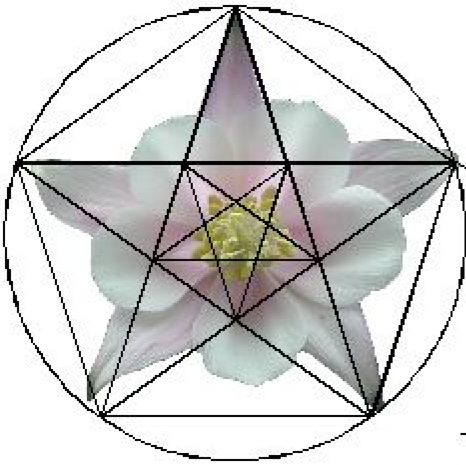
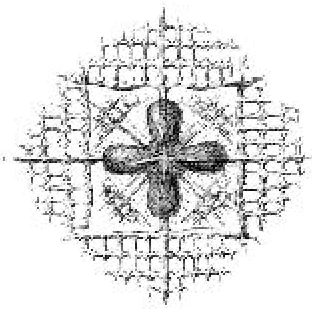
Mathematical Ideas For Artists

Workbook





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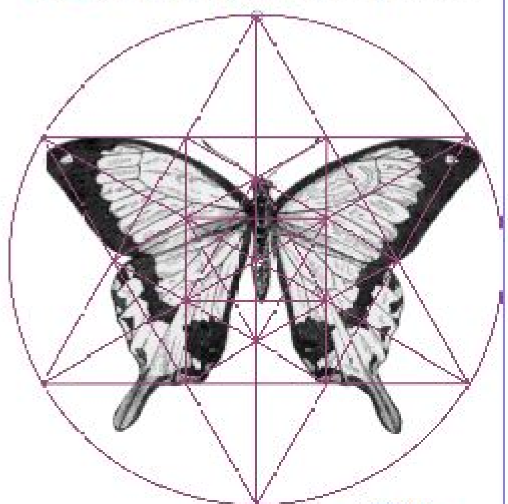
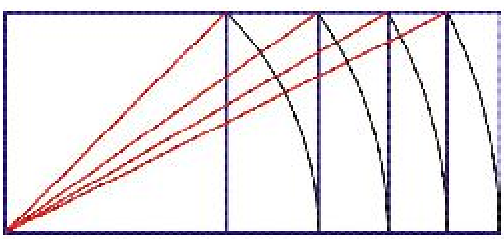
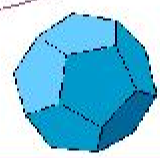




California College of the Arts



Mathematical Ideas for Artists

California College Of The Arts
Michael S. Schneider

Course Description

Mathematical ideas have always influenced societies, and artists are often among the first to explore and express their meanings and implications. This course presents a variety of mathematical ideas from across cultures and times, particularly those that are still useful to artists, craftspeople, architects and designers, from the patterns of nature to the mathematics underlying modern computers. Each class involves visual presentations and hands-on activities for exploring these ideas in the Reader/Workbook. Homework for each class involves creating (or planning a design for) something original to demonstrate an understanding of the mathematical ideas. The textbook supplements the ideas and helps prepare for each next class. Along with Homework, grading is based on a Midterm Exam, Final Exam, coming to class prepared and class participation.

Course Outline

Class # **Topic** (/\ = bring a Compass, straightedge)

1. Introduction to the Course
2. Unity and Polarity
3. *Ad Triangulum* Symmetry - /\
4. *Ad Quadratum* Symmetry - part 1 - /\
5. *Ad Quadratum* Symmetry - part 2 - /\
6. Root-Rectangle Symmetry - /\
7. ***Mid-Term Exam-*** /\
8. Tessellations
9. Mysteries of Seven - /\
10. Pentagonal Symmetry - /\
11. Fibonacci Numbers
12. Golden Rectangle Symmetry - /\
13. The Platonic Solids
14. ***Final Exam-*** /\
15. Class closure

Expectations

In addition to the general expectations of the college, please:

- Attend every class and please arrive on time.
- Bring the Reader and Tools (see below) to class when necessary.
- Actively participate in class discussions and activities.
- Complete reading assignments and turn in homework on time.
- Make up work from any missed class.
- *Drinks are okay* but please *no warm or fragrant food, strong perfume* or *scented hand creams*, etc., in class ;)
- Please *put away your smartphones* during class.
- You may photograph the screen but please no photography, video, audio or other digital recording of people without prior permission.

This course is about curiosity and creativity. If you're eager to learn, then this class can broaden your perspective and deepen your work as an artist.

Course Materials

Books

- Textbook: "A Beginner's Guide To Constructing The Universe" (HarperPerennial Publishers, 1995 paperback) by Michael S. Schneider. (Available as paperback and eBook.) Read the assigned pages.

- Reader: The "Mathematical Ideas" Reader-workbook for this class is obtained through *Green Copy* in Oakland. Please bring it to every class without exception. Instead of a notebook you may wish to keep notes on the Reader's blank pages. Please be accurate in your work. When doing geometry also use colored pencils to help *make your Reader a work of art*! Please complete any unfinished activities at home.

Tools

Please bring to class when appropriate:

- **A sturdy geometric compass** - Λ -. The kind with an unmovable, threaded bar is best. Try to avoid the kind with a wobbly ball-bearing. It would be nice if it could draw with colored pencils or colored leads.

- Straightedge (metal or plastic best, at least 6 inches).

- Colored pencils, sharpener and eraser.

Grading Policy

Midterm Exam — 25 %

Demonstrate your knowledge of the mathematical ideas and geometric skills studied in the first half of the semester. Questions come from class discussions, the textbook and the Reader.

Final Exam — 25 %

Covers the mathematical ideas studied *since* the Midterm exam, although a few ideas carry over.

Homework – Quantity & On-time — 15%

After seeing the mathematical ideas of class each week you'll create something original, in any media, based on those ideas, due the following week. Please bring your homework on time since part of its value is seeing what others have done with the same ideas. Late homework will be accepted but with penalty. If you're absent, you're responsible for finding out what happened in class and may bring in homework the week after you return. Homework also includes reading textbook pages and completing Reader activities not finished during the previous class. Each week's topics and assignments are described beginning on the next page.

Homework - Quality — 15%

Homework displaying insight, creativity, originality, craftsmanship, relevance and effort are most valued.

Attendance — 10%

Complete attendance and showing up on time are keys to success. If you miss a class please make every effort to find out what happened, speak with a friend, get their notes and do the activities in the Reader as well as possible. After you've done that, please ask me any questions you may have. CCA's official policy is that three unexcused latenesses equal one absence, and three unexcused absences (= 20% of the classes!) are grounds for failure.

Preparation — 5 %

You'll have a more enriching experience if you come prepared, which means having done any required reading in the text, bringing your Reader and tools (compass and straightedge) when required. Please bring the Reader to *every* class. Not bringing the Reader and/or tools will be considered being unprepared for class that day, which is recorded. The Reader contains hands-on activities which complement the slide-lecture presentation and discussion. Any unfinished activities should be completed at home. Please let me know if you have any questions.

