot ScreenPlay 1.2 Softbit Soundation 1.0 sound CD NetScape 2.0 America OnLine 2.6

EVALUATION

Both formal and casual evaluation of the applications have been conducted through the weekly meeting with Prof. Remington and Dr. Zakia. More casual feedback for the interactive application was from Prof. Keough and Prof. Ciolek. Particularly in the Spring quarter, I was taking a independent class for graphic theory with Pro. Ciolek, so I had more chances to talk with her.

The thesis application was up for the three weeks during the thesis show. Comments towards the work were very positive. Prof. Remington and Mrs. Remington visited the show and commended me. Prof. Mary Ann Begland, the chair person of the Graphic Department, brought flowers for me and explained that she liked my work. Prof. Ver Hague and Prof. Ciolek attended the show and experienced the interactive application on my computer. They were pleased with my digital book and understood how much I had done. Dr. Zakia was impressed with the poster and gave me feedback in terms of Semiotics. Prof. Klinkon also gave me positive feedback.

Prof. Charles Arnold in School of Photographic Arts and Science, was attracted to my posters and asked "How did she make it?". His mention made me so happy because I know that he is one of the best photography professors at RIT Later on Prof. Douglas Ford Rea, also a professor in the Department of Applied Photography, liked my posters and asked about Iris print with interest of output quality.

There were some other people at the show who gave me positive feedback and wanted to purchase my posters. I wished I had had some extra copies.

FUTURE PLANS

During the research phase, I considered the possibility of a publication in Korean. Including digital application, the combination of graphic theory and other theories in my thesis is a good way to educate students and inform others in related fields.

I also considered other job opportunities such as teaching. I would like to continue studying for a Ph. D in design psychology in the context with mathematics.

CONCLUSION

Through the various phases of this thesis project, sometimes I encountered difficulties and obstacles such as time management, unexpected problems, the lack of adequate language skill, and so on. However this thesis project has proven my ability both in researching and designing.

It took a long time to combine all the information I gathered from the different fields of study. One of the most important lessons I learned through this project is, the more input and the more efforts, the better output.

On the other hand, I was very happy with my applications in both print media and the digital book in terms of aesthetic criteria. Whenever I design, I try to improve and refine for the best possible layout. Also, as a graphic designer, the challenge of the output method such as Iris printout and interactive multimedia application was a success.

I have completed many other different aspects, which can be good resources for anyone to do research on the related subject. Those are contained on the CD-ROM with the two posters, interactive digital book and the other extras.

I am also doing my best to complete this thesis report for my viewer as a showcase poviding design proccess. If someone finds any errors in my thesis, I will appreciate it if they can notify me. Thank you.

APPENDICES

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Thesis Proposal

Thesis Proposal for the Master of fine Arts Degree

College of Imaging Arts and Sciences
Rochester Institute of Technology

Title: Pattern, The Cultural Agenda

Submitted by: Seung-eun Lee   Date: September 20, 1994

Thesis Committee:
Chief Advisers: Prof. R. Roger Remington
Associate Advisers: 1. Prof. Robert Keough
2. Prof. Richard D. Zakia

Thesis Committee Approval:
(signature of Chief Adviser)

Date: 9/21/94

Approval, Department Chairperson:
(signature of Department Chairperson)

Date: 9.21.94

Computer needs other than word processing:
Yes x No _____
Explain need of equipment:

Committee Approval: ____________________

____

____

THESIS PLANNING REPORT

Graduate Graphic Design
College of Imaging Arts and Sciences
Rochester Institute of Technology

Seung - eun Lee
421 Kimball Drive
Rochester, NY 14623

November 8, 1994

Project Title

Pattern, the Cultural Agenda

Designer and Address

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Documentation of Need

Research that compares and analyzes Eastern and Western patterns would be helpful to a designer, artist, folklorist, and other interested people. I intend to analyze and interpret by creating a series of posters and a book as a reference guide, or an interactive application that is user-friendly and interesting for the target audience.

Problem Statement

We see patterns easily in designs around us. Even long before the invention of writing, pattern has been an important element in cultural development down through the ages, providing people with a means of expressing their sensibilities. We may regard pattern as another kind of cultural agenda. It is a pleasure that to make applications with patterns in the field of design and art. Pattern is an formal element which creates visual impact, and it offers unlimited possibilities in design and artwork. Yet few people understand how pattern was developed and applied in different ways concerning cultural and historical aspects. To help people understand patterns, I intend to compare and analyze them in Eastern and Western contexts of visual communication.

Mission Statement

This thesis will inform and educate designers, artists, and other interested people about pattern in relation to historical and cultural aspects which will aid in their design and artwork.

Goals	Objectives	Processes and strategies
Research and Analysis Eastern and Western Patterns	•The users should be able to identify the distinction between Eastern and Western culture.	•Gather fundamental information about Eastern and Western pattern. •Compare Eastern and Western patterns by providing.
Synthesis Information of Pattern in Relation to Culture	•The users should be able to identify the use of pattern in design.	•Gather information on patterns in design. •Present visual examples of design work that has patterns in them. •Study use of patterns in Eastern Western culture •Present visual examples
Ideation of Conceptual Solutions	•The user should be able to define how patterns have been used and applied in the Eastern and Western cultures.	•Create interactive media application. •Create a series of posters. •Make a reference guide.
Evaluate the Application	•Present information to potential users.	•Interview with students, artists or designers •Talk to the committee
Produce the Interactive Media	•The user should be able to recognize and understand this work about pattern in relation to culture.	•Map out all the major components of the interactive media application •Produce the application on computer.
Evaluate the Project	•After completing this project the user will be able to give me some good feed back.	•Develop questionnaire •Interview user about presentation level of understanding.

Methodology

Pattern

Based on order, and represented a blend of the organic and geometric: a synthesis of objective and subjective understanding of nature.

Pattern and Semiotics

Semiotics, a term derived from the Greek, is the theory of how different signs are constituted and classified according to their uses and interpretations. Semiotics also identifies symbols as a particular way of representing something. This involves acceptance of the convention and its sharing within a community. The sharing generates a uniform response to the symbol and tendency to define its integrity in interpretation. In this point, patterns are expected to be analyzed on semiotics.

Nadin, Mihai, and Richard D. Zakia. Creating Effective Advertising Using Semiotics (New York: The Consultant, 1994) 3, 67.

Pattern and Culture

Two ways of ascertaining whether a pattern is a culturally meaningful property. One way is to study its role in perception and how it is utilized in form recognition. The other is to study its occurrence in cultural context.

Pattern, Anthropology and Culture

Pattern arrangement appears to reflect culturally meaningful patterns of human behavior. Since the discovery and explanation of patterned human behavior is the essence of anthropology, it would seem that an analytical technique which can isolate behavior patterns consistently and objectively would be a grate asset for the study of certain kinds of cultural activities. Practically every culture in the world is known to decorate at least some portions of its material possessions with repeated patterns.

Washburn, Dorothy K., and Donald W. Crowe. Symmetries of Culture (Seattle and London : U of Washington P, 1988) 29.

Pattern and Design

Design is a multifaceted phenomenon which can be subject to a number of different categorizations. There is one kind of classification scheme which focuses on the attribute of design structure, an attribute which prior investigations have shown to be sensitive to problems of group identity, exchange, and interaction--problems which are foremost in the minds of anthropologists, archaeologists, and other humanistic theoreticians of behavior today.

Washburn, Dorothy K., and Donald W. Crowe. Symmetries of Culture (Seattle and London : U of Washington P, 1988) 41.

Symmetry in Perception

Cross-cultural studies suggest that symmetry is a salient feature which all peoples use, to greater or lesser degrees depending on their age and level of education, to assess forms, remember them, compare them with other forms, and reproduce them. That is, with differences in response time and accuracy of reproduction, all peoples use symmetry as diagnostic feature in the perception of form. Symmetry is as a cognitive perceptual universal, basic to the processing of all shape information. A culture's symmetries are part of that culture's cognitive organization map, and the classification of symmetries is a meaningful measure of the way members of a particular culture perceive their world.

Christie, Archibald H. Pattern Design (New York: Dover, 1969) 19-45.

Pattern and Religion

The early association of pattern--work with magico-religious ritual-- started ornamental development upon a path from which it broke a way only in comparatively recent times. Close contact with magic and religion connected ancient devices with a vital element of the culture prevalent when they came into being. Perplexing problems await those who examine these broad distinctions in detail, and would attempt a cult classification of pattern devices. The roads traversed by all ancient and modern religious movements as they spread, either by force of arms or by peaceful penetration, are strewn with symbolic devices left by the way. Every religion, as it expanded its sphere of action carried with it its own symbolic figures, and imposed them upon the system it found already in use.

Washburn, Dorothy K., and Donald W. Crowe. Symmetries of Culture (Seattle and London : U of Washington P, 1988) 24.

Thesis Timeline

	R I T	Thesis	Project
9.6			The First meetiing with Prof. Roger Remington Decide on Thesis topic
9.13			Meet with Dr. Richard Zakia Meet with Prof. Robert Keough
9.20			Confirm the Thesis Committee Turn in Proposal to the School of Art Situation analysis & mission statement
9.27			Goal/Objectives/Strategies
10.4			Timeline & Implementation plan
10.11			Pragmatics Dissemination Evaluation
10.18			
10.25			Thesis Proposal draft
11.1			
11.8	◀11.9 Last daytime class	Thesis Proposal due	Turn in Final Proposal
11.15	◀11.17 Fall/Winter break begins		Make list of book to research Gather more specific information about patterns Classify the list of information
11.22	◀11.24 Thanksgiving Day		
11.29	◀11.30 Winter class begins		
12.5		First Committee meeting Review Proposal	Gather information and research Semiotics
12.12			
12.19	◀12.20 Last date of classes before Holiday break		
12.26			Develop cross system on cultural, historical ground
New Year 1.3	Class resume		Database Category
1.10			Develop Posters

	R I T	Thesis	Project
1.17			
1.24			
1.31			Research and review all information
2.7			
2.14		Tentative Thesis meeting Review information, Database structure	Present the information to professionals and students in the field
2.21			
2.28	Winter break begins ◀3.3 Winter/Spring break ends ◀3.6 Daytime class begin		
3.7		◀3.13 First Thesis Show opens	
3.14			
3.21			Prepare Show
3.28	Class resume		
4.4		Second Thesis Show opens	
4.11			
4.18			
4.25		◀Third Thesis Show opens	
5.2		Evaluate Project	Begin writing Thesis book
5.9			
5.16		Signed by each committee member	Finished Thesis
5.23			Commencement

Evaluation Plan

Objectives	Evaluation Strategies
•The users should be able to identify the distinction between Eastern and Western.	The user will be given a questionnaire to fill out asking him/her to identify the distinction between Eastern and Western culture.
•The users should be able to identify the use of pattern in design.	The user will fill out a questionnaire and identify the use of pattern in design.
•The user should be able to define how patterns have been used and applied in the Eastern and Western.	The user will be asked to define the way patterns have been used and applied.
•The designer will present information to the potential users.	The user will be asked to compare in the aspect of culture.
•The user should be able to recognize and understand this work about pattern in relation to culture.	The user will be asked to discuss patterns in terms of cultural and historical background. The user will give feedback by semantic statements.
•After using this project the user will be able to give me some good feed back.	The user will be asked to use the applications and will answer question.

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Glossary of Terms

CONTINUANCE Relating forms of the components of forms to emphasize their differences in one or more aspects, such as shape, size, color, texture, direction, and/or position.

CULVILINEAR PATTERNS Showing the construction of the wave, the ogee, the net, and etc.

DAMASK On the plan of waved upright lines, crossed by horizontal bands of rosettes.

FIGURE A form or shape, determined by outlines or exterior surfaces.

FORM Any visual entity comprising all the visual elements of shape, size, color, and tex ture, suggesting or embodying plane and/or volume.

MOTIF A theme, or dominant recurring visual element, form, or subject.

MULTIPLICATION Creating multiple copies of a form.

PATTERN Frequence or widespread incidence.

Designs built up of devices repeated regularly in more or less compact compositions that conform so exactly to modern ideas of formal ornament as to be what are now recognized as 'patterns'.

Pattern necessarily implies a design composed of one or more devices, multiplied and arranged in orderly sequence.

Results from the repetition of an element or motif.

Repetition and variation.

A spot, a line, a shape, or an image repeated over and over and assume the result is a pattern.

To call such rudimentary instances of repetition 'patterns' is render the whole con cept of pattern quite meaningless.

Superficial decoration of form, and form as dictated by function.

Based on order, and represented a blend of the organic and geometric: a synthesis of objective and subjective understanding of nature.

Pattern is essentially two-dimensional: its ornament is surface ornament in rela tion to the structure, however plastic its expression may be.

Pattern is not only of representation, but also of rhythm: it tends to exclude illu sion in favor of symmetry.

RADIAL SYMMETRY A type of balance in which elements radiate from a centralpoint, producing a circular shape or form.

REFLECTION Flipping a shape to establish its mirrored image.

RELATION ELEMENTS Elements governing the placement and interrelationship of forms in a composi tion.

REPEAT A pattern composed of two or more identical elements, or units.

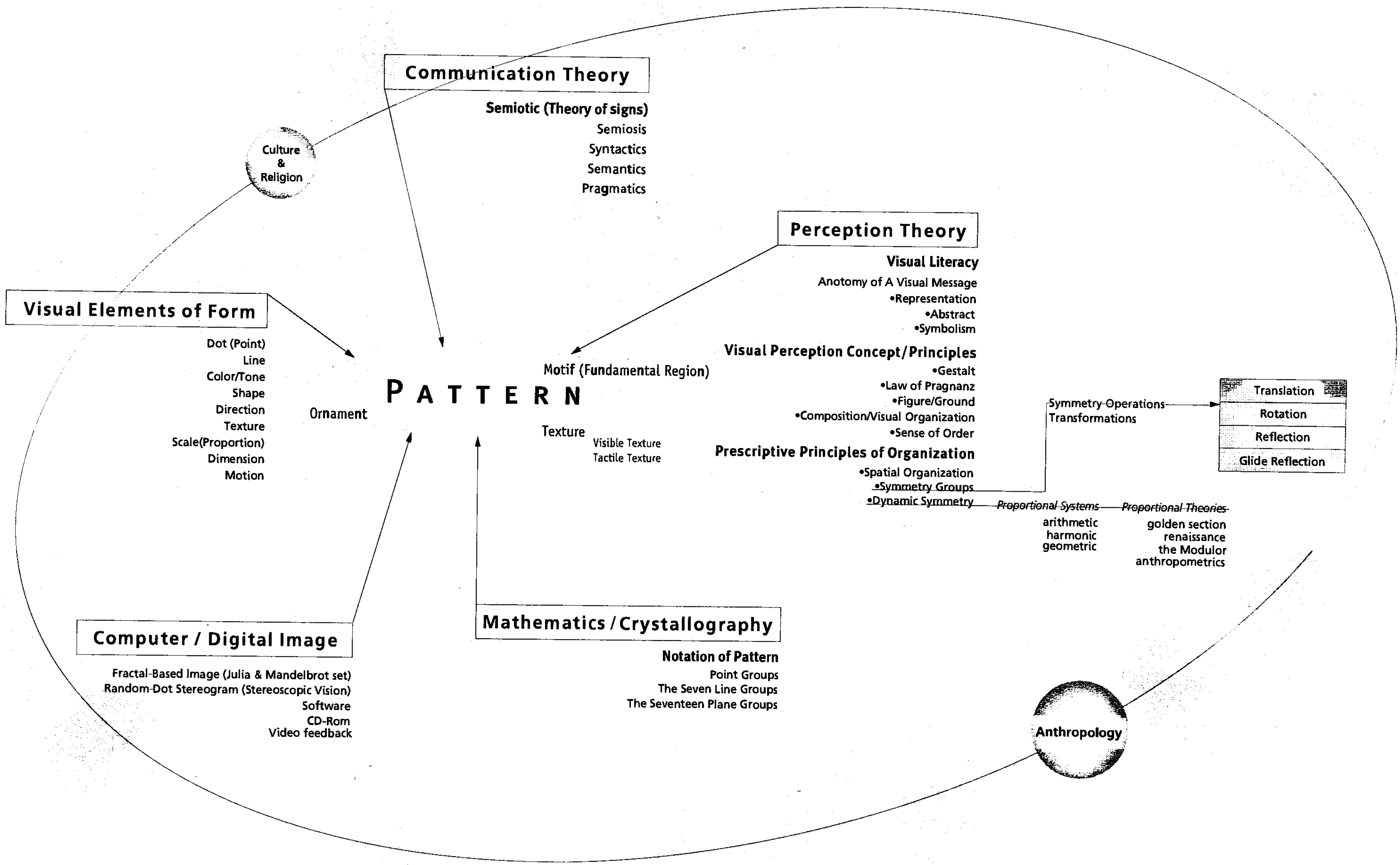
REPETITION Repeated use of one form. Generally, repetition of its shape, size, color, and tex-ture--as well as its direction, position, space, and gravity--but repetition can be restricted to shape or any specific element, with variation of the other element.

SHAPE The characteristics of a line or a plane, or the appearance of a form from a partic ular angle distance. A planar shape is normally defined by an outline and this can be filled with color, pattern, and/or texture. Shape is the most important element among the visual elements. Shape and form are sometimes used almost synony mously; but shape excludes all reference to size, color, and texture, while form encompasses all such elements.

SYMMETRY A shape or form with its mirrored image in a bilateral arrangement.

UNIT The figure that is the basic element of a pattern.

UNIT FORM A form used repeatedly in a composition.