Participation — 5 %

Speak up! I encourage and appreciate your participation in class, your questions, comments, insights and additions to the discussion.

Course Outline and Homework Assignments

Class 1: Introduction
Description of the Course, expectations, grading, and topics.
The impact of mathematical ideas on cultures through history.
Relationships between mathematics, nature and art.
How can this mathematics class enrich my own art?

Homework: Write an essay (typed or handwritten neatly). Include in it:
(1) Your *Mathematical* Autobiography (including *where*).
(2) Your major at CCA and why you chose it.
(3) What, in your life, are you *especially* interested in?

Homework: Read the textbook Preface and Chapters 1 and 2. (The Introduction is optional.)

Class 2: Unity and Polarity: Computer Mathematics
Mathematical ideas: Although we use the Base-10 "Decimal system" (Hindu-Arabic) numerals today, modern computers use the Base-2 "Binary system" to calculate with. Binary numbers are a symbol of the principles of unity and polarity which play big roles in Asian *yin-yang* philosophy, modern sciences, politics, relationships and other places.

Classwork: Understand the principles of unity and polarity in nature and art. Learning to read and write binary numbers as computers use them, and see appearances of unity and polarity in nature, art and design, and in the art of ancient cultures and in modern digital technology.

Homework: Create something original which demonstrates your understanding and interest about the principles of unity and polarity, binary mathematics, conflict and cooperation, etc.

Textbook: Read Chapters 3 & 6.

Class 3: *Ad Triangulum* Symmetry
Mathematical ideas: Geometry expresses number relationships as visual space. Construct triangles and hexagons and see examples of their symmetries and subdivisions. See historical applications of this symmetry in arts, crafts, design and architecture.

Classwork: Reader - Do geometric constructions subdividing a Triangle and Hexagon, and use them to analyze images from nature, art and design.

Homework: Create something original to show that you understand the ideas of *Ad Triangulum* symmetry.

Textbook: Read for next class in Chapter 4 (only pages 60-77).

Class 4: *Ad Quadratum* Symmetry – Part 1
Mathematical ideas: Symmetries of the Square.

Classwork: Workbook - Do geometric constructions and subdivisions of the Square, analyze relevant images from nature and art.

Homework: Create something original using these ideas of *Ad Quadratum* symmetry.

Textbook: Read for next class Ch. 8 (minimum pages 267-275).

Class 5: *Ad Quadratum* Symmetry – Part 2
Mathematical ideas: Symmetries of the Octagon (8) and Dodecagon (12).

Classwork: Workbook - Do geometric constructions and subdivisions of the Octagon and Dodecagon, analyze relevant images from nature and art.

Homework: Create something original using these ideas of *Ad Quadratum* symmetry. (Text: No reading.)

Class 6: *Root-Rectangle* Symmetry
Mathematical ideas: The "Pythagorean Theorem" reveals direct relationships among rectangles and square roots. See the geometry used in the Root Rectangles in arts, crafts and architecture over many cultures and centuries.

Classwork: Geometric construction of the Root Rectangles. Explore their historical and modern applications in the arts, crafts and architecture.

Homework: Create something original based on Root-Rectangle symmetry. (Due the class *after* the Mid-Term exam.)
Textbook: No reading. Study for the Mid-Term Exam.

Class 7: Mid-Term Examination
Covers material of the previous classes.

Homework: Look at the images in the Reader.
(Your "Tessellation" homework is due *next class,* not today.)

Textbook: No reading.

Class 8: Tessellations
Mathematical ideas: There are geometric ways to fill a two-dimensional plane without having overlaps or gaps.

Classwork: See the four main "transformations": Translation, Rotation, Reflection and Glide-Reflection and examples of each..These tessellations appear in nature, science, arts, crafts, religion, M. C. Escher and modern designs.

Homework: Create an original tessellation in any medium.

Textbook: Read for next class Chapter 7.

Class 9: Mysteries of Seven
Mathematical ideas: The number 7 is an outlier among the first dozen numbers, and a seven-sided figure cannot be precisely constructed with compass and straightedge. Thus, seven-sided figures do not appear in nature but there are other sevens, associated with wonder and mystery.

Classwork: Learn to (approximately) construct 7-fold geometry and see how it appears in historical art and design. Activities in the Reader.

Homework: Create something original using 7-fold symmetry.

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Textbook: Read in Chapter 5 pages 96-114 and 135-139.

Class 10: *Pentagonal* Symmetry
Mathematical ideas: Fivefold symmetry appears widely in nature, art, science and philosophy.

Classwork: Geometrically analyze pentagonal symmetry in nature and art.

Homework: Create something original using pentagonal symmetry.
Textbook: Read pages 115-128 and 164-173.

Class 11: Fibonacci Numbers
Mathematical ideas: The Fibonacci Numbers make a number sequence that grows by building upon itself, a "recursive" series. It also appears in patterns of natural growth and art.

Classwork: Activities in the Reader with Fibonacci Number patterns and examine examples of their appearance in nature's living architecture.

Homework: Create something original to show that you understand something about the principles of Fibonacci numbers.

Textbook: Read pages 128-164.

Class 12: ***Golden Rectangle Symmetry***
Mathematical ideas: This special rectangle, considered most beautiful, allows the balance of parts with each other and the whole. Learn how to construct a Golden Rectangle frame and subdivide it into squares and smaller Golden Rectangles. Construct the Golden Spiral in a Golden Rectangle and its appearance in art, architecture and design.

Classwork: Activity Book - Geometric constructions of Golden Rectangles and spirals, and analyzing art and design using the Golden Ratio.

Homework: Create original art based on Golden Rectangle symmetry.

Textbook: Read in Chapter 4 pages 81-89.

Class 13: The Platonic Solids
Mathematical ideas: There are only five ways to divide three-dimensional space equally in all directions around a point, called the five Regular Polyhedra or "Platonic Solids": the Tetrahedron, Cube, Octahedron, Icosahedron and Dodecahedron. See and explore the characteristics and relationships among them, from prehistory to Bucky Fuller and beyond.

Classwork: Learn to identify the five Platonic Solids in different situations. Build them and other structures using *ZomeTool* construction kits.

Homework: Please study for the Final Exam. No Homework is due for this topic, unless for extra credit you're inspired to create something original involving the Platonic Solids (but please not just the foldouts in the Workbook).

Class 14: Final Exam

Based (mostly) on material *since* the Mid-Term exam. A few ideas carry through from earlier classes (constructing a square, etc.).

Class 15: Class Closure

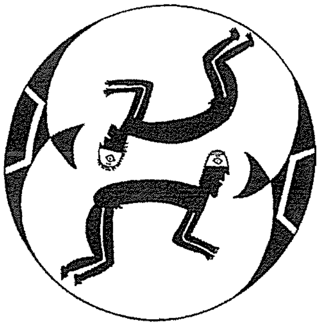
The final exam will be returned, answers explained.