Communication Theory
Semiotic (Theory of signs)
Semiosis
Syntactics
Semantics
Pragmatics
Culture & Religion
Perception Theory
Visual Literacy
Anotomy of A Visual Message
•Representation
•Abstract
•Symbolism
Visual Perception Concept/Principles
•Gestalt
•Law of Pragnanz
•Figure/Ground
•Composition/Visual Organization
•Sense of Order
Prescriptive Principles of Organization
•Spatial Organization
•Symmetry Groups
•Dynamic Symmetry
Symmetry Operations
Transformations
Translation
Rotation
Reflection
Glide Reflection
Proportional Systems
arithmetic
harmonic
geometric
Proportional Theories
golden section
renaissance
the Modulor
anthropometrics
Visual Elements of Form
Dot (Point)
Line
Color/Tone
Shape
Direction
Texture
Scale(Proportion)
Dimension
Motion
Ornament
PATTERN
Motif (Fundamental Region)
Texture
Visible Texture
Tactile Texture
Computer / Digital Image
Fractal-Based Image (Julia & Mandelbrot set)
Random-Dot Stereogram (Stereoscopic Vision)
Software
CD-Rom
Video feedback
Mathematics / Crystallography
Notation of Pattern
Point Groups
The Seven Line Groups
The Seventeen Plane Groups
Anthropology

Appendix 3

Appendix 4

Quotes and Notes

Proportion and symmetry are beautiful all over the world! Plato

See how various the forms and how unvarying the principles. Owen Jones

The repetition of the same pattern side by side produces another or several others. Owen Jones

The important point for us to observe is that all these constructions and the laws connecting them can be arrived at by the principle of looking for the mathematically simplest concepts and the link between them. Albert Einstein

An image too may be from mirror into mirror handed on. Lucretius

Where order in variety we see, and where, though all things differ, all agree. Alexander Pope

One can hardly overestimate the depth of geometric imagination and inventiveness reflected in these patterns. Their construction is far from being mathematically trivial. The art of ornament contains in implicit form the oldest piece of higher mathematics known to us. Herman Wey

What can be the reason of my being alone in this field? Why does none of my fellow artists seem to be as fascinated as I am by these interlocking shapes? Yet their rules are purely objective ones, which every artist could apply in his own personal way! M. C. Escher

All things began in order, so shall they end, and so shall they begin again; according to the ordainer of order and mystical mathematics of the city of heaven. Thomas Browne

Aesthetic feelings arise primarily because of an unusual degree of harmonious interrelation within the object. George David Birkhoff

The whole and each particular member should be a multiple of some simple unit. Owen Jones

Every detail should bear a defined relation to the general composition. Viollet-le-Duc

Our experience hitherto justifies us in believing that nature is the realization of the simplest conceivable mathematical ideas. Albert Einstein

In summary, a work of art should induce a sensation of mathematical order, and the means of inducing this mathematical order should be sought among universal principles. Le Corbusier and Ozenfant

It's most remarkable that order can be the same for everyone and design can be so different. Louis Kahn

Symmetry principles appeals to human aesthetic sensibilities as well. Istvan Hargittai

Geometrical properties are characterized by their invariance under a group of transformations. Felix Klein

So pattern, even if a technique of relief is employed, is essentially two-dimensional; its ornament is surface ornament in reaction to the structure, however plastic its expression may be. Pattern is an art not only of representation, but also of rhythm; it tends to exclude illusion in favor of symmetry. Pattern in wide sense exists in everything possessing mass and proportion, form and color, that is seen in relation to a define space.

Pattern is essential to beauty; but if it is taken in the restricted sense of applied ornament beauty can well exist without it, since proportion of mass, of form, and of color can have their being in the actual structure of any creation, independently of any added diversification. on the other hand, pattern itself must rely for its beauty on this essential balance of mass, form, and color, so that in pattern as well as in structural design the principles of harmony can be expressed, studied and revealed.

Art and science are very different, but they both spring from cultivated perceptual sensitivity. They both rest on a base of acute pattern recognition. At the simplest level, artists and scientists alike make it possible for people to appreciate patterns which they were either unable to distinguish or which they had learned to ignore in order to cope with the complexity of their daily lives. Frank Oppenheimer

Once is an instance. Twice may be an accident. But three times or more makes a pattern. We crave something familiar in a chaotic world. Thought has its precincts, where the cops of law and order patrol, looking for anything out of place. Without pattern, we feel helpless, and life may seem as scary as an open-backed cellar staircase with no railing to guide us. We rely on patterns, and we also cherish and admire them. Few things are as beautiful to look at as a ripple, a spiral, or rosette. They are visually succulent. The mind savors them.It is a kind of comfort food. Feast here on some of the wonders in nature's pantry. Diane Ackerman

Whilst the mathematical laws governing living shapes and living growth were thus shown to fit in curiously with the theories and patterns of Greek and Gothic Aesthetics, discovered by the archeological line of investigation, still a third school of thought and research contributed to the revival of mathematical Aesthetics. Matila Ghyka

Some people can read a musical score and in their minds hear the music.... Others can see, in their mind's eye, great beauty and structure in certain mathematical functions.... Lesser folk, like me, need to hear music played and see numbers rendered to appreciate their structures. Peter B. Schroeder

Surely, among the most important goals of every geometrical instruction is the strengthening of the faculty for spatial imaging and the power for spatial modelling. Arthur Schoenflies

Mathematics anxiety derives those arfflicted of access to the grammar needed to express oneself spartially. Arthur L Loeb

In the growth of a shell, we can conceive no simpler law than this, namely, that it shall widen and lengthen in the same unvaring proportions: and this simplest of laws is that which Nature tends to follow. The shell, like the create within it, grows in size, but does not change its shape; and the existence, and may be made the basis of a definition, of the equiangular spiral. D'Arcy W. Thompson

Appendix 4

Texts on Applications

The theoretical concepts of symmetry deal with group theory and figure transformations. Figure transformations, or symmetry operations refer to the movement and repetition of an one-, two-, and three-dimensional space.

Paul Klee's Pattern is consisted of visual elements, dots, lines, planes. Steps in the form generation process, as out lined by Paul Klee. The point moves into a line, the line into a plane, and the plane into a volume.

Fractal is a branch of mathematics that reveals patterns in a coastline, swings of commodities prices, and properties of new materials such as aerogels. The brainchild of maverick mathematician Benoit Mandelbrot, who coined the term in the 1970s and popularized it in the 1980s, fractal allowed him to eschew traditional geometric analysis in favor of his own flair for visualizing phenomena. Among his discoveries is Z2+C, the Mandelbrot Set, which relies on digital computers to distinguish the simplest boundary between chaos and order. It's graph is a colorful design, the result of aniterative feedback loop, with different colors representing this recursive equations acceleration toward infinity. Jeffrey Goldsmith

One of the most practical applications of symmetry is tiling--the seemingly endless repetition of some basic motifs following some rules, simple or sophisticated, to cover an entire surface. Tiling can be used to decorate or investigate properties of geometrical shapes. Tiling pattern is usually displayed by a single motif or by only a few motifs of interesting shapes, without gaps and overlaps. Repetitive interlace patterns are one of the hallmarks of **Islamic and Moorish art**. Through the study of various collections of such pattern, it is easy to verify that, despite the considerable complexity of the design, most of the interlaces are formed by strands of a small number of shapes--often just a single shape stretching over many repeats of the design.

Symmetry is often defined as the rhythmic repetition of like shapes, in nature or in designs made by human hands. It is a fundamental concept in both art and science, used to analyze, create, order, classify, and explain. **Maurits C. Escher** 's use of symmetry was unusual in many respects: he did not merely fit congruent shapes together to form decorative patterns but made recognizable shapes in contrasting colors whose interpretation challenge the viewers' sense of perception.

Once ancient man began to live in communities, various taboos came into being regarding his way of life. Together with the concept of revering heaven, a totemist belief system came to control life. To Eastern cultures, clouds eventually came to symbolize longevity and immortality, the greatest desires of mankind from the most ancientimes on. Man began the practice of sacrificial rites in order to ask the spirits to grant this wish, and he made the cloud image its symbol. Cloud shapes were carved on sacrificial utensils in the hopes that the desires they symbolized would reach heaven. **The cloud motifs** appear in descriptions of the realm of heaven that are scattered through ancient legends, and serve as symbolic representations of this ideal realm. These representations can be found in the depictions of heaven drawn on tomb murals, in the colorful designs of architectural decorations, on clothing, and on utensils.

Pattern arrangement appears to reflect culturally meaningful patterns of human behavior. Since the discovery and explanation of **patterned human behavior** is the essence of anthropology, it would seem that an analytical technique which can isolate behavior patterns consistently and objectively would be a grate asset for the study of certain kinds of cultural activities. Practically every culture in the world is known to decorate at least some portions of its material possessions with repeated patterns.

tàijí strands for both a concept in Oriental Philosophy and the graphical symbolizations of that concept. The name has been variously translated as *the supreme ultimate, the great primal beginning,* and even, following the Chinese characters literally, *the great ridge pole...* The basic idea is that the fundamental substance of all things is a unitary, indescribable, unnameable something that has nevertheless been called, for convenience's sake *Tao.* The Tao has two elemental modes of operation or states of being: ***Yin and Yang***.

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Appendix 6

Glossary

AIFF	Audio interchange File Format. A standard Macintosh sound format for different applications.
Algorithm	A procedure for solving a particular problem. Devising an algorithm in essence means formulating a method by which the solution to a problem may be found.
Alpha channel	An 8-bit channel reserved by some image-processing applications for masking or additional color information.
Anti-aliasing	The rendering of hard-edged objects so they blend smoothly into the background.
Arabesque	Surface decoration of rhythmic, fancifully intertwined linear patterns of flowers, leaves, scrollworks, etc.
Art and Craft Movement	An English-based movement begun about 1850 and dominated by the theories of William Morris. It strove to raise the artistic level of industrial design and to integrate high aesthetic principles with fine workmanship.
Art Nouveau	A style of decoration that found expression in architecture and items of interior design, illustration, and dress. Highly stylized, organically flowing plant forms are the most common design motifs of art nouveau, which was chiefly an American and European movement that crested in popularity between1895-1905. It was known by various names in different countries: "Jugenstil" in Germany, "Stile liberty" in Italy "modernism" in Spain.
ASCII	American Standard Code for Information Interchange. A standard scheme for encoding alphanumeric characters so that they can be stored in the computer. Each character input from the keyboard is represented by 7 bits.
Asymmetry	Lack of symmetry, designating an unequal spatial arrangement.
Axiom	An axiom is a statement that is assumed to be true without proof. Axiom is a syninym for postulate.
Batik	A form of resist dyeing in which non-printing areas are blocked out wax, which cracks in the dyeing process, causing a background of linear texture.
Bilateral symmetry	Symmetrical balance in which a central axis cutting through the design would produce two identical mirror image.
Bit map	Images or fonts that are described as pixels. Commonly used to black & white images as opposed to grayscale or color ones.
Cast member	The term that Macromedia uses to describe a single graphic element, sound, movie or animation within Macromedia Director.
CINEPAK	Video compression method developed by Radius, a leading company in video digitizing hardware and software. This is compression algorithm is characterized as long compression time but with high ratio of file size to image quality, thus achieve smooth playback which is commonly used on CD-ROMs.
CD-ROM	Compact Disc-Read Only Memory. A format for storing computer data or compressed audio or video data on a compact disc in digital format. One CD has the capacity to store up to 650MB of data.
Chiral	Describes an object that cannot be superimposed on its mirror image.
CMYK	A color generation where any color is produced by mixing combinations of cyan, magenta and yellow. It is the basis of many printing systems, where a fourth color black(k) is added to provide greater depth of contrast. Images in such printing systems are often referred to as CMYK.
Compression	Encoding a file, image, sound, or movie with a special algorithm to reduce space requirements for storage or transmission.

Appendix 6 Glossary

Continuity Relating forms of the components of forms to emphasize their differences in one or more aspects, such as shape, size, color, texture, direction, and/or position.

Contour In two-dimensional representation, the line that represents the edge of a form or group of forms. The outline or outmost edge of a plane that defines its shape.

Crystallography The study of the external form of the crystals and their internal structures, i.e. the arrangement of atoms in them.

Culvlinear patterns Showing the construction of the wave, the ogee, the net, and etc.

Cylindrical symmetry The top and bottom of a cylindrically symmetrical object may be different, but every thing is the same all around its vertical axis.

Decorative Art Imprecise collective term for such art forms as ceramics, enamels, furniture, glass, ivory, metalwork, and textiles, especially when they take forms used as interior decoration.

Decorative design Embellishment or enrichment of the surface of an object, either through the structural process or by application after the structure is completed.

DPI Dot per inch. A unit measurement for screen display and printing resolution.

E-mail Electronic mail. Messages sent and received with computers. Massages may be sent and stored for later retrieval.

EPS Encapsulated PostScript. A file format used to transfer PostScript image information from one program to another.

Fibonacci series A discovery by Renaissance scholar Leonardo da Pisa in which the law of natural growth are found to follow a specific mathematical pattern.

Figure The positive shape or form occupying space.

File format A standardized way of storing visual documents in the computer for future use or for further manipulation.

Flatbed scanner A digitizing scanner rather like a photocopier, with a flat glass bed. Flatbed scanners are available for b/w(line), grayscale(tone) or full color image digitizing.

Fractal A term invented in the 1960s for geometry that focuses on "fractured" or broken uneven shapes.

Fret A type of ornamental pattern, seen in many variations, consisting of straight lines joining at right angles, sometimes intersecting other such lines at right angles.

Geometry shape A shape composed of straight line and/or circular arcs.

Gestalt Theory The principle that maintains that the human eye sees objects in their entirely before perceiving their individual parts. From the German word for "form," it is based on psychological theory.

Golden ratio A geometrical proportion known at least since Euclid and regarded as a universal law of the harmony of proportions in both art and nature. The common formula is: to divide a finite line so that the shorter part is to the longer part as the longer part is to the whole.

Grid Non-printing line pattern to help arrange shapes in a formal organization.

Ground Negative space occupying the void in the background.

GUI Graphical User Interface. The way which users relate to the equipment they operate. A computer's ability to handle data so fast that the user perceives no The measure of how detailed and fine an image is.

Appendix 6 Glossary

Half-tone Dot or line pattern used in printing to represent grayscale, particularly in the reproduction of photograph.

Hue The quality that distinguishes a color from all other colors in the color wheel. The name of a color.

Icosahedron An icosahedron is a 2D shape with six equal sides and equal angles in its corners.

Interactive multimedia The generic term for programs and applications that include a variety of media (such as text, images, video, audio and animation), the presentation of which is controlled interactively by the user.

Interlace Decoration formed of entwined, interwoven linear elements.

Lattice A visual structure system that can be used in conjunction with symmetry operations transformations in the creation of compositions.

Line of Symmetry A line of symmetry is the line that divides an object into two halves that are the same.

Lingo Name given by Macromedia to Director's scripting environment or language.

Logarithmic spiral The spiral found in biological forms representing growth patterns that increase in size without changing shape.

Madelbrot Set The Mandelbrot Set, discovered by Benoit Mandelbrot, is a famous fractal, i.e., a shape containing an infinite amount of fine detail.

Modula Characterized by repetitive and/or interconnecting units that can be assembled in different ways.

Moirê An optical phenomenon created by the interference of waves. The pattern can be observed by layering two pieces of striped transparent material that are slightly offset.

Mosaic A surface decoration made by inlaying small pieces of various colored material to form pictures or patterns.

Motif A theme, or dominant recurring visual element, form, or subject.

Multi-media Any form of communication through the use of multiple components such as sound, movies, animation, graphics or interactively.

Negative shape A shape that appears as a hole or gap with the background showing through.

Online service A service that offers electronic mail, conferences, chat, information resources, and other content and communication services. Users connect to online services through the use of computers, modems, and phone lines.

OS Operating System. A program that manages the resources of a computer, such as the input/output devices, memory, file retrieval and so forth. The operating system is loaded into the computer when it starts up, and supervises the running of other programs and application.

Pattern Design composed through the repetition of one or more visual elements and attributes within a single composition.

Pixel Short for picture element, a pixel is one dot of a screen image. On the Macintosh it is 1/72 of an inch square.

Ornament An attractive design in the plane or space whose part obey the symmetry of a point group or of a space group.

PICT A standard data format in which many Macintosh illustrations are encoded. Data can be created, displayed on a screen, and printed by routines incorporated in the Macintosh system.

Glossary

Permutation	A transformation of a finite set of objects to itself in such a way that distinct objects are transformed to distinct objects.
Periodic	A periodic function is a function that keeps repeating the same values.
Point group	Crystallographic terminology used to indicate the group of all the operations of geometric symmetry of an object that leave invariant at least one point of that object.
Postscript	A scripting language developed by Adobe Systems in the 1980's.
Photo CD	An image file format and color standard conforming to Kodak's specifications for CD photo finishing.
Pragmatics	The branch of semiotics that deals with the relationships among signs, symbols, and their users.
Quasi crystal	Discovered in 1984, these crystalline-like substances display symmetries in their atomic patterns that are impossible in periodic patterns.
Quicktime	An animation format that is complied by a series of PICTS and audio developed by Apple Computer Inc. A standard data format in which many Macintosh illustrations are encoded.
Radial symmetry	A type of balance in which elements radiate from a central point, producing a circular shape or form.
Randomness	A condition characterized by a lack of visual relationships or systematic arrangement among elements in a format.
Repetition	Repetition is the use of the same compositional figure or form more than once in the same format.
Resolution	The measure of how detailed and fine an image is. Measure of the detail in an image. Images are measured pixels (dots) per inch, and in the number of bits used to describe the color values at each pixel.
RGB	Red. Green, and 8lue. A model for defining color within a computer system which assigns values to the percentage of the three primary colors of light which make up a color.
Rhythm	A recurrence or repetition of visual elements ina regular, harmonious pattern. The degree of purity and brilliance in a color.
SCSI	Small Computer System Interface. An industry-standard interface between computers and peripheral device controllers.
Semantics	The relationships among signs and symbols and objects they represent.
Semiotics	The theory of signs first wet of Charles Peirce. Semiotic describes relationships between signs and their referents. Semiology is the term used in Europe.
Space group	Crystallographic terminology used to indicate the group of all the operations of geometric symmetry possible in a discrete pattern, infinitely extended in the plane or in space, which exhibits the transitional periodicity of a lattice of points.
Spherical symmetry	Everything is the same in all directions (as if on the surface of sphere)
Static	Describes a composition of figures or forms that appear to be at rest and visually balanced.
Tactile texture	Texture that can be felt with hand.
Symmetry	The correspondence between opposite halves of a figures or forms that appear to be at rest and visually balanced. The correspondence in size, shape, and relative position of parts on opposite sides of a median line or about a central axis.

Appendix 6 Glossary

Symmetry operations — The specific rules that govern the position, orientation, and act in of a figure as it is repeated to create a compositional group or pattern.

Syntactics — The study of the formal properties of signs and symbols and their relationships to other signs.

Tessellate — Tessellate is to cover a surface with polygons without leaving any space between.

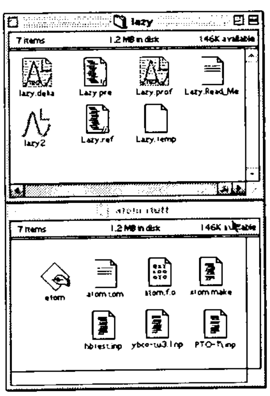
Texture — Dots, lines, or tiny shapes spreading evenly or unevenly over a surface.

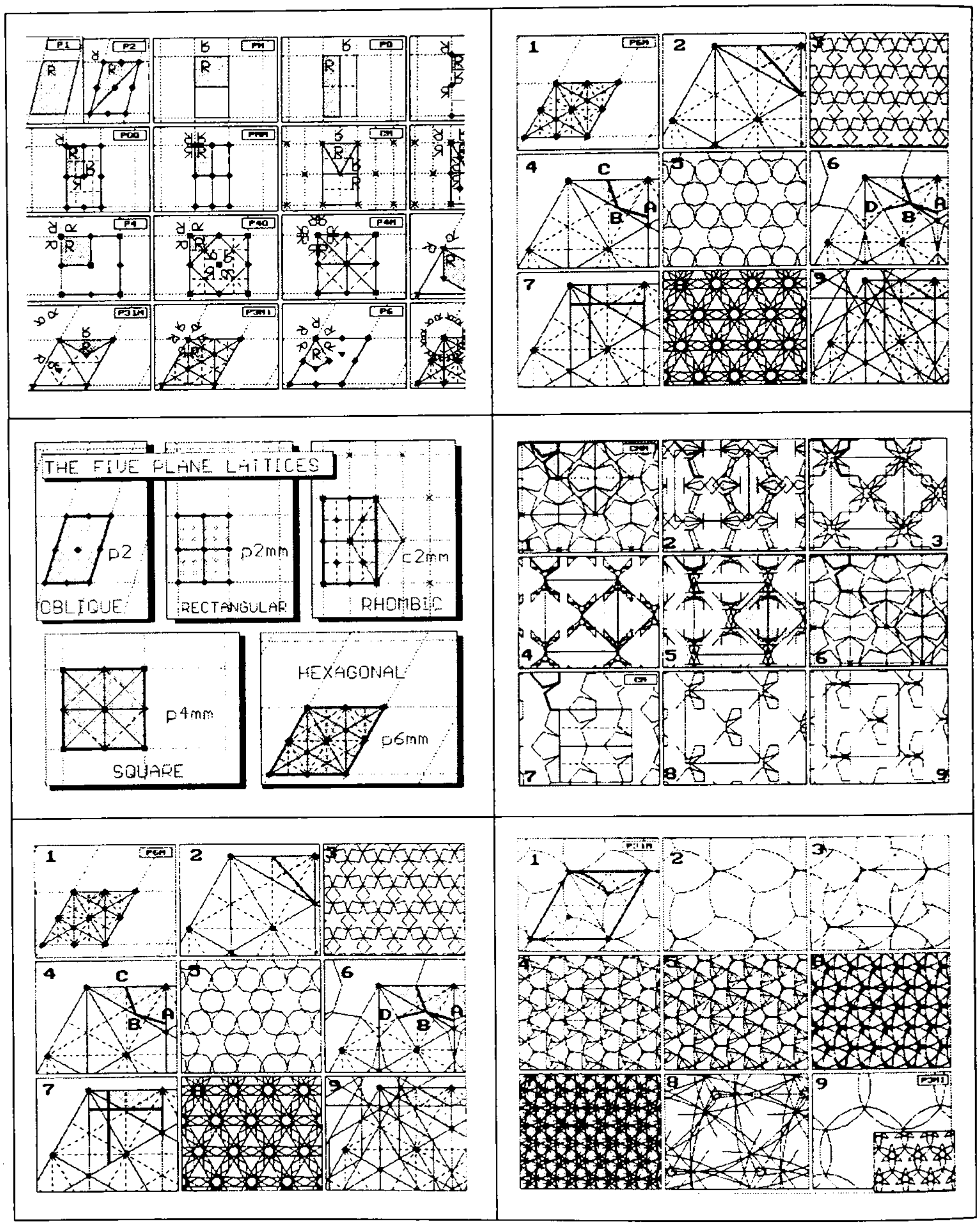
TIFF — Tagged Image File Format A file format used to represent black-and-white, grayscale, or color bit mapped images, particularly those produced by scanners.

Visible texture — Texture that can be seen by the eye but cannot be felt with hand.

Appendix 7. a

SYMPATI & LAZY



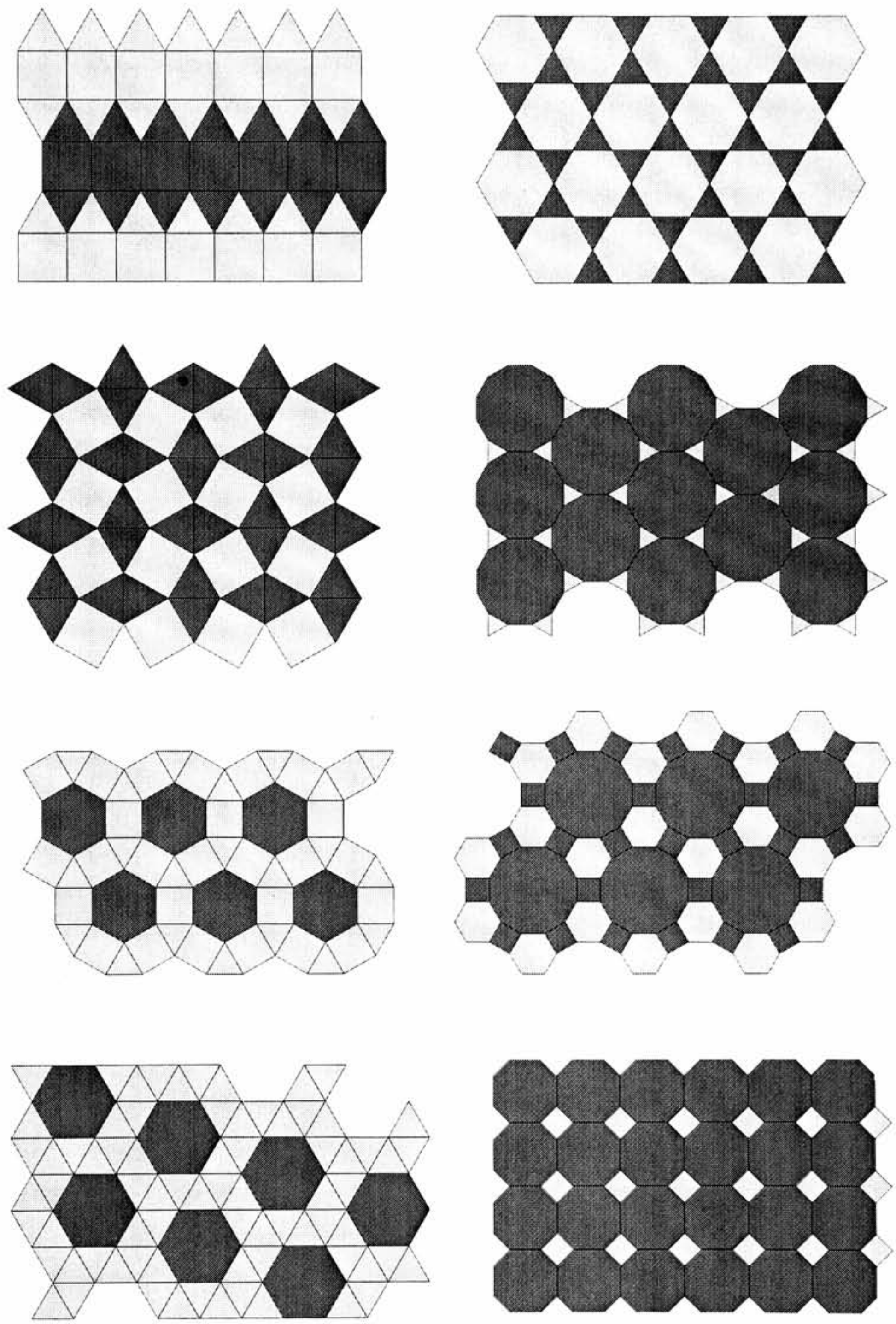


SYMPATI (SYMmetry PATtern Interaction) is an interactive graphics package for use in am IBM compatible PC with MS-DOS environment.

The regularity of these tilings is sufficiently pleasing to the eye that each will make an attractive pattern for tiling a floor, perhaps to complement one of the seventeen basic wallpaper patterns considered earlier.

Tiling

Appendix 7. b



Any such tiling of the plane must have as its symmetry group one of the seventeen groups of wallpaper.
Keith Devlin,
Mathematics; The Science of Patterns (1994)

M. C. Escher's Art Work On Symmetry Operation

Appendix 7. c

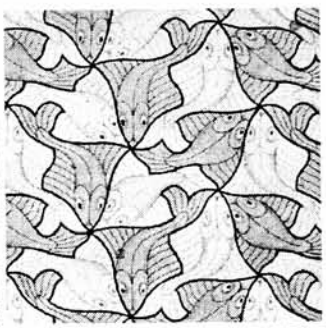
p1

p2

p3

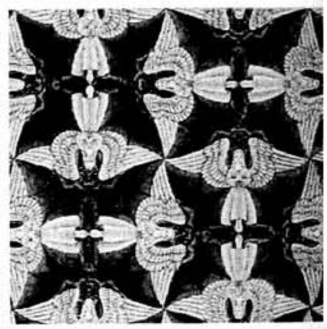
p4

p6



p2gg

p3m1

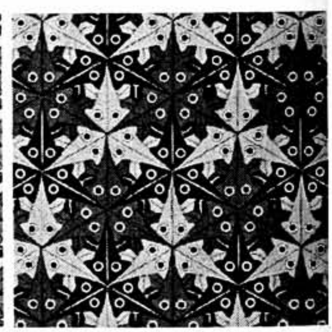


p4gm

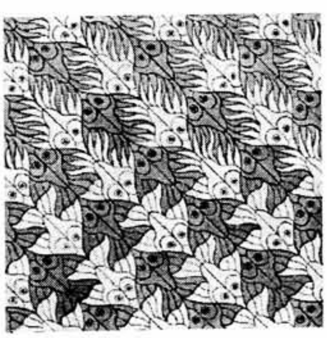
p2mm

cm

pg



p31m



p2mg

The Regular Division of the Plane

Doris Schattschneider, M.C. Escher, Visions of Symmetry (1990)

Escher repeatedly emphasized that the regular division of the plane interested him more than any other subject that he dealt with in his work. Escher's system follows:

- Rectangles a. one motif and two colors ; b. one motif and three colors; c. two motifs and three colors.
- Triangles a. with threefold rotation points; b. with sixfold rotation points; c. with three-and sixfold rotation points.

Escher's system is not particularly satisfactory from a logical point of view because different vantage points are used for each subdivision. The mathematical system that is used in crystallography is logical, and some parts of this were adopted by Escher. There are four different ways in which the duplicate can be moved;

1. Translation

2. Reflection

3. Glide Reflection

4. Rotation

The list continues. Every wheel with spokes, cogs, or paddles represents a point group. The group of highest of infinite order is the circle, which has complete rotational symmetry.

Appendix 7. d Point Group

Group 1
It repeats only under the operation of a full 360˚ rotation.

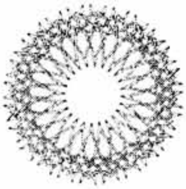
Group m
The addition of a mirror to an asymmetric motif produces a pattern with bilateral symmetry.

Group 3
Three rotation bring a group-3 pattern into coincidence with itself: a 120˚ rotation, a 240˚ rotation, and 360˚ rotation.

Group 4
Four fold rotation charaterizes the pattern of group 4. Any two idential lines that radiate from the rotocenter and are separated by 90˚ mark the boundaries of the fundamental region.

Group 5
The pattern of group 5 is charaterized by five fold rotation.

Group 24
Twenty four fold rotation charaterizes the pattern of group 24.

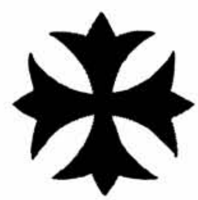


Group m
The addition of a mirror to an asymmetric motif produces a pattern with bilateral symmetry. A full rotation about a central point brings the pattern into coincidence with itself.

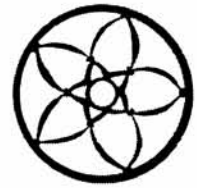
Group 2mm
The figure of group 2mm ensures that it will appear the same right-side-up and upside-down, that it will have an identical appearance after a turn through 180˚.

Group 3m
Group 3m patterns have three bilaterally symmetric arms spaced at 120˚.

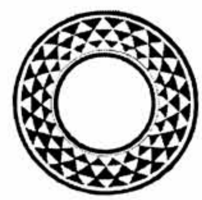
Group 4mm
Four intersecting mirrors produce the pattern of group 4mm. The fundamental region is one-eight of circle and bounded by mirror lines.



Group 5m
The symmetry of five intersecting mirrors, which characterizes group 5m. The fundamental region of the pattern is a 36˚ sector bounded by mirror lines.



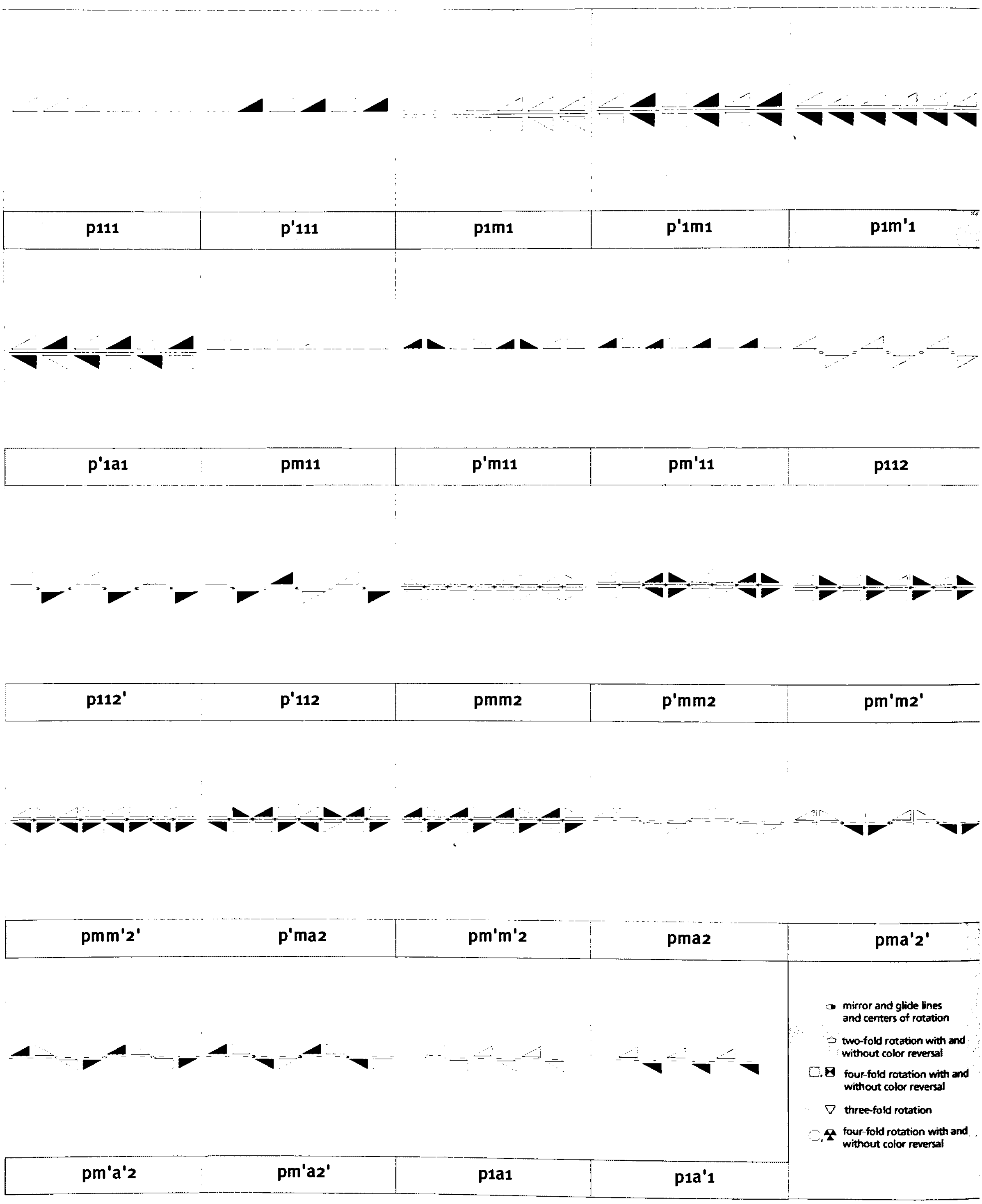
Group 24mm
Twenty four intersecting mirrors produce the pattern of group 24mm.