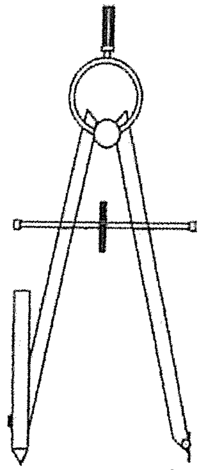
To understand the designs of the *whole universe* you only have to know about the numbers

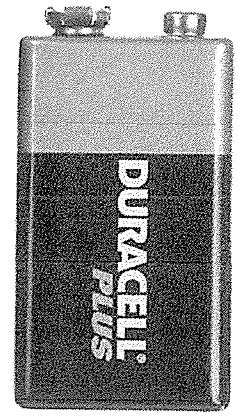
1 2 3 4 5 6 7 8 9 10 11 12

The numbers 1-12 naturally form four groups:

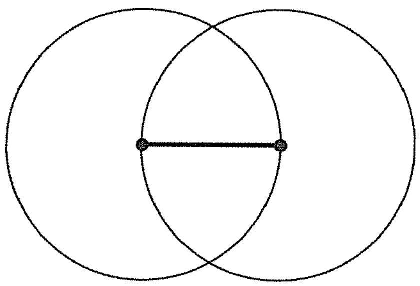
Starting Principles: 1, 2
Numbers of Structure: 3, 4, 6, 8, 12
Numbers of Life: 5, 10
Numbers of Mystery: 7, 9, 11

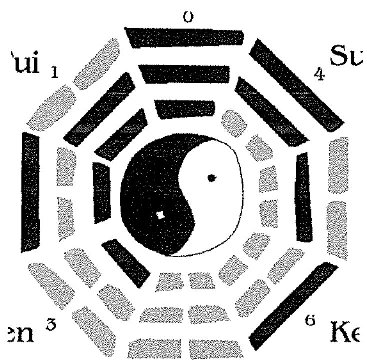


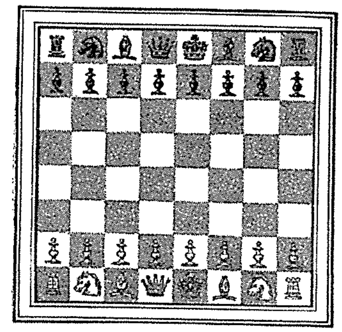


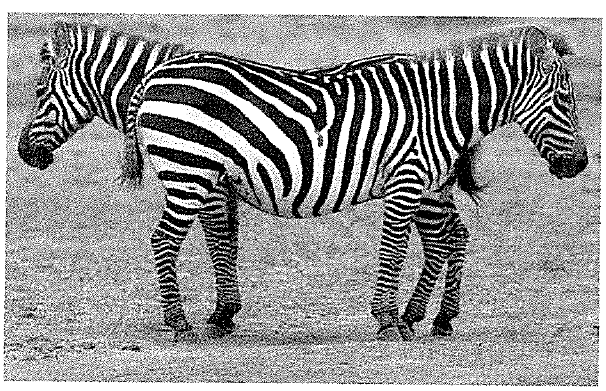


Unity and Polarity









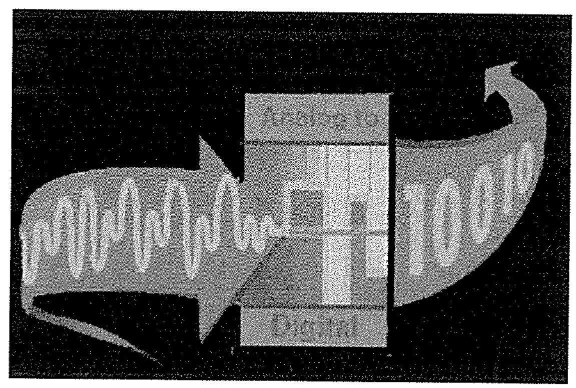
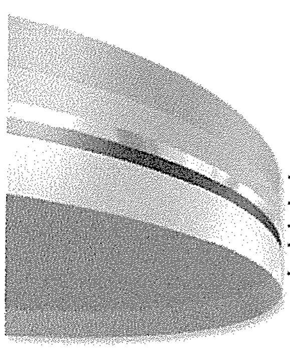


Figure 1



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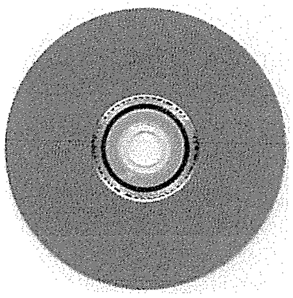
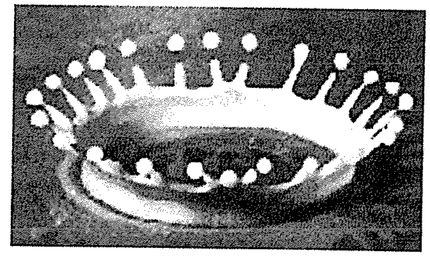
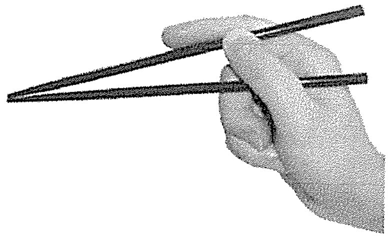
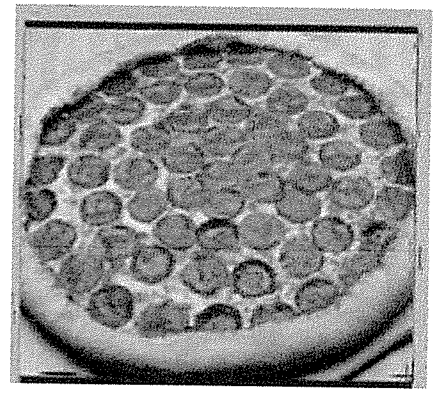
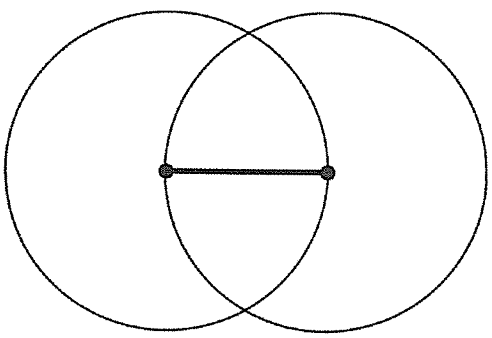
Unity & Polarity