The group of highest or infinite order is the circle, which has complete rotational symmetry.
Peter S. Stevens
Handbook of Regular Patterns. (1981)

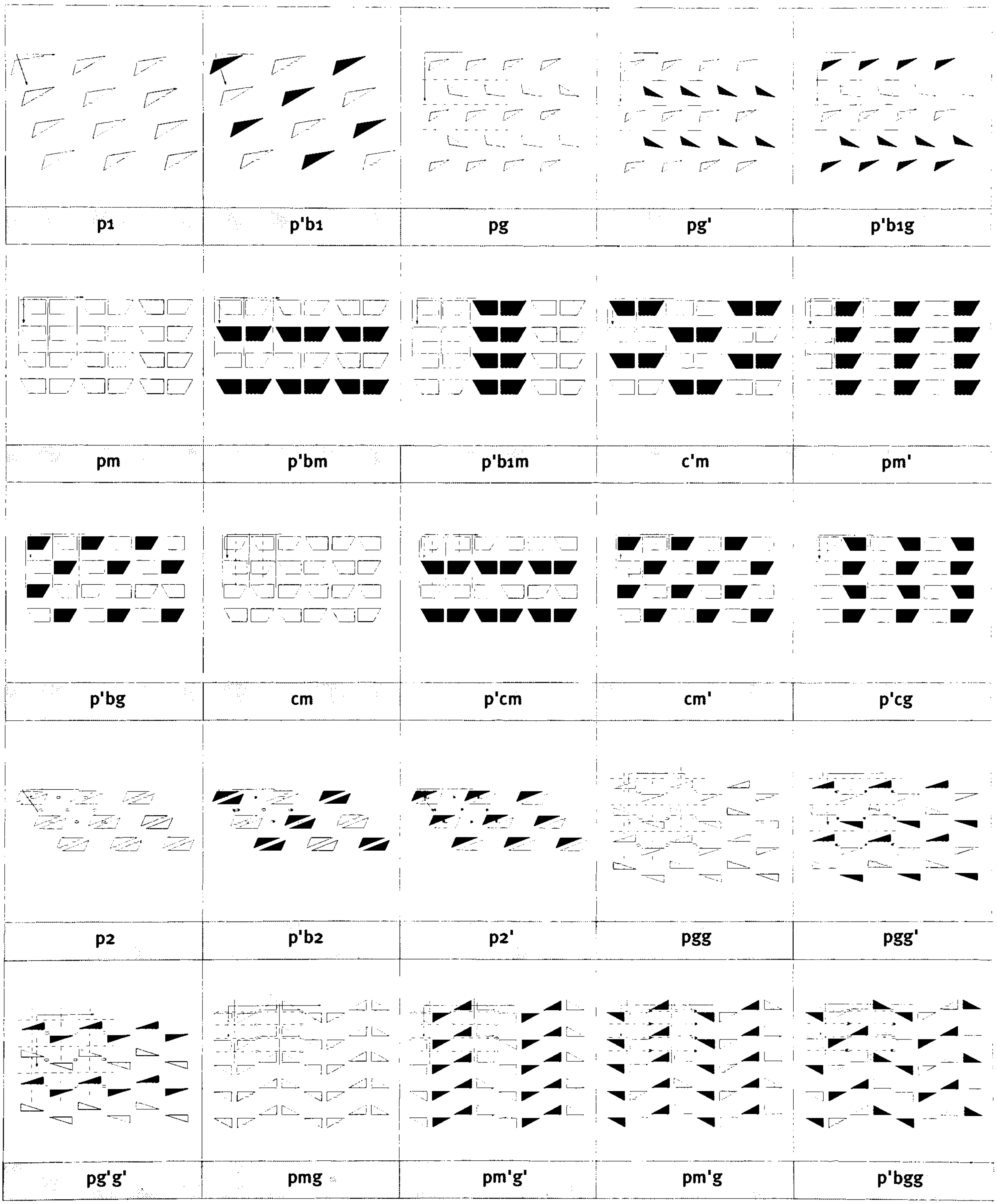
Appendix 7. e

7 One Color & 17 Two Color-One Dimensional Patterns



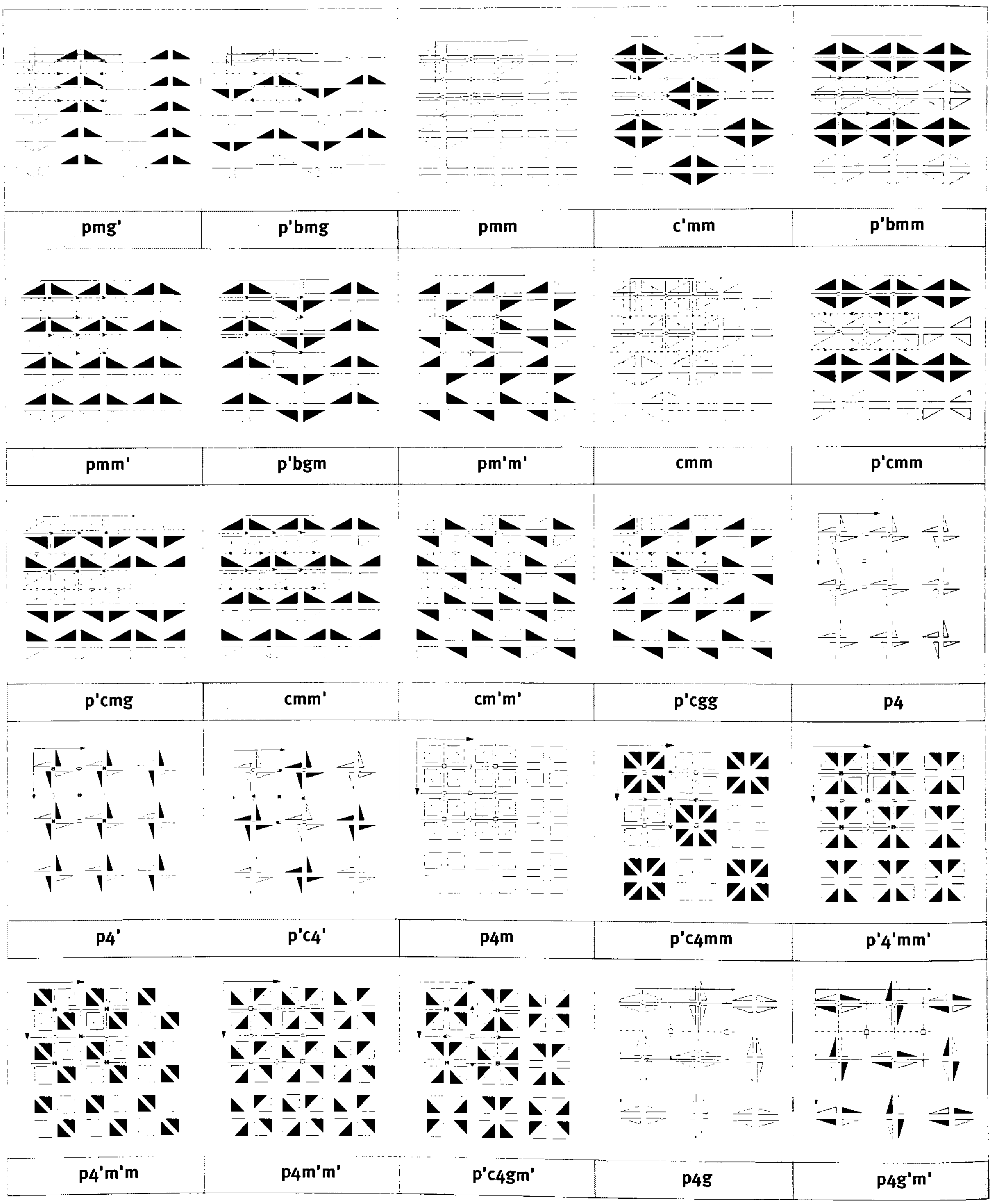
Appendix 7. f

17 One Color & 46 Two Color-Two Dimensional Patterns 1



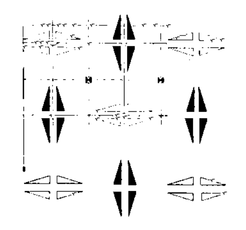
Appendix 7. f

17 One Color & 46 Two Color-Two Dimensional Patterns 2

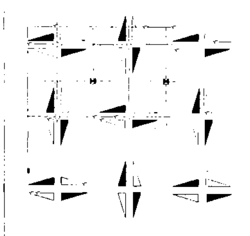


Appendix 7. f

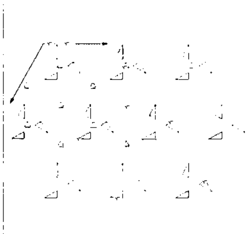
17 One Color & 46 Two Color-Two Dimensional Patterns 3



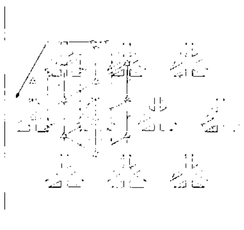
p4'g'm



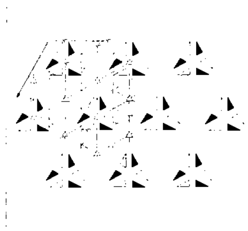
p4'gm'



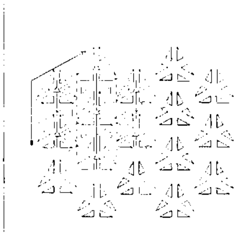
p3



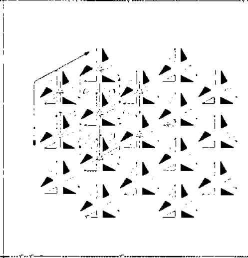
p3m1



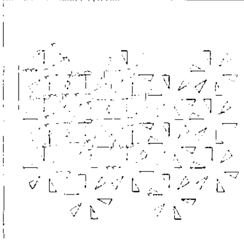
p3m1



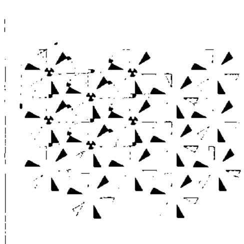
p31m



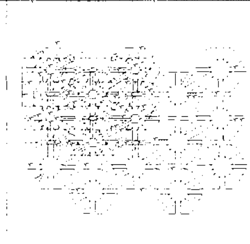
p31m'



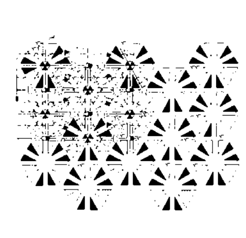
p6



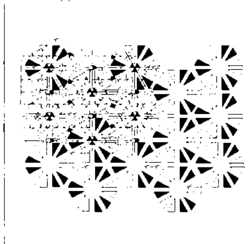
p6'



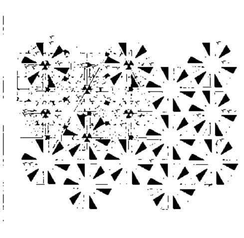
p6m



p6'm'm



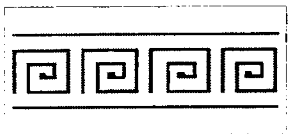
p6'mm'

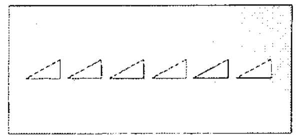


p6m'm'

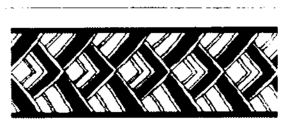
Appendix 7. g

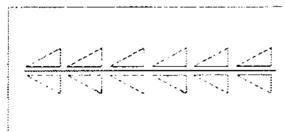
Multi-Cultural Patterns of One-Dimensional Symmetry Group

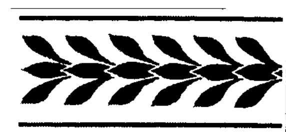

Chinese

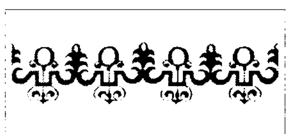

p111

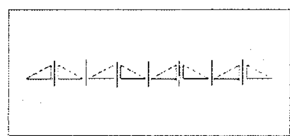

Chinese

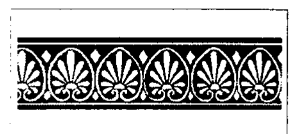

Persian


p1m1

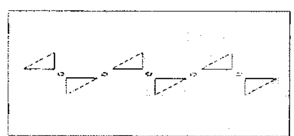

Persian

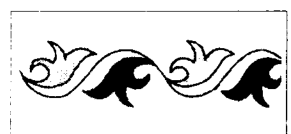

French, 17C

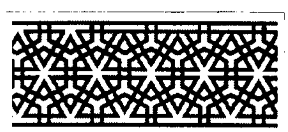

pm11

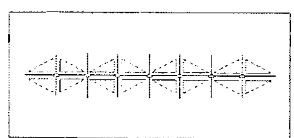

French. 17C

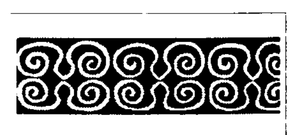

Chinese


p112

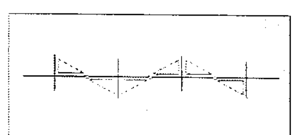

Chinese

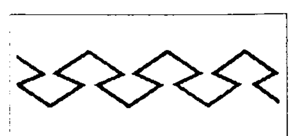

Chinese

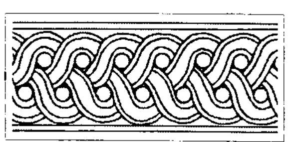

pmm2

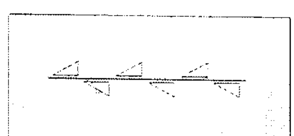

Chinese

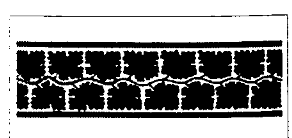

Chinese/Ancient Greek


pma2


Chinese/Ancient Greek


Ancient Greek

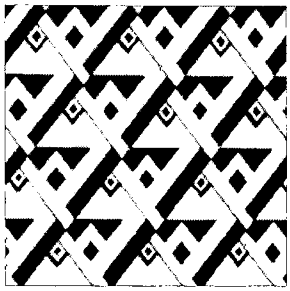

p1a1


Ancient Greek

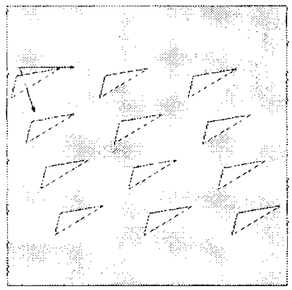
Appendix 7. h Multi-Cultural Patterns of Two-Dimensional Symmetry Group 1

Group p1

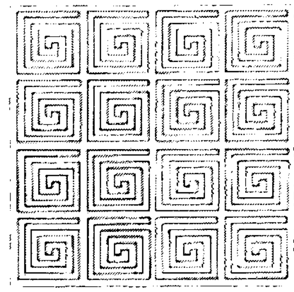
Group p1 pattern contains group1 motifs and no reflections. The designation p1 reveals that the corners of the primative cell p mark points with group1 symmetry.



Inca,Pre-Colombian Peru



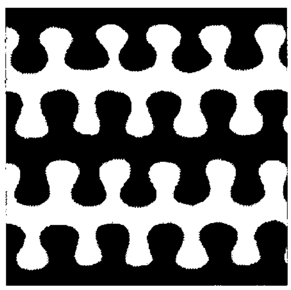
p1



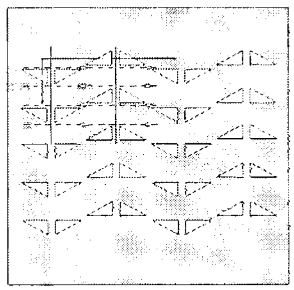
Chinese

Group pmg

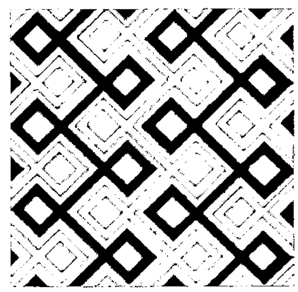
group pmg has both mirror reflections and two-fold rotations. Glide reflection axes pass between the units, perpendicular to the mirror axes. Zigzag pattern is the most recognizable form.



Medieval heraldic



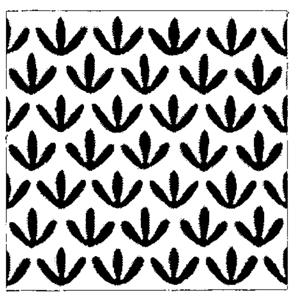
pmg



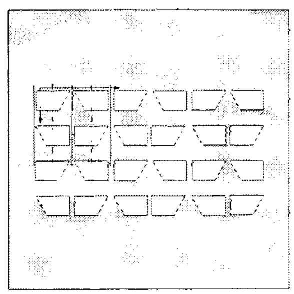
Arabian

Group cm

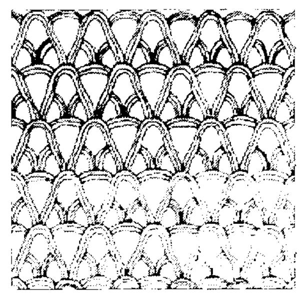
Group cm is a staggered form of group pm. The stagger occurs along lines of glide reflection between the mirror lines.



Pre-historic, New Mexico



cm

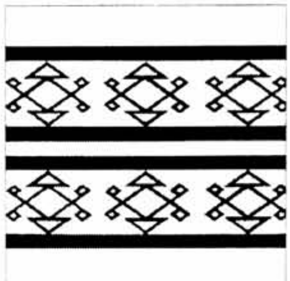


Mesopotamian

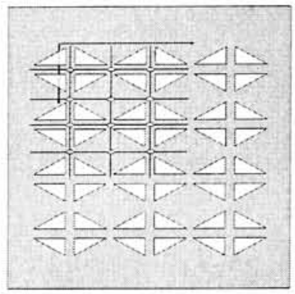
Appendix 7. h Multi-Cultural Patterns of Two-Dimensional Symmetry Group 2

Group pmm

Group p1 pattern contain group1 motifs and no reflections. The designation p1 reveals that the corners of the primative cell p mark points with group1symmetry.



Ancient Rome



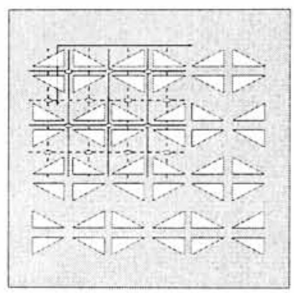
pmm

Romanesque

Group cmm

Structure class is similar to pmm exept that the units are offset so that glide axes is pass midway between the mirror axes in both directions. Two-fold centers are located on all intersections of mirror axis with mirror axis and glide axis with glide axis.

Medieval



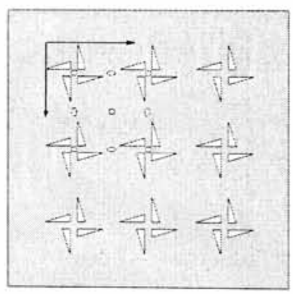
CMM

Japanese

Group p4

These have both two-fold and four-fold centers but no mirror reflections or glide reflections. The fouf fold centers are located at the center of units made up of four rotating a symmetrical parts.

Ancient Rome



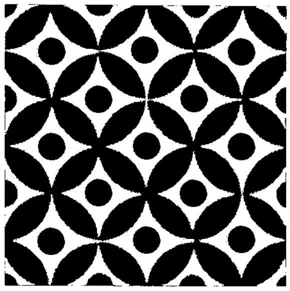
p4

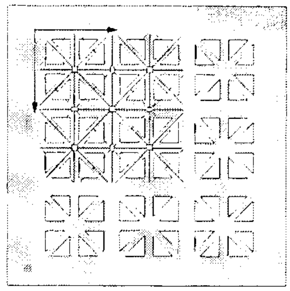
Egypcian

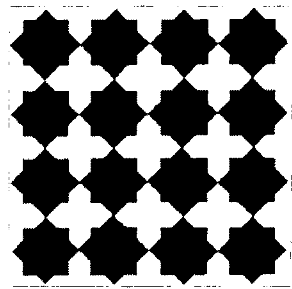
Appendix 7. h Multi-cultural Patterns of Two-Dimensional Symmetry Group 3

Group p4m

Group p4m is found as a grid of squares. There are mirror axes in four directions as well as glide axes in two directions.

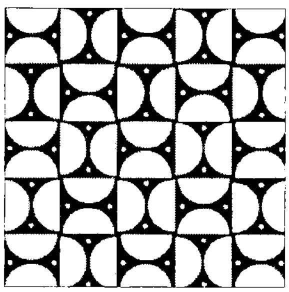

Ancient Rome

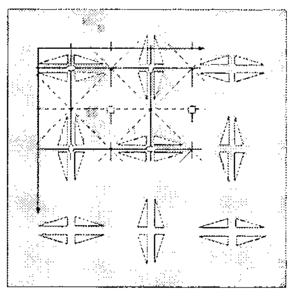

p4m

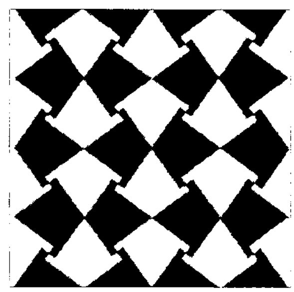

Islamic

Group p4g

These patterns have glide reflections in four directions, and mirror reflections in two of those directions. Glide axes lie half way between, and parallel to, the mirror axis, as well as diagonal to the mirror axis.

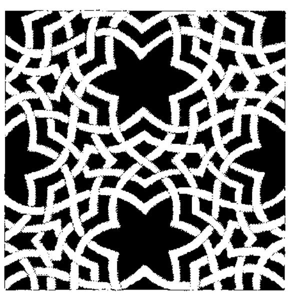

Medieval

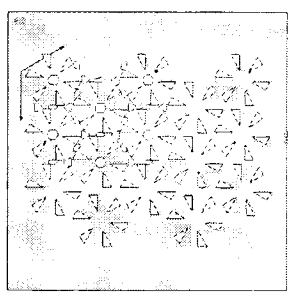

p4g

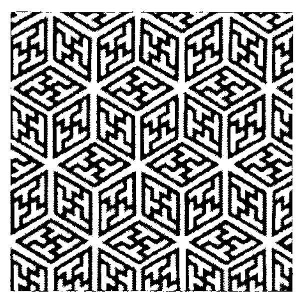

Arabian

Group p6

The group with sixfold centers without mirrors is called p6 pattern.

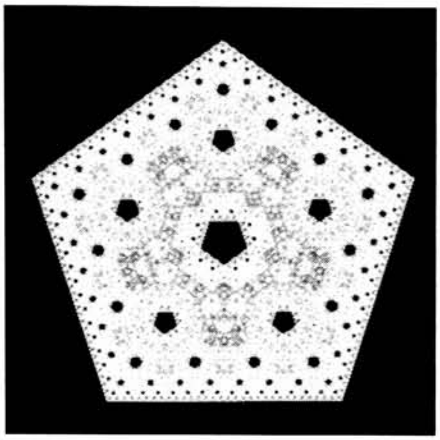

A sketch by Leonardo da Vinci

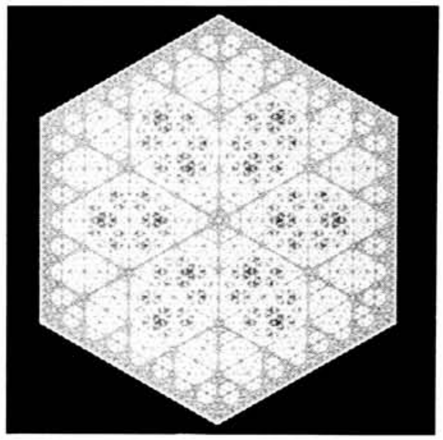

p6

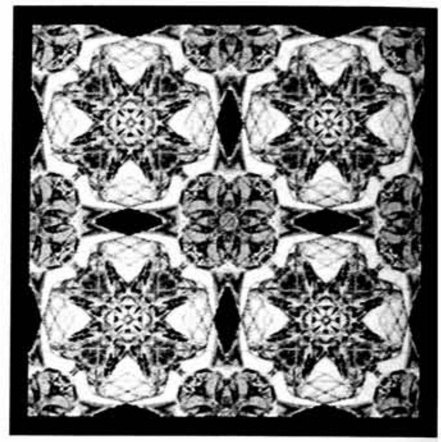

Arabic

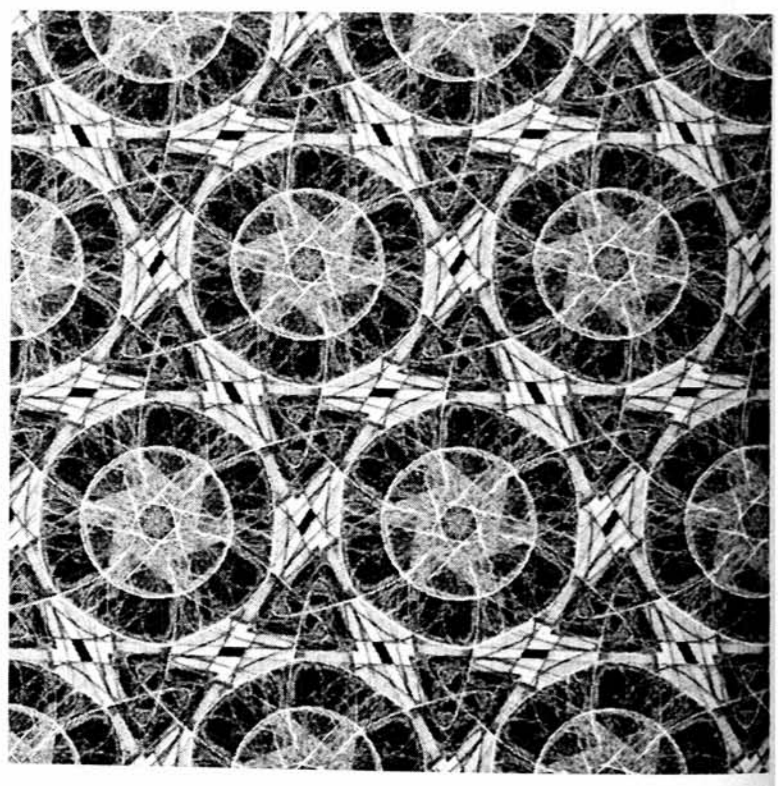
The images of symmetric chaos were produced on the computer using symmetric chaos method.

Appendix 7. i Order of Chaos


a


b


c

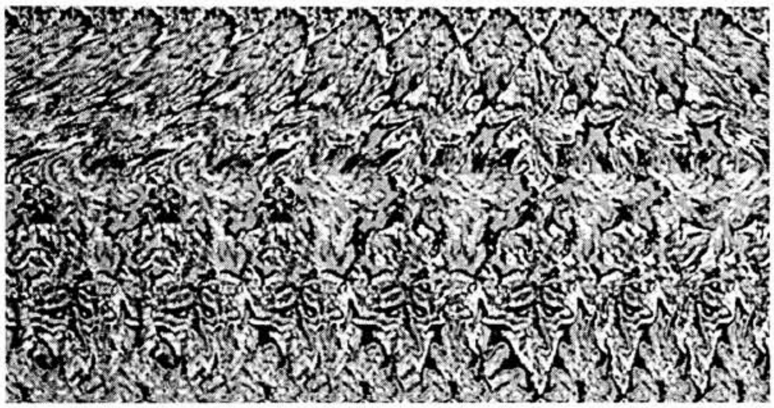

d

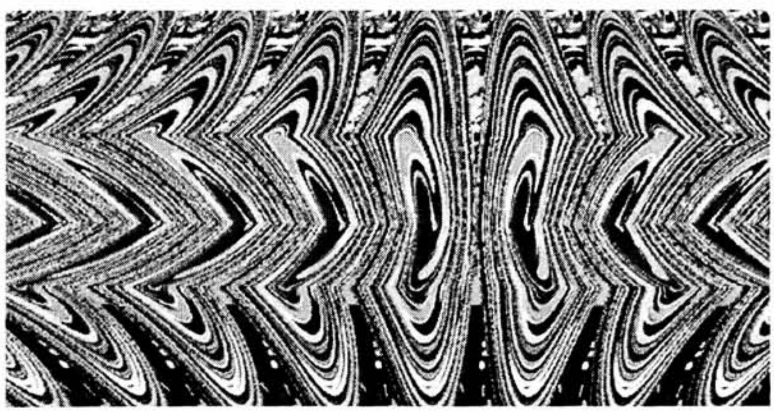
a: The Sierpinski Pentagon is created using algorithmic repetitions of pentagons which form a system of regularity.
b: The Sierpinski Hexagon
c: Victorian Tile
d: Fractured Symmetry
Michael Field and Martin Golubitsky Symmetry in Chaos (1992).

The image seen by the right eye is identical to that seen by the left in all but a central square region, which has been cut out, shifted a little to one side and stuck down again onto the background. The white gap left behind was then filled with a random pattern of dots. If the two images are viewed through a stereoscope, the square that was cut out appears to float in front of the background.

Appendix 7. j

Pattern of 3D Random Dot Stereogram

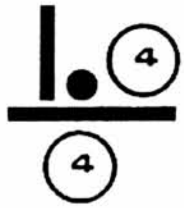




from **Magic Eye**
Andrews and McMeel
A Universal press Syndicate Company

Paul Klee

The first part of the Sketchbook (sections I.1-I.13) introduces the transformation of the static dot into linear dynamics. The line, being successive dot progression, walks, circumscribes, creates, creates passive-blank and active-filled planes. Line rhythm is measured like a musical score or an arithmetical problem. *Sibyl Moholy-Nagy*



Passive lines which are the result of an activation of planes (line progression) (Fig. 8):

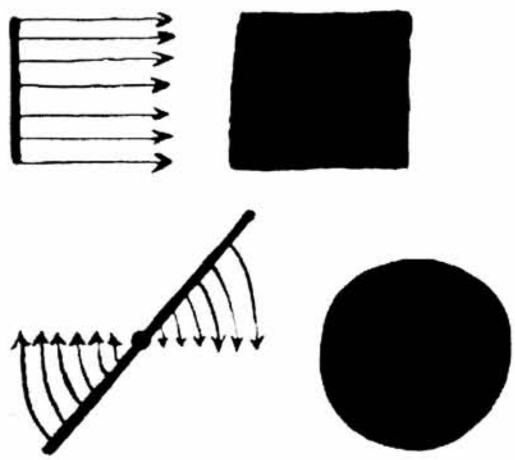
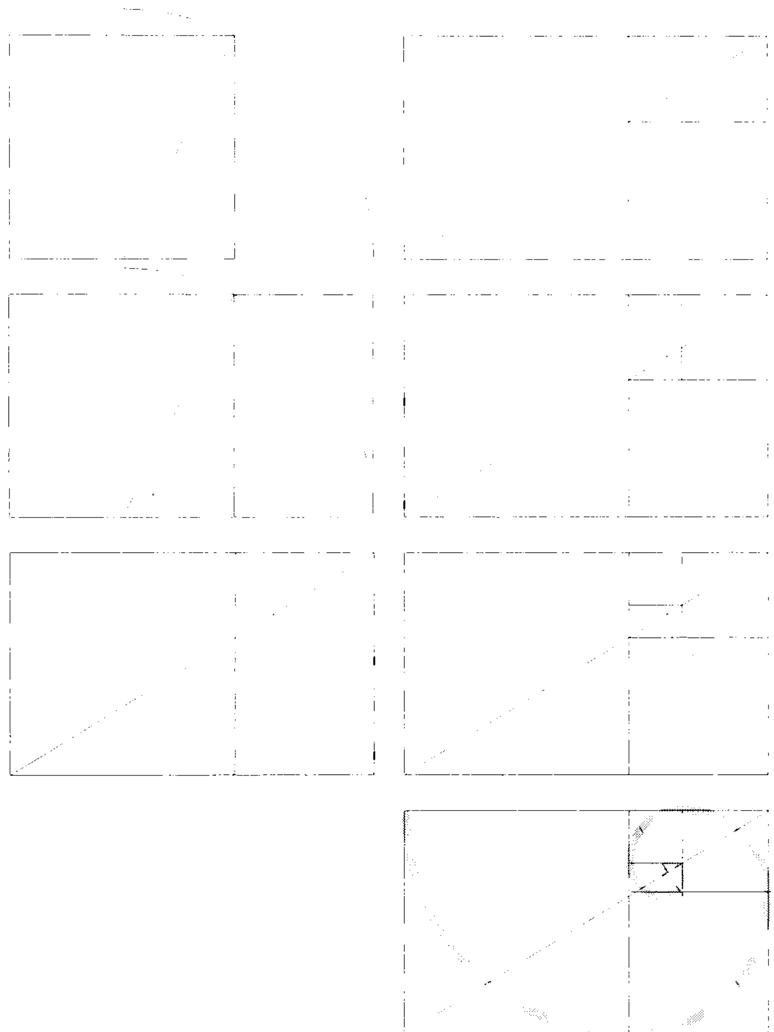


Fig. 8

Passive angular lines and passive circular lines become active as planar constituents.