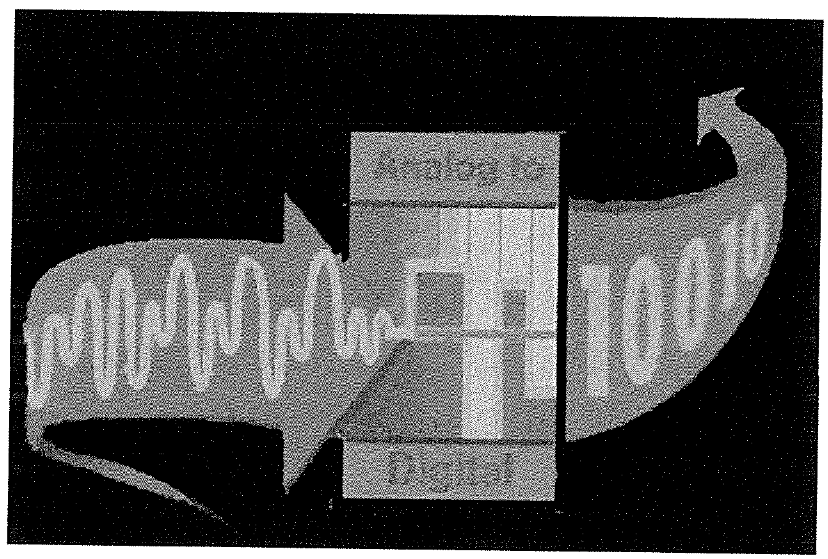


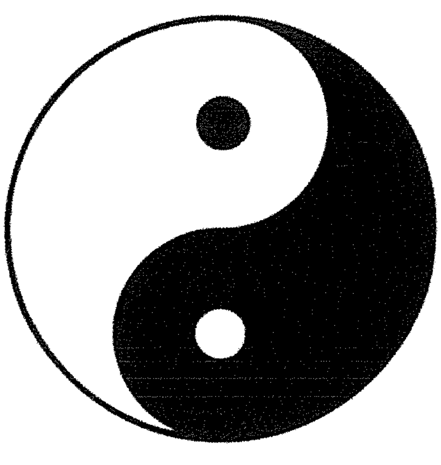


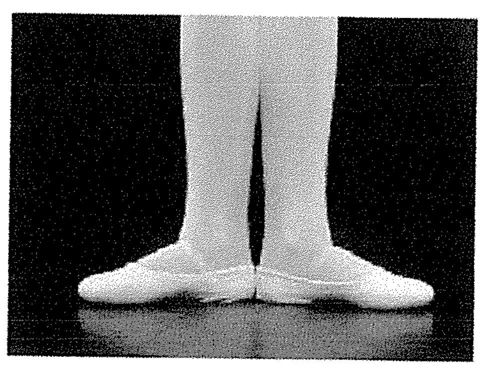












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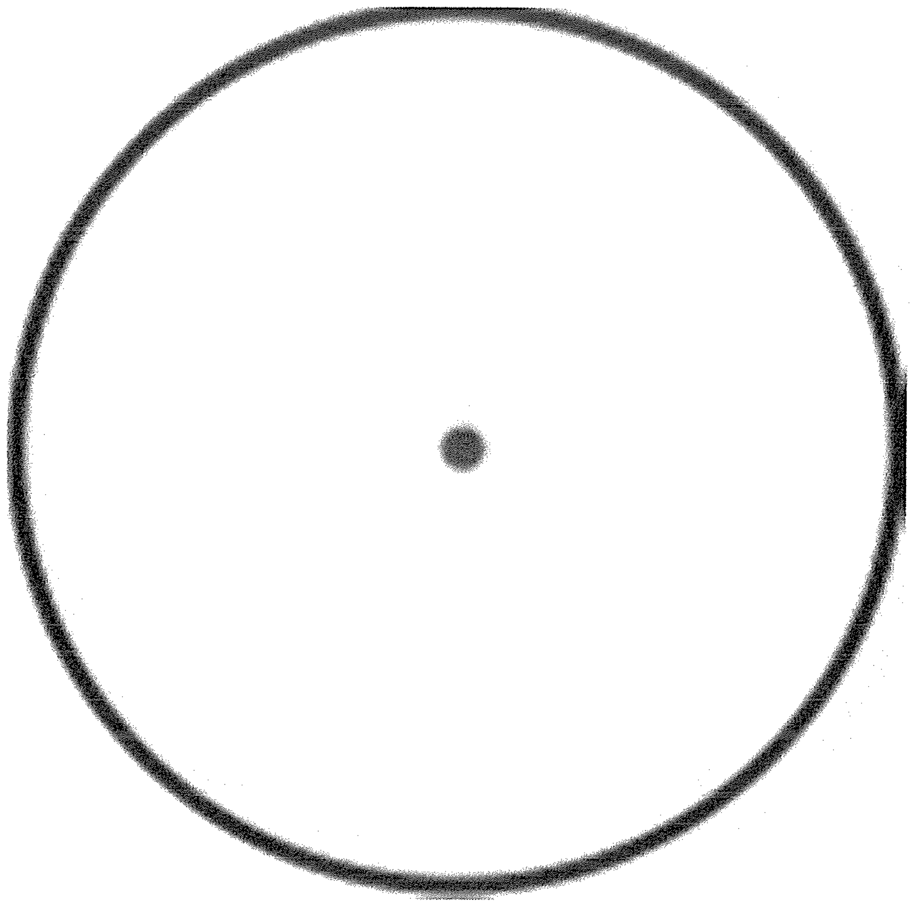
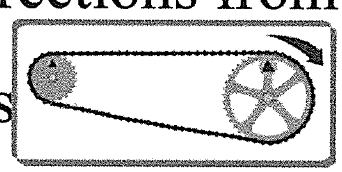


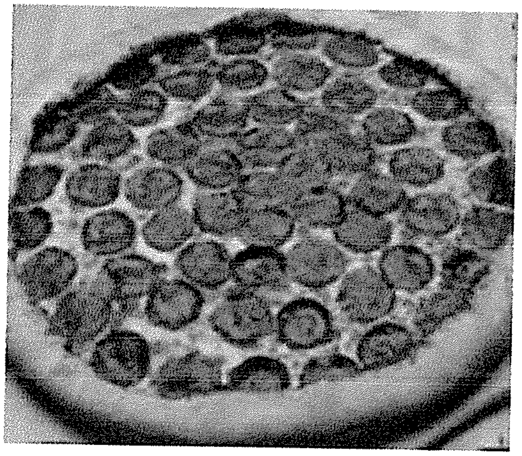
A *practical* symbol of:

* Unity, Wholeness, Completeness
* Equality in all directions from the center
* Repeating Cycles 
* Containing most inside with the least around

(Read Chapter 1 in **ABGTCTU** to find out why!)

Circle: The shape with
The Most *Inside* with the Least *Around*

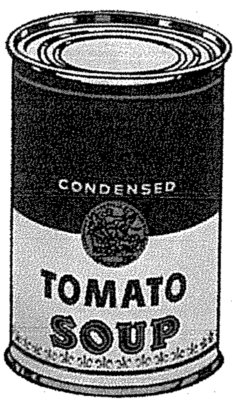
Of all shapes *with the same length of crust*, ***round*** pizzas hold the most toppings.