Appendix 7.1 Golden Mean

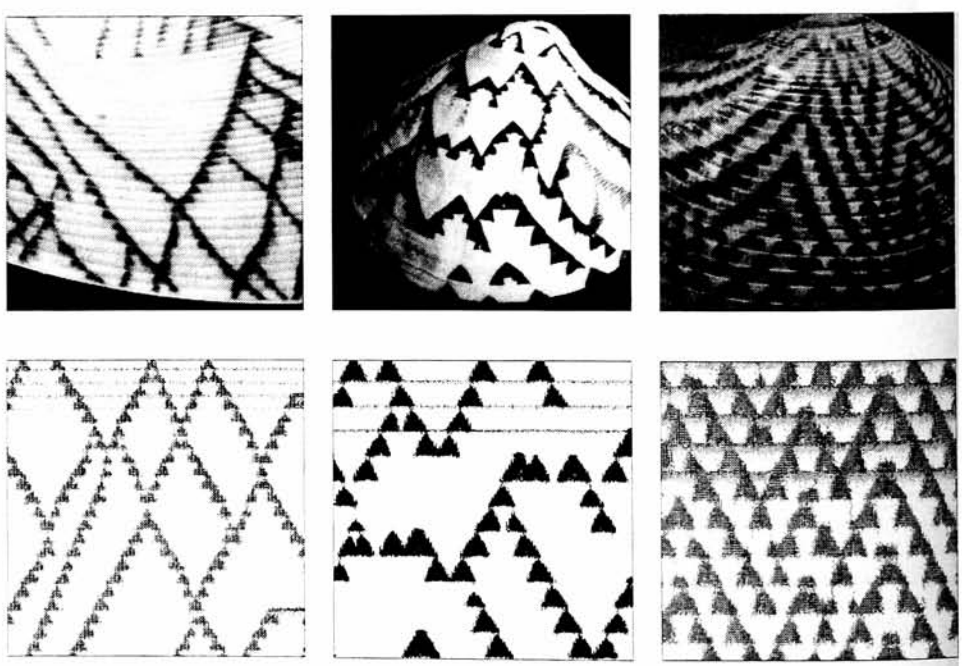
The golden rectangle with proportions corresponding to the golden ratio. There are mathematical relationships between the features of the golden rectangle and the spiral that show the connection between the spiral and the golden section.



The golden mean rectangle has a ratio of 1:1.618.

Several shells display triangles as their basic pattern element, and the patterns are similar to the famous Sierpinsky triangles with their fractal geometry.

Algorithmic Beauty of Sea Shell

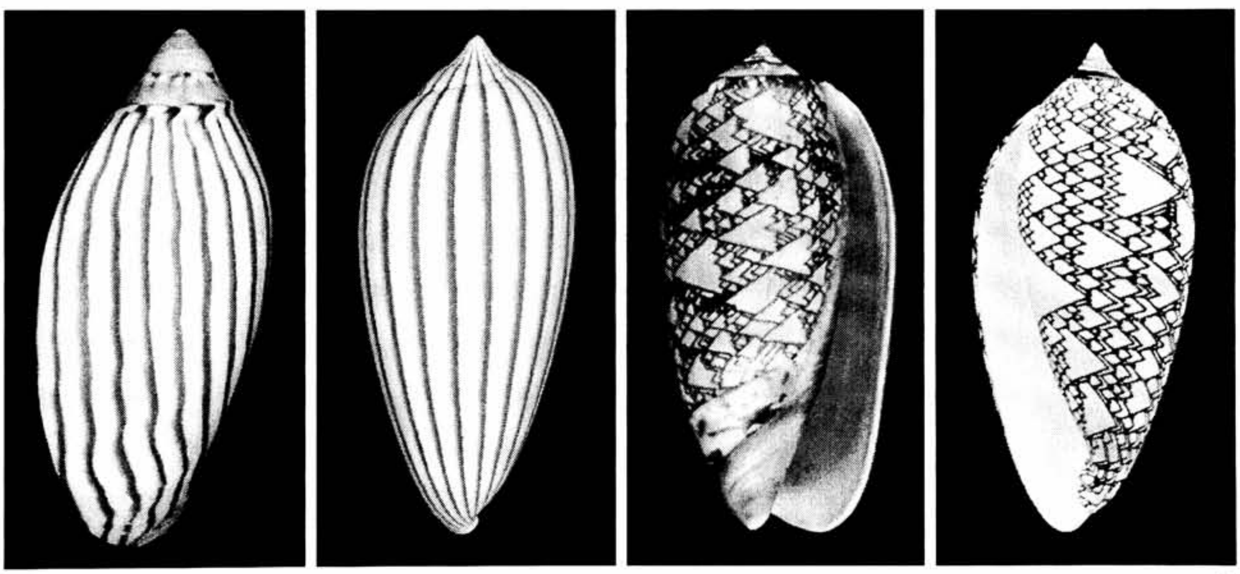


a b c

Change of connected triangles. **a**, **b**: pattern on different species of Lioconcha, **c**: Sunetta meroe.
Meinhardt, Hans, The Algorithmic Beauty of Sea Shells (1995)

Appendix 7. n Algorithmic Beauty of Sea Shell

With the logarithmic spiral shape, it also reveals various colors and patterns on their surfaces effected by flowing water. Like tree's annual ring, most shell patterns are historical records of what happens at the growing edge.

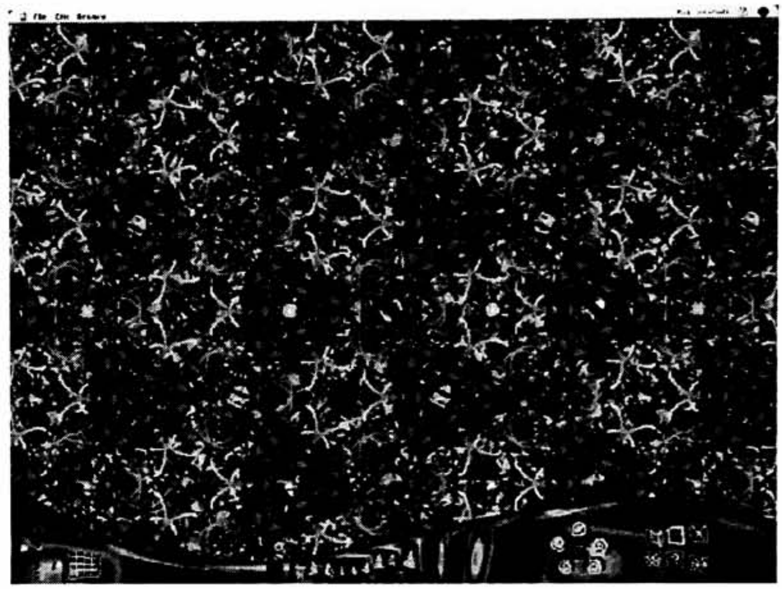


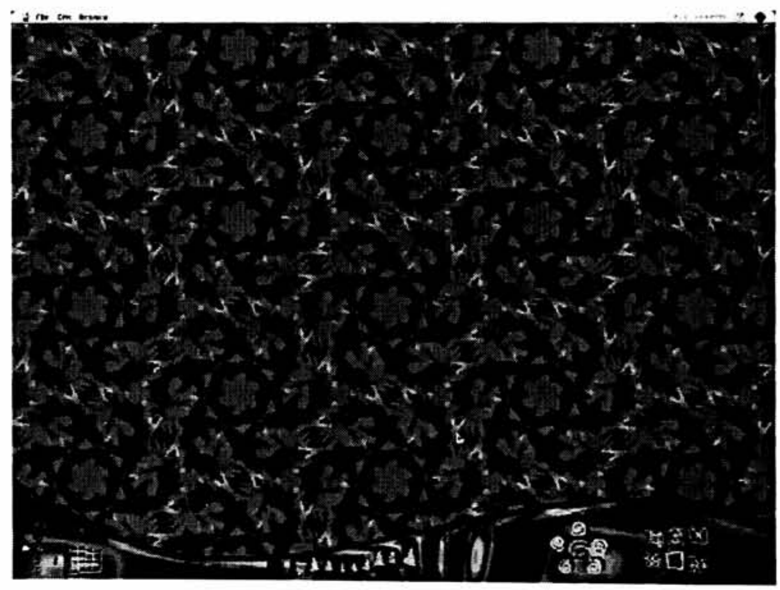
a b

a: A photograph and model of Amoria ellioti: Patterngenerated stripes perpendicular to the direction of growth, can be found in Amoria ellioti.
b: A photograph and model of Oliva Porphyria.
Meinhardt, Hans,
The Algorithmic Beauty of Sea Shells (1995)

Appendix 7. o

Motion Pattern



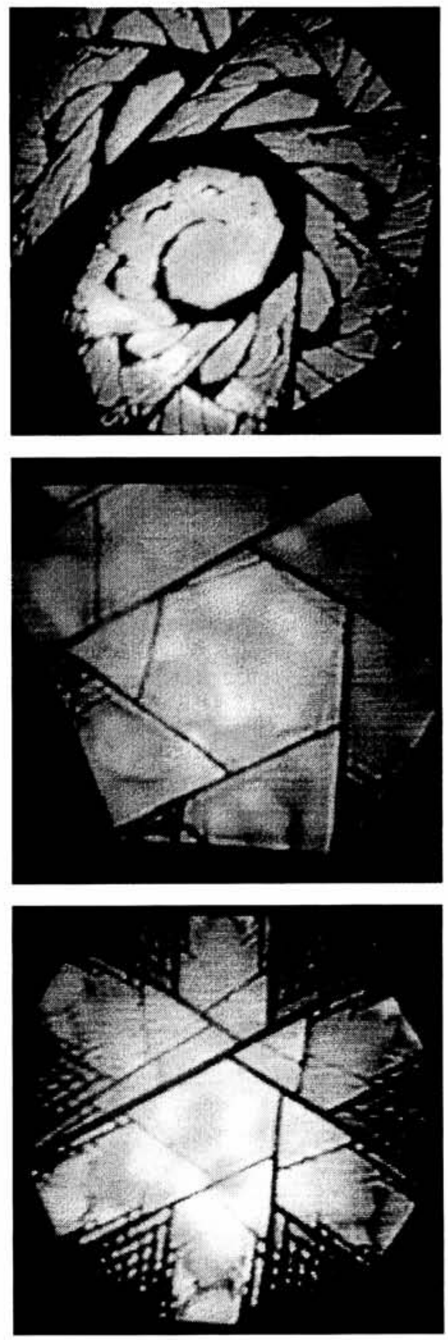


The Groove Thing

With 9 kaleidoscopic visions, 6 symmetry levels on CD-ROM it brings user to a world many call their optical nirvana.

Video feedback creates an electronic light show that produces an endless variety of chaotic fractal patterns.

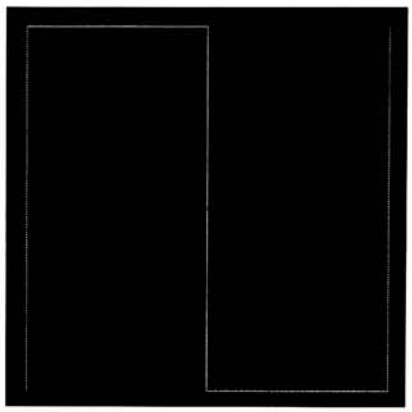
Appendix 7. p Video Feedback Pattern

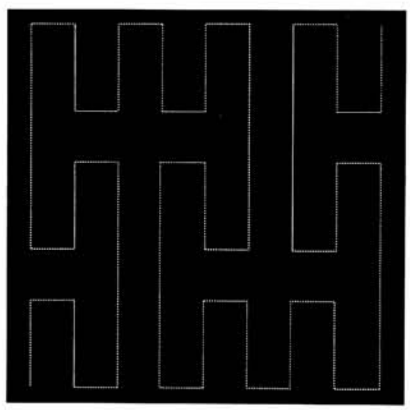


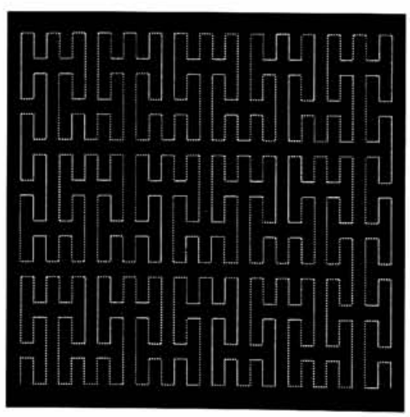
Alice Yang. Strange Attractor, Signs of Chaos (1989).

Symmetries and self-similarities abound in the world of geometry, and a great deal of music also shares these properties. Throughout the nineteenth and twentiethe centuries, historians and theorists have discovered musical self-similarities of various kind. Among musical symmetries and self-similarities are those that can be produced using Lindenmayer-system curves to generate melodies and rhythmic patterns.