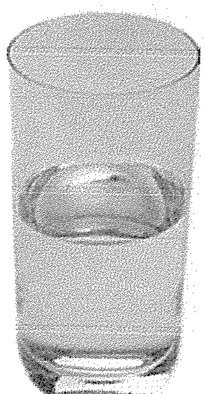


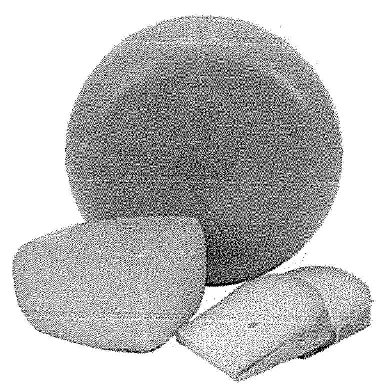
So if you like toppings, **get the round pizza** and not the square, rectangle or triangle with the same perimeter

Cylinders – Extruded Circles

They hold the most inside using the *same amount of material*.







Using the same metal, any other shape of can (except sphere) would hold *less* soup (or water, sand or cheese).

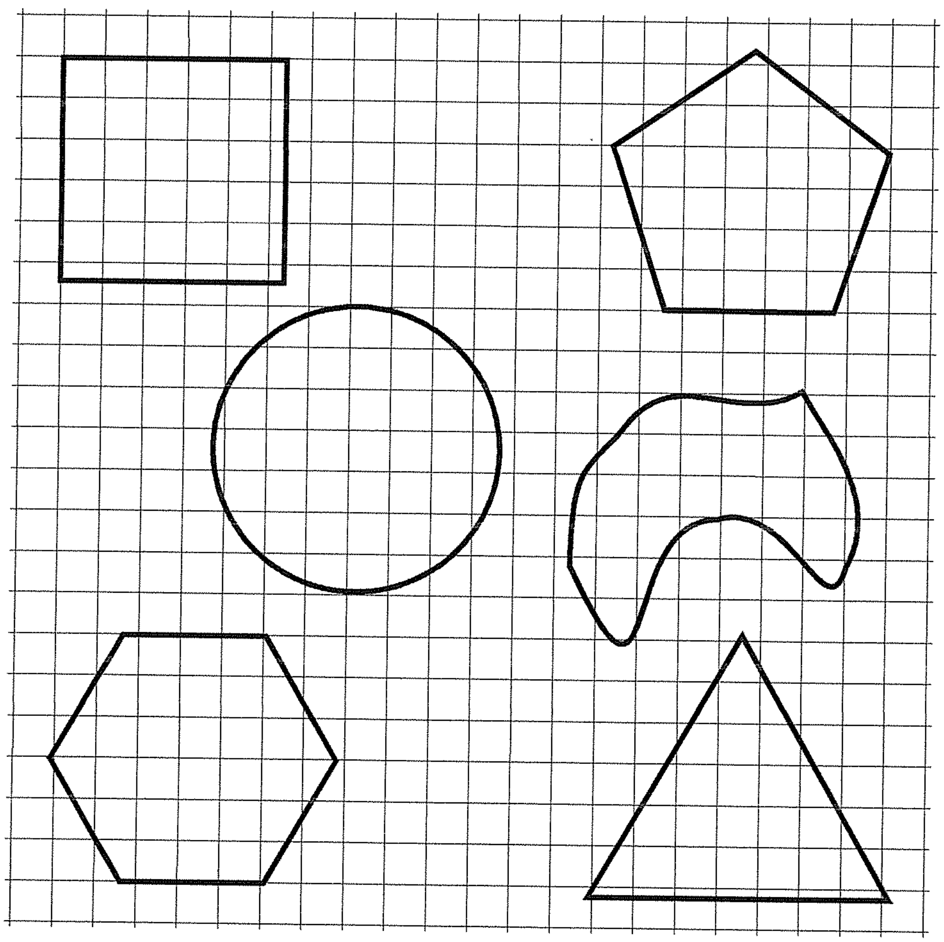
Try this to prove that **a circle encloses the most area having the same perimeter (circumference) as other shapes:**

Tie a loop of string.

Use the loop to form different shapes over graph paper, a checker board or checkered table cloth.

Count the number of squares each covers (encloses).

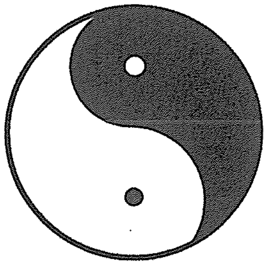
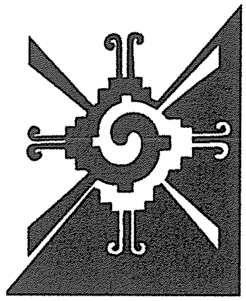
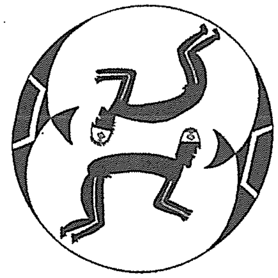
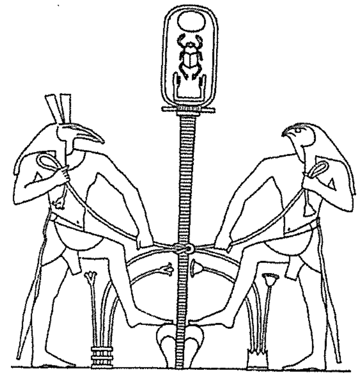
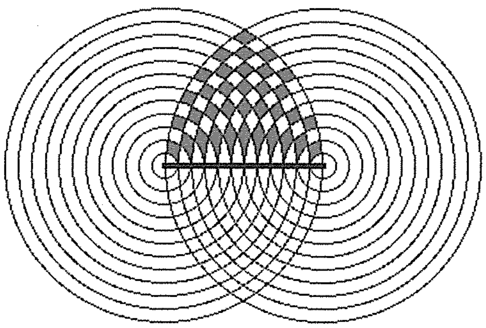
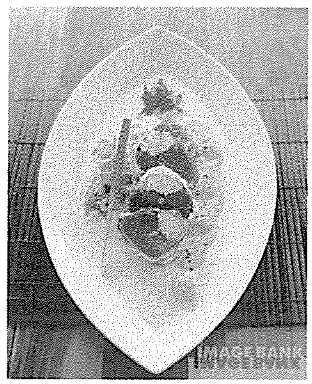
The circle will always enclose the most!

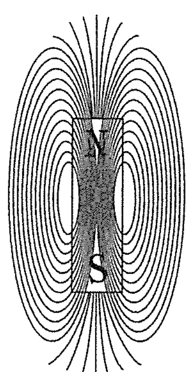


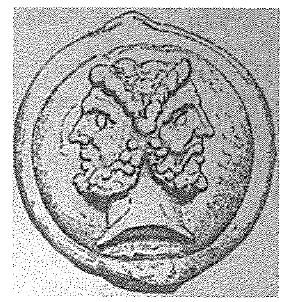
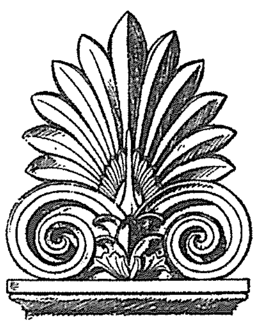
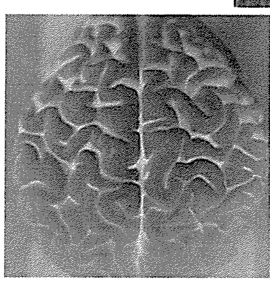
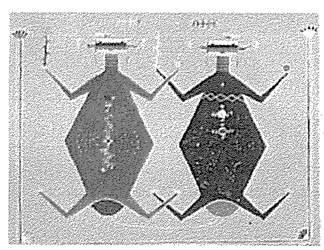
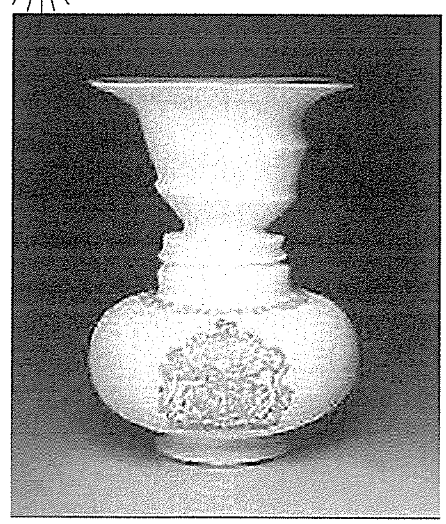
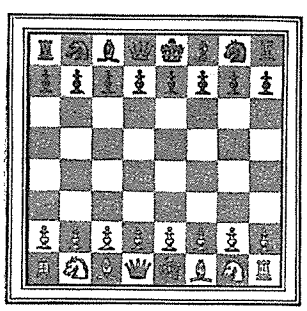
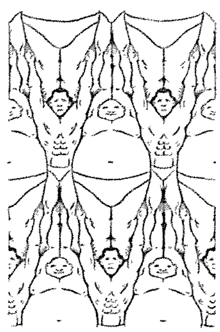
not drawn to scale

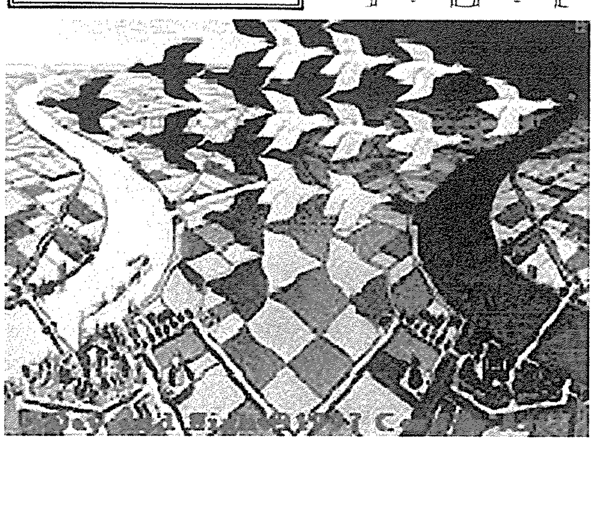
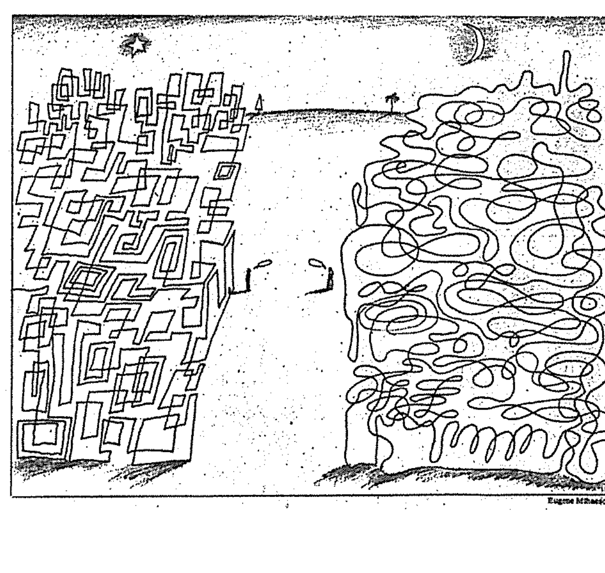
Polarity, Opposites, Complements

Notice the different ways that Two interplay.