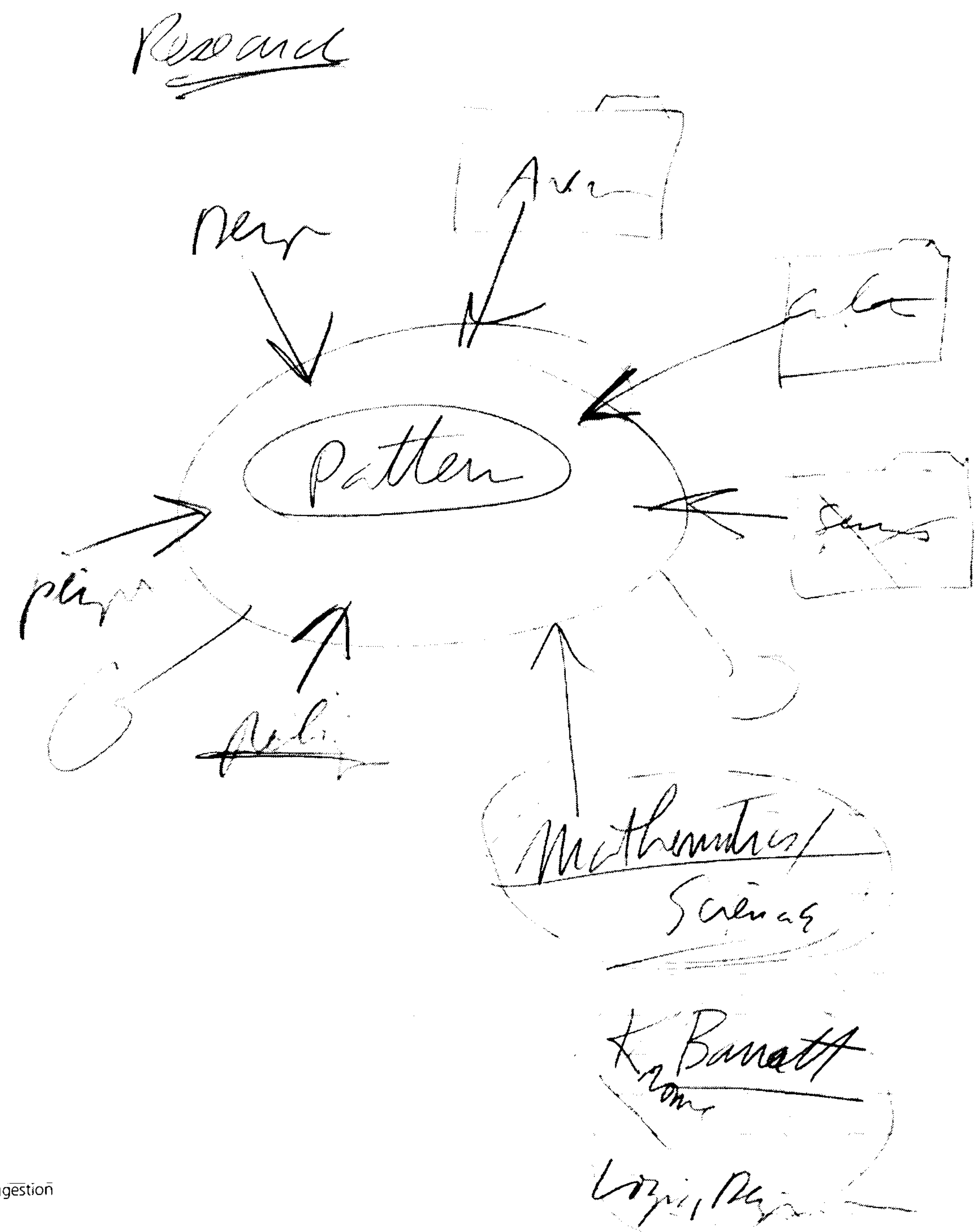
Appendix 7. q Patterns of Music





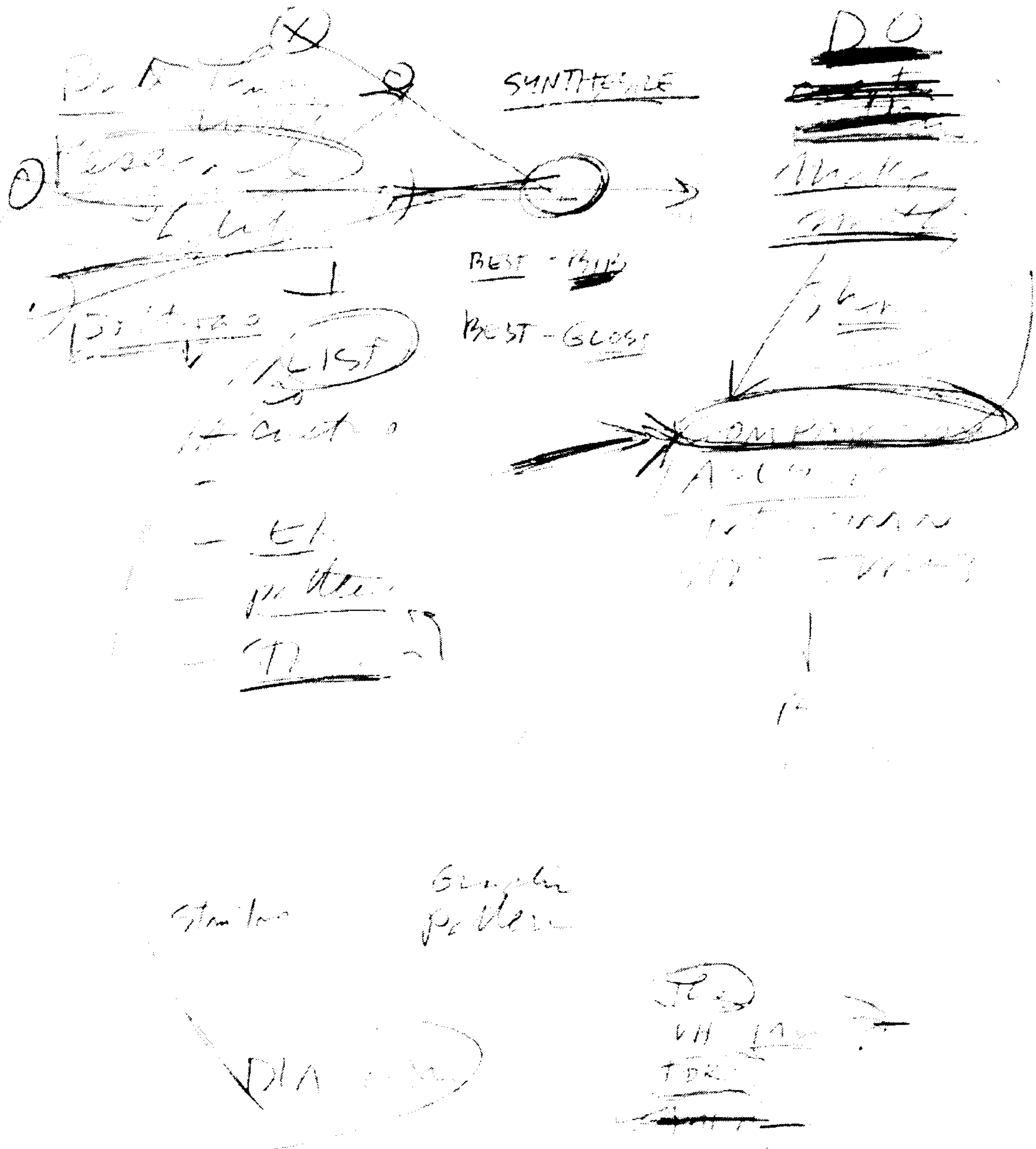


Appendix 8 Advisor's Notes 1



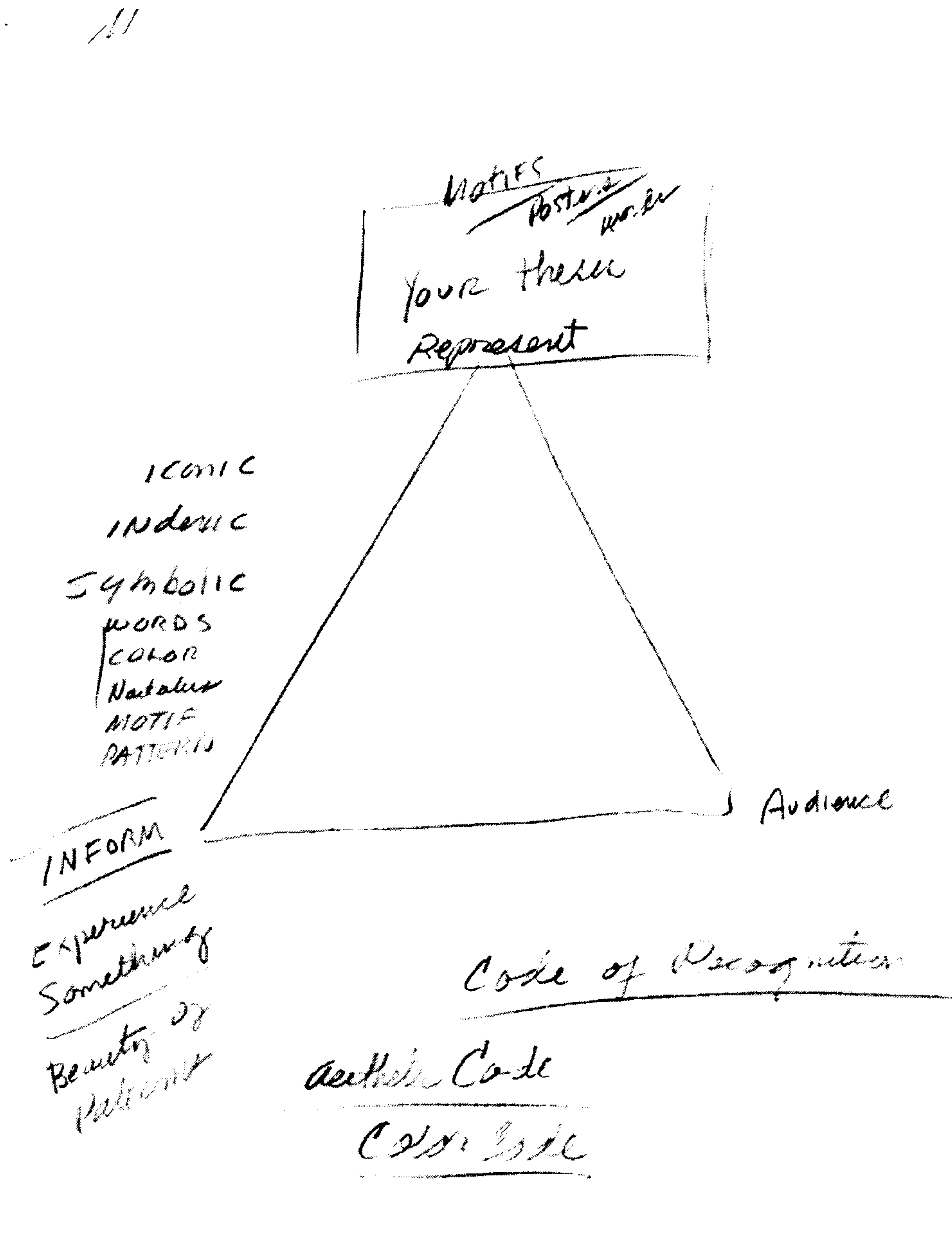
Prof. Remington' suggestion

Appendix 8 **Advisor's Notes 2**



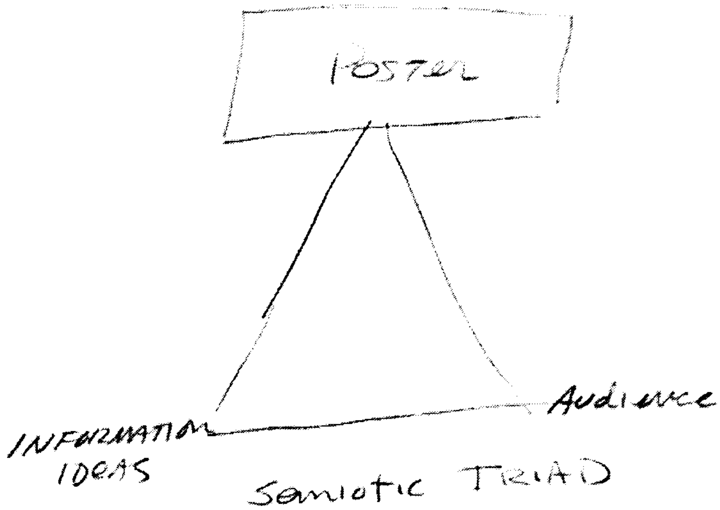
Prof. Remington' suggestion

Appendix 8 Advisor's Notes 3



Dr. Zakia's suggestion

2



In my thesis I wanted to convey this information:

- ✓ 1. Patterns are created using mathematics + crystallography
- ✓ 2. Patterns use repetitive motifs and symbols
- ✓ 3. Patterns have an aesthetic
- ✓ 4 Patterns are culturally defined
- 5. Patterns are used in many ways; textile design, fashion design, etc ↓

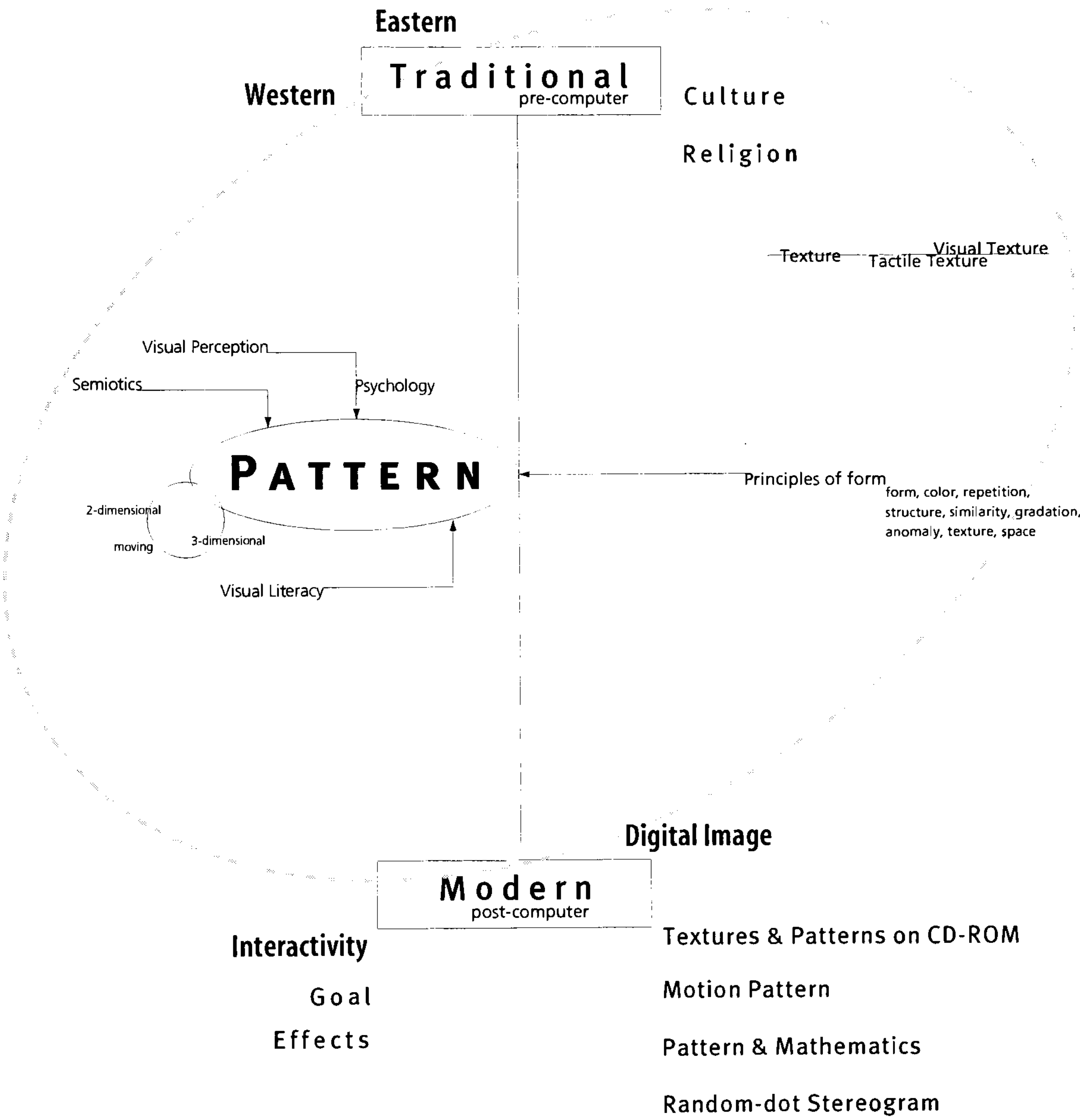
The poster contains words, pictures, symbols, colors etc. In designing my poster I considered the 3 ways of Representation.

1. Iconic —
2. Index —
3. Symbolic

Dr. Zakia's suggestion

Appendix 9. a

Prior Research Map



Appendix 9. b **Invitation Notes**

Seung-eun Lee

Prof. Robert Keough

Please came and give me a good feedback.

THESIS COMMITTEE MEETING

On Tuesday, December 13, 1994

At noon

Room 3510

Seung-eun Lee

Prof. Roger Remington

THESIS COMMITTEE MEETING

On Tuesday, December 13, 1994

At noon

Room 3510

Seung-eun Lee

Dr. Richord D. Zakia

Please come and give me a good feedback.

THESIS COMMITTEE MEETING

On Tuesday, December 13, 1994

At noon

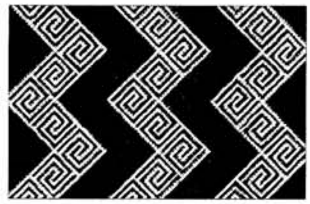
Room 3510

These patterns are classified according to the motifs under such heads as a fret, diaper, fret diaper, interlaced, powdered, and conventional foliage by W. and G. Audsley.

Appendix 9. c Pattern Classification

Fret

An ornamental design contained within a band or border, consisting of repeated, symmetrical and often relief geometric figures.

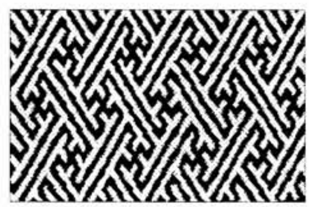


Diaper

A pattern with small, duplicated diamond shape figures.

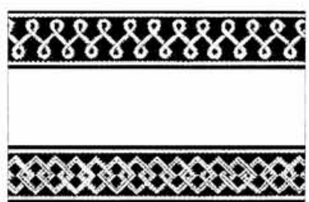
Fret Diaper

Diapers based on the fret, but with curved lines instead of angular.



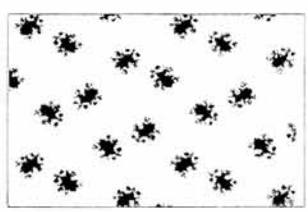
Interlaced

The semblance of structural interweaving, tying up, or binding together inherent in such designs, is often adroitly exploit.



Powdered

An equal weight of pattern and space in all parts, so that the general effect may be uniform to the eye.



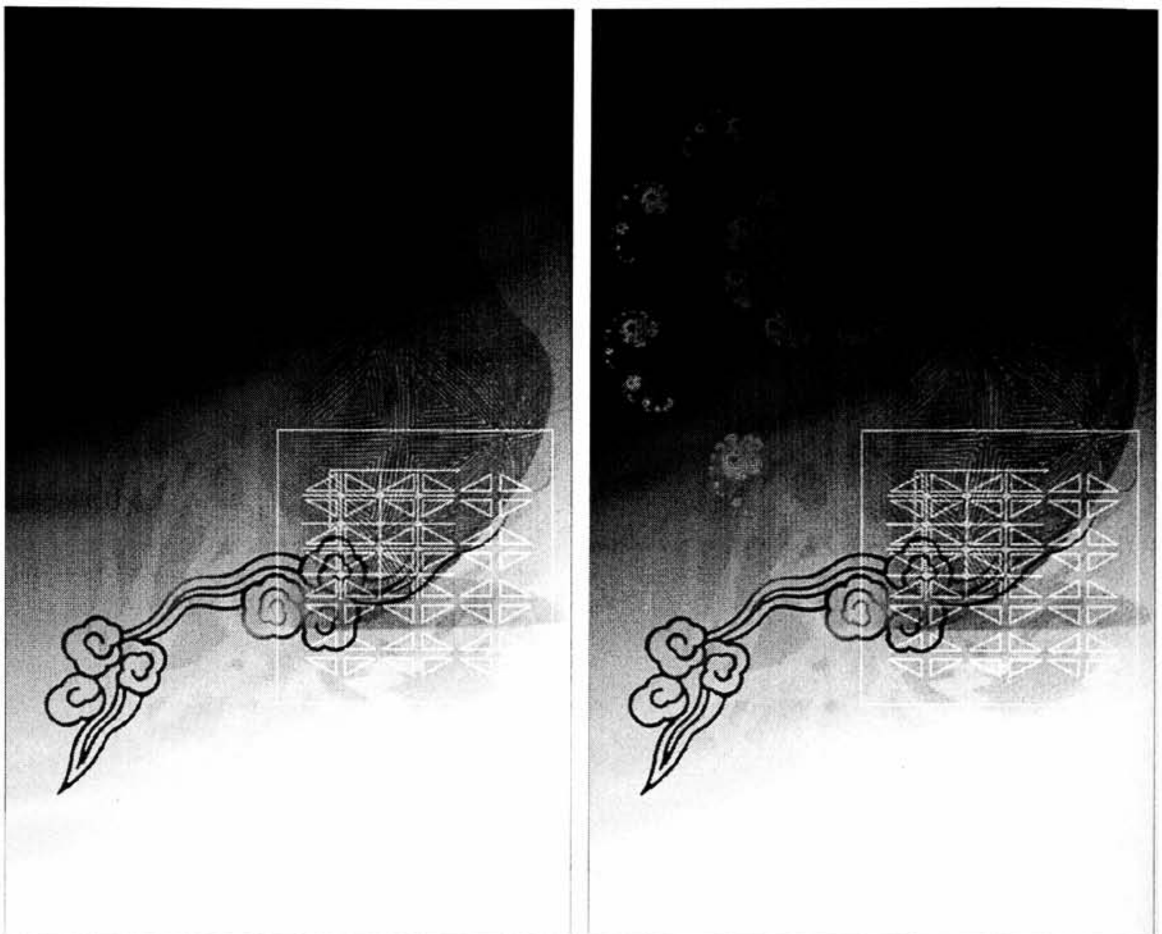
Conventional Foliage

Floral sprigs purely imaginative or closely imitating natural foliage.