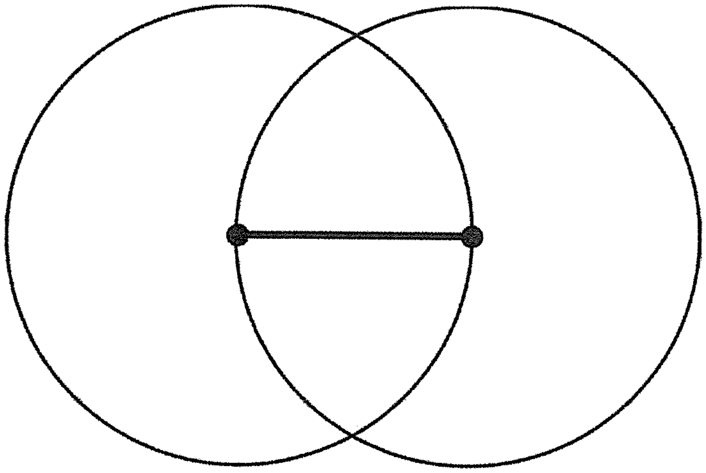


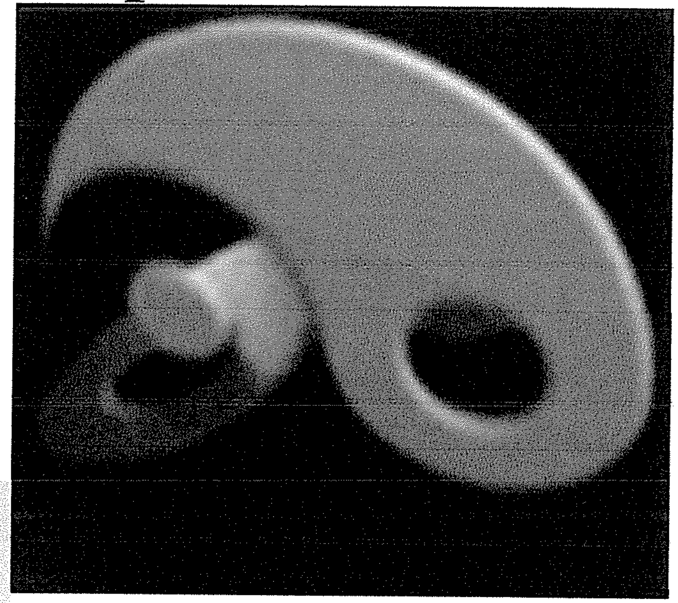








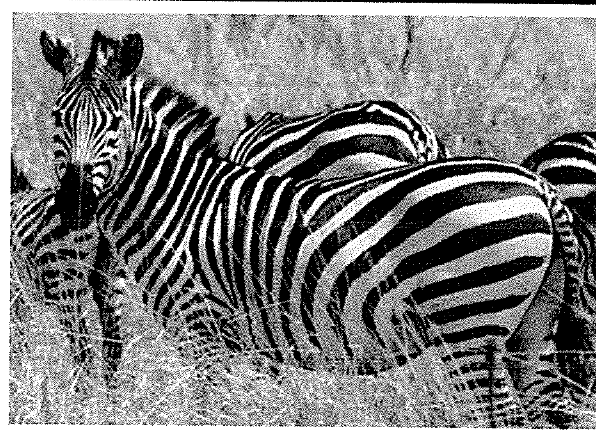



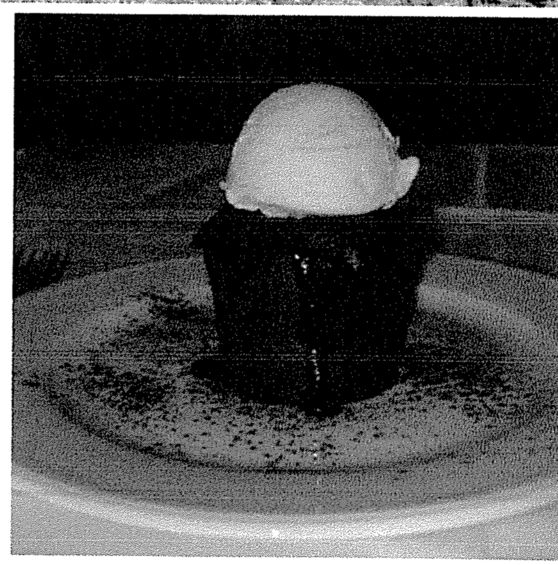
2 --Polarity:

Opposites and Complements Conflict and Cooperation.

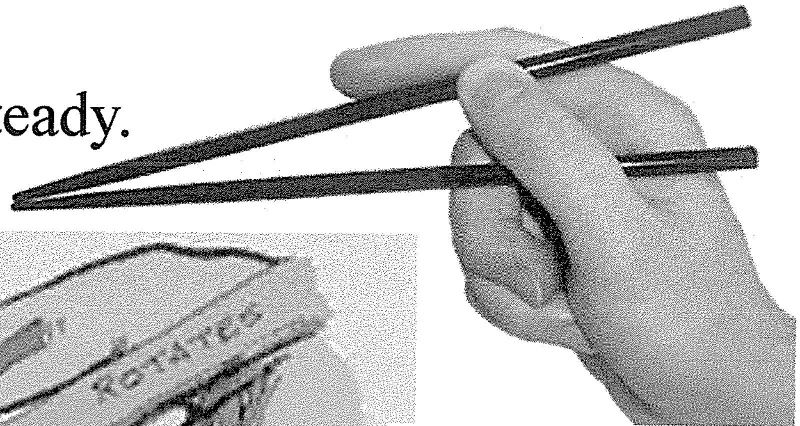


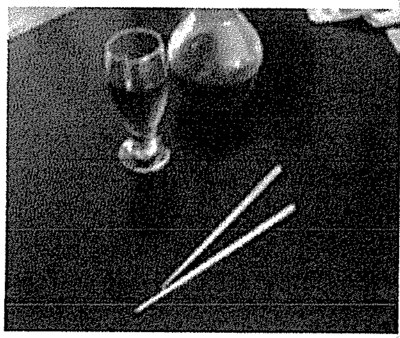


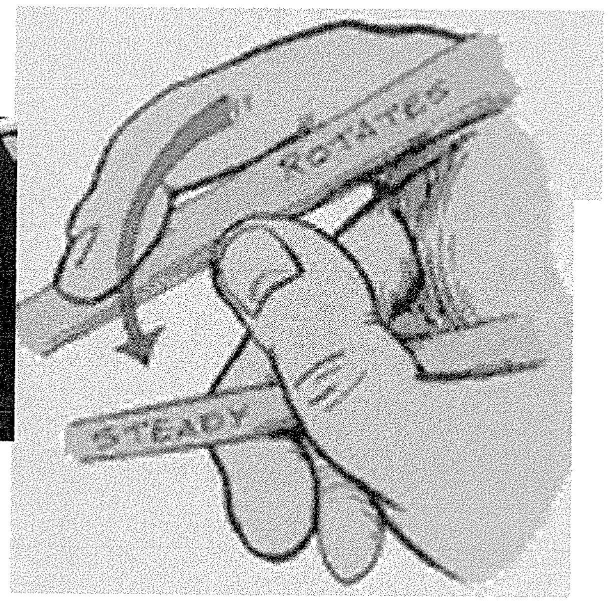




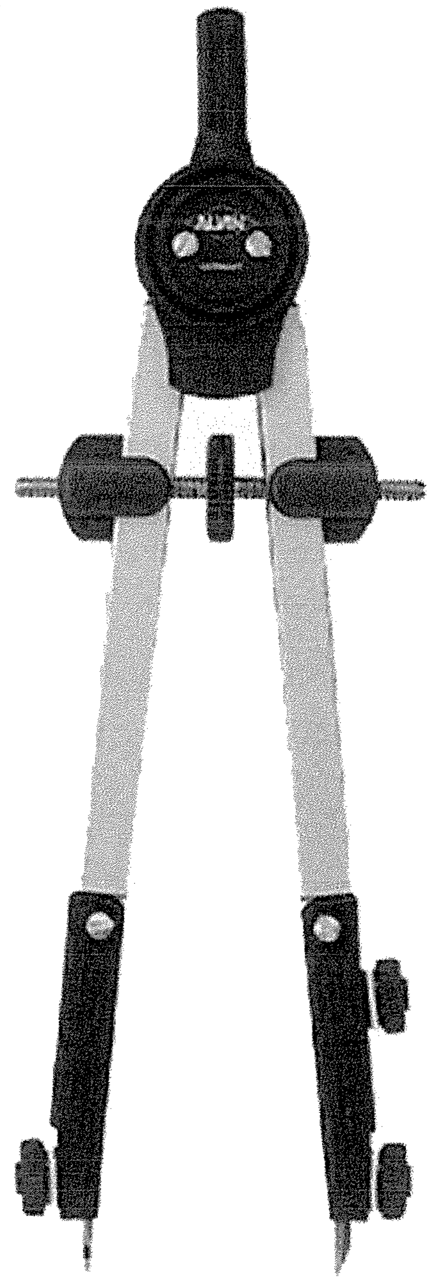
Chopsticks work by Polarity
One stick moves;
One stick remains steady.