Designs and Patterns from Historic Ornament
W. & G. Audsley (1968)

Appendix 9. d

Early Sketches 1



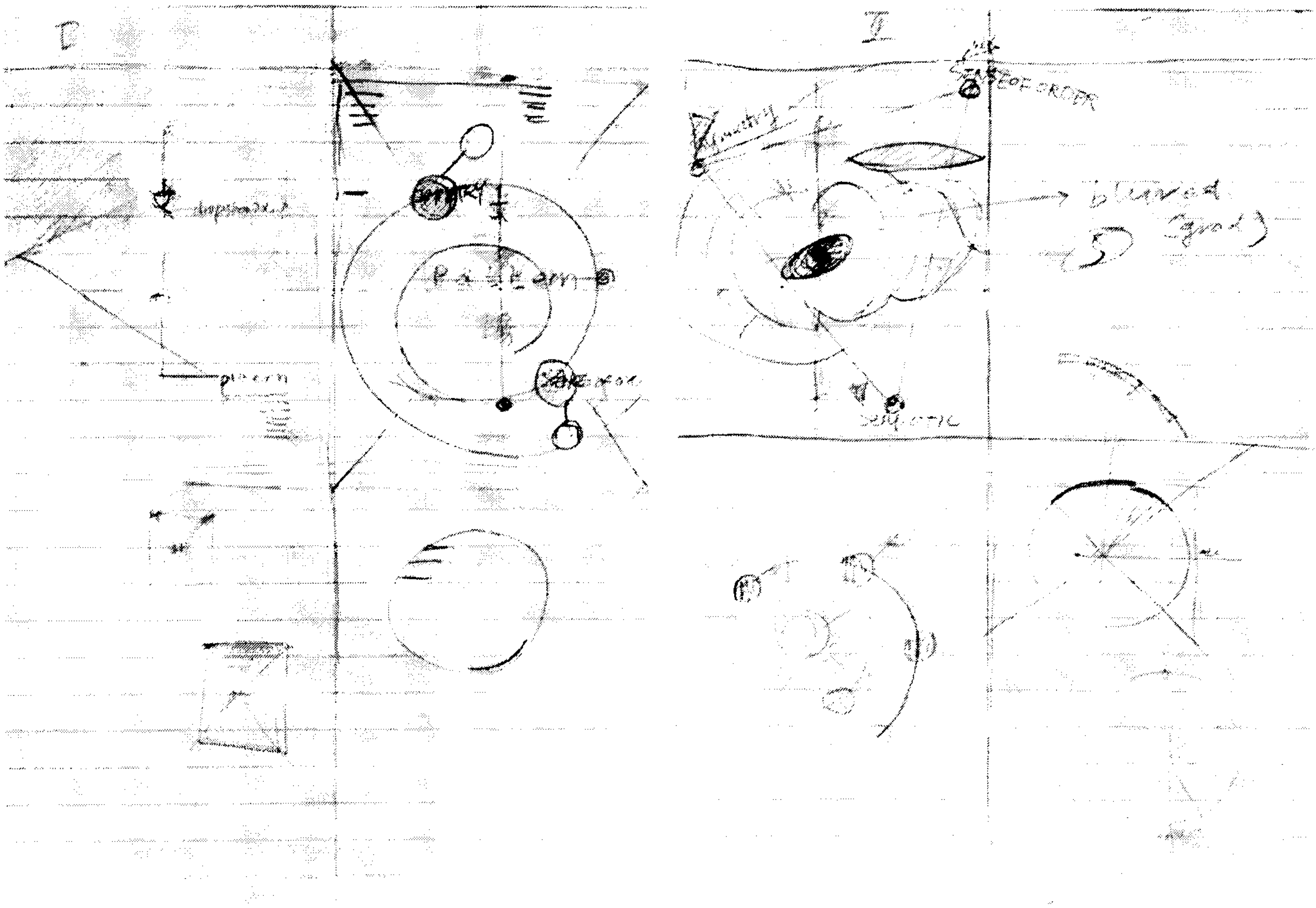
The cloud motifs appear in descriptions of the realm of heaven that are scattered through ancient legends, and serve as symbolic representations of this ideal realm.
Sang-soo Ahn, Asian Art Motifs from Korea. vol.4 Cloud Patterns (1993).

Early Sketches 2

Early Sketches 3

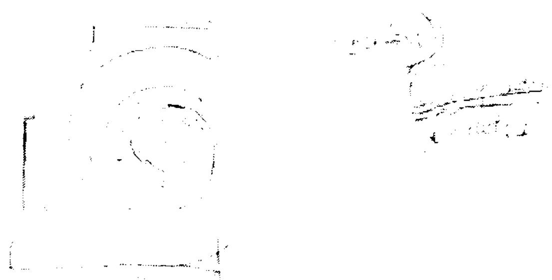
Appendix 9. e

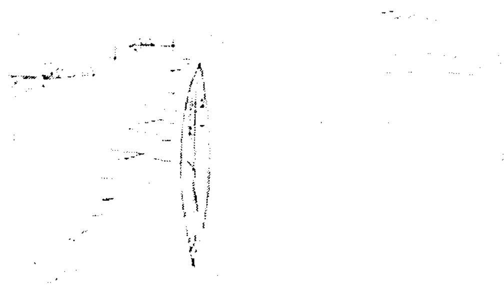
Sketches 1

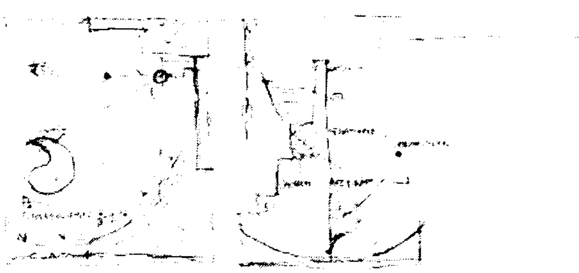


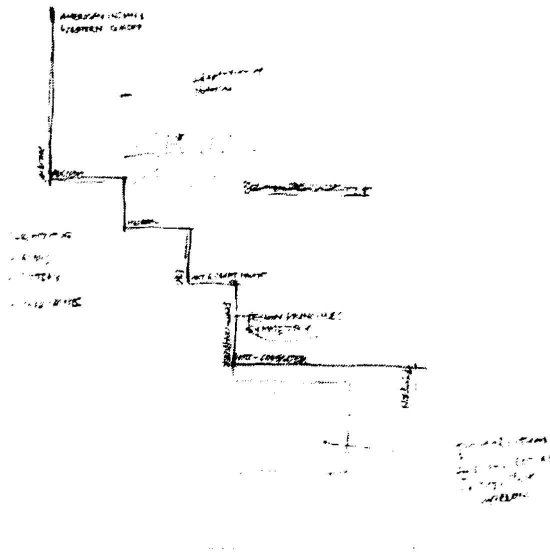
Appendix 9. e

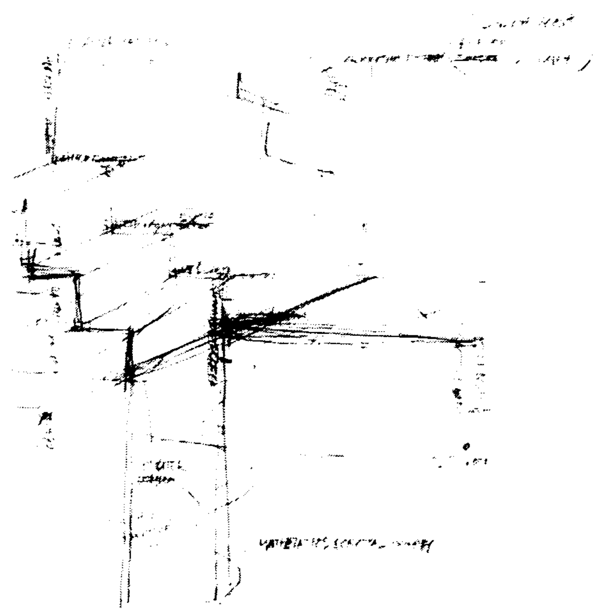
Sketches 2



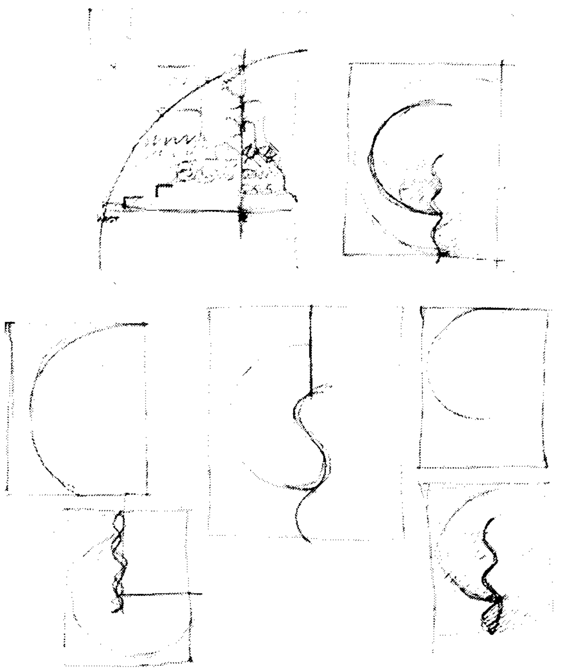


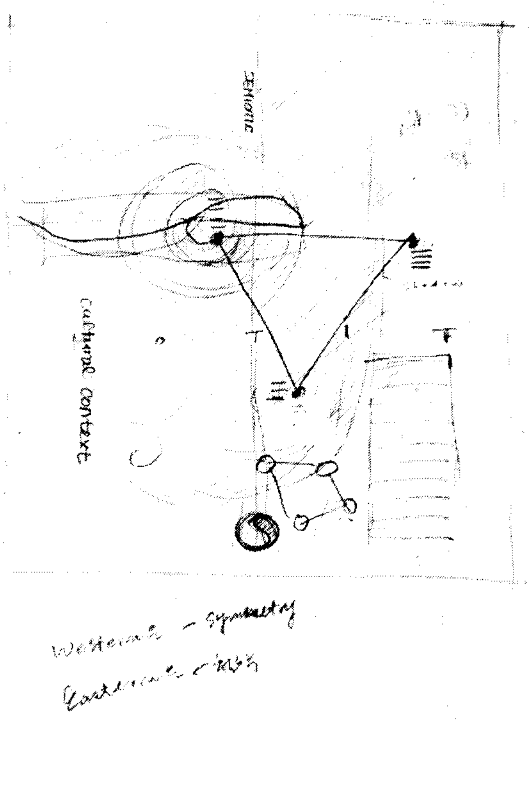






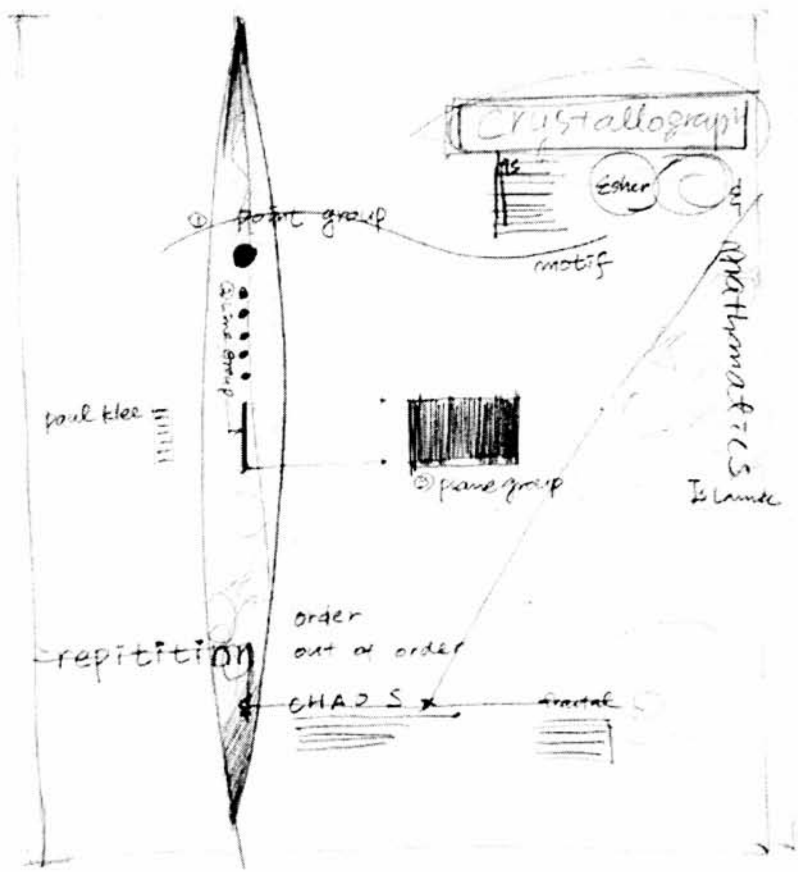
Appendix 9. e **Sketches 3**



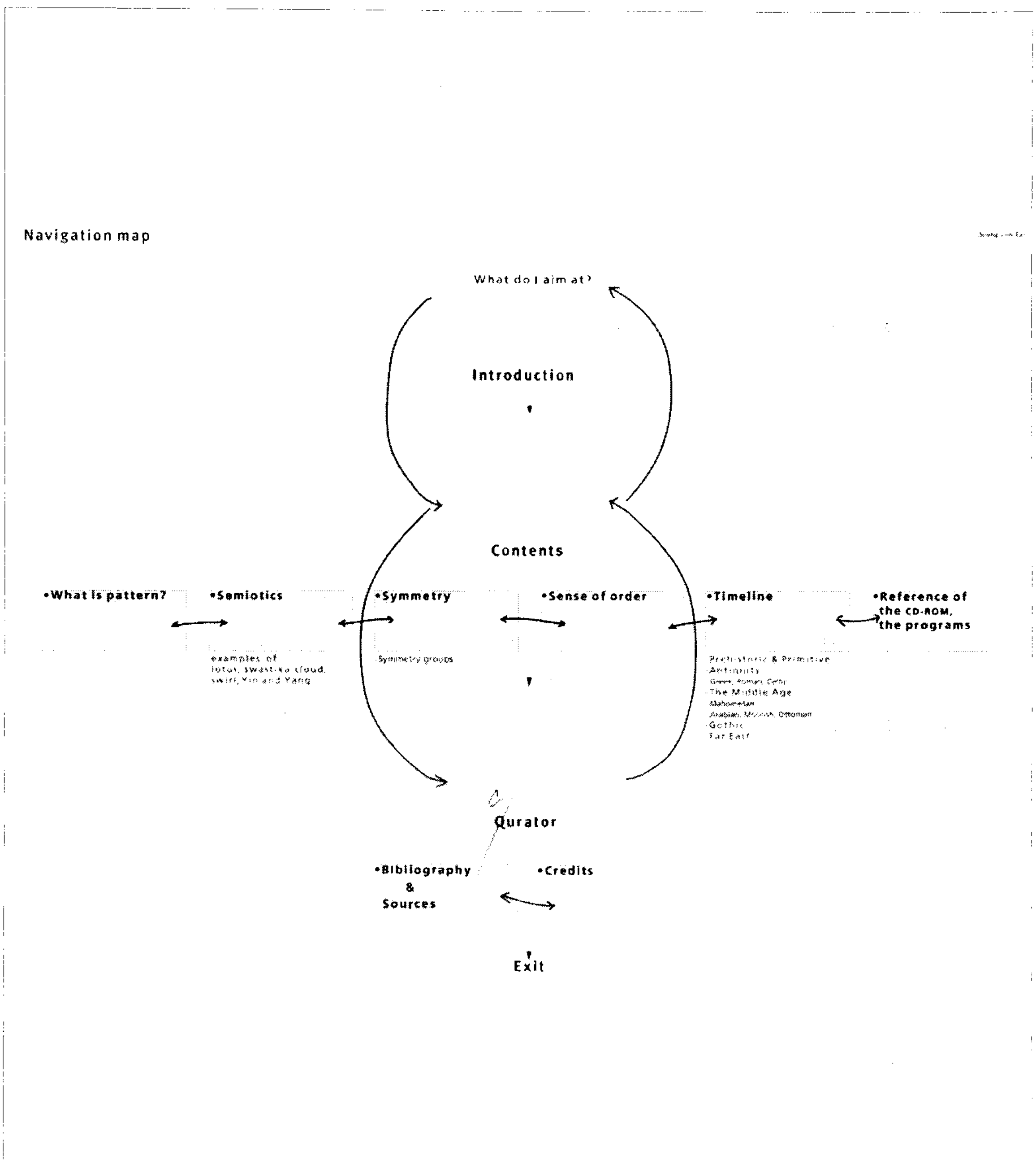


Appendix 9. e

Skeches 4



Appendix 9. f **Navigation Map**



Navigation Map for the
Interactive mutimedia application

Appendix 9. g

Thesis Statement

Pattern is a colossus. It is too big to see whole at one time. Pattern is an aesthetic repetition but it is also something more in relation to other fields of study, such as mathematics particularly Symmetry Group Theory. While researching, I found that pattern can not be understood within the frame of graphic theory alone. My work required me go to study culture, religion, art history, textile, folk art, graphic theory, mathematics, crystallography, psychology, and even music. This work attempts an analysis and synthesis of two perspectives, that is mathematics/ crystallography and patterns from different culture. The short four days in Boston for research was valuable, and the computer was helpful to organize and create this work. I am pleased with that. I am deeply indebted to my thesis committee: Prof. Roger Remington, Prof. Robert Keough, and Dr. Richard Zakia for their helpful advice. I also would like to express my appreciation to Pro. James Ver Hague, Prof. Heinz Klinkon, Prof. Nancy Ciolek, faculty members in Graphic Department and my best friends, Gedeon Maheux, David Seah, Yih-Chi Wang, and Ms. Jo Cone for their beautiful friendship.

Thesis Statement at the Show