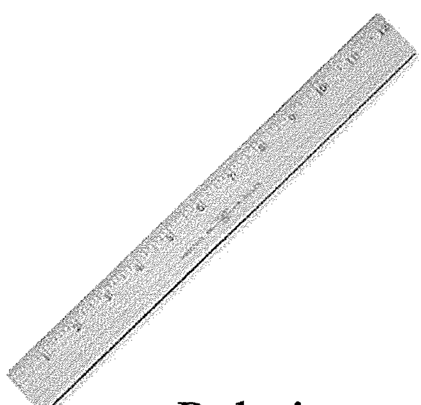






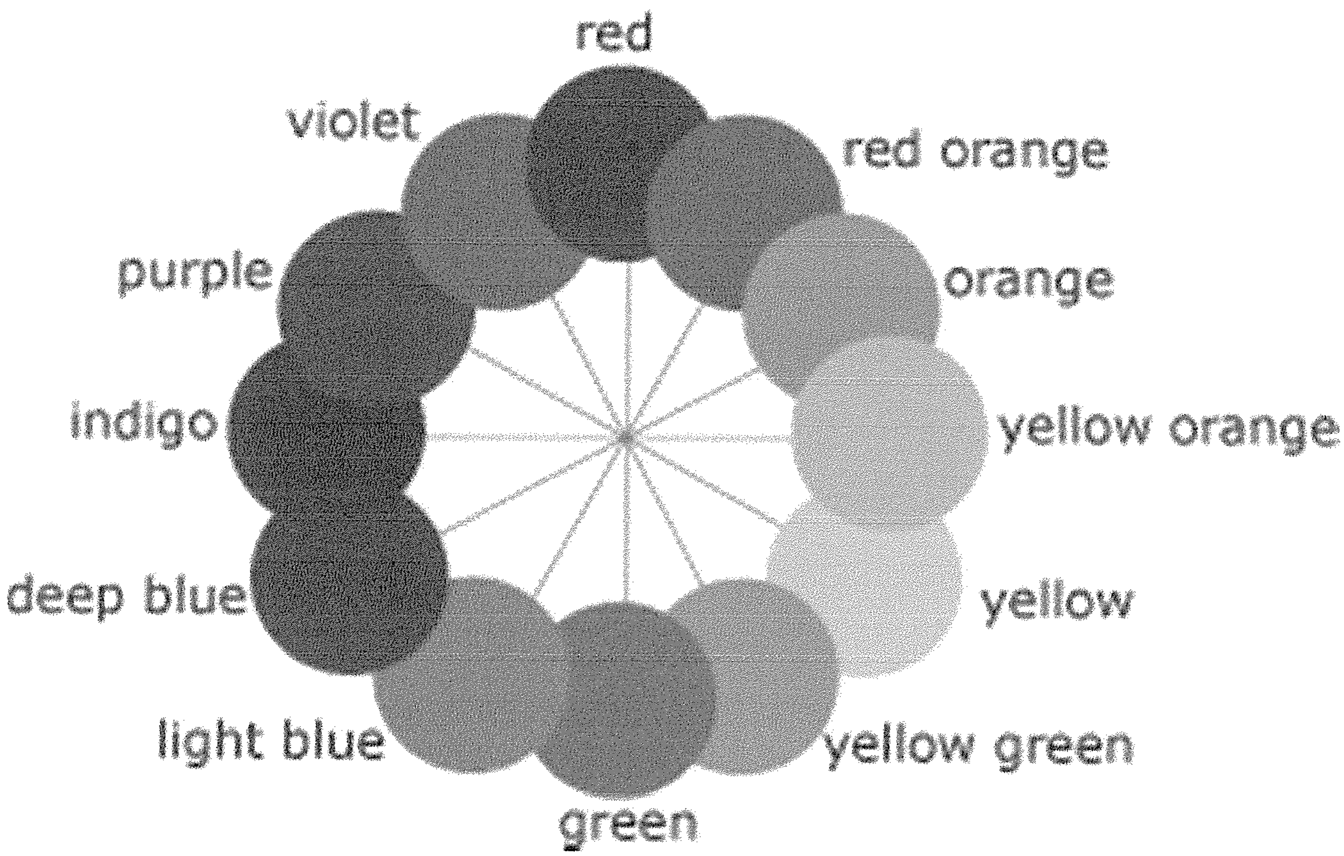
A Compass works by Polarity
One leg rotates on a single point;
The other leg moves, creating
infinitely many points





Polarity:
Straight &
Curved

Complementary Colors



Complementary colors create ***visual tension***.

They can both excite and annihilate each other, and in so doing can bring out the best in each other.

How to read & write numbers in the Binary System

To write any number in the Binary system:
First write out the Powers of 2 (from right to left):
Start with 1 at the right and keep doubling (from right to left).

1024 512 256 128 64 32 16 8 4 2 1

Don't go higher than the number you're trying to write.

Write a 1 under a Power Of Two to **count** it;

Write a 0 under a Power Of Two to ***not* count** it.

The values ABOVE the 1s added together tell us the value of a Binary number.

For example to write the number **99** in Binary:
Write the Powers of Two from 1 to 64 (since 128 and beyond would be too large):

Write a 1 under the 64 (since 64 is the largest Binary value to fit into 99).

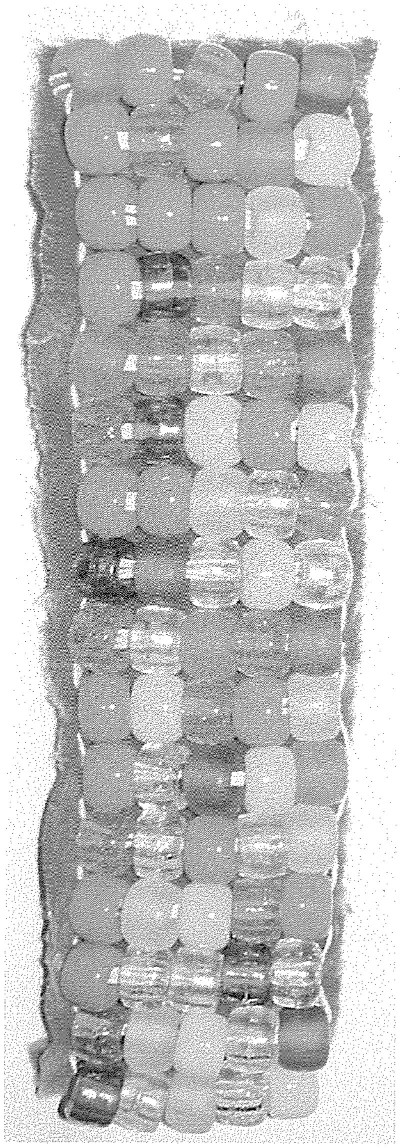
64	32	16	8	4	2	1
1						

How much is still needed to get to 99? Just subtract 99-64 =35.
To get 35 more, put a 1 under the 32, under the 2 and under the 1.
Everything else gets a 0 (since they're not needed):

64	32	16	8	4	2	1	
1	1	0	0	0	1	1	= 99

(since 64+32+2+1 = 99)

Count from 0 to 15 in Binary:



Student-made
Binary Bead Bracelet

Place-Valaue Columns

	8	4	2	1
0 =				
1 =				
2 =				
3 =				
4 =				
5 =				
6 =				
7 =				
8 =				
9 =				
10 =				
11 =				
12 =				
13 =				
14 =				
15 =				

Numbers (0-26) and Alphabet (A-Z) in *Binary Code*

		16 8 4 2 1
0.	Space	00000
1.	A	00001
2.	B	00010
3.	C	00011
4.	D	00100
5.	E	00101
6.	F	00110
7.	G	00111
8.	H	01000
9.	I	01001
10.	J	01010
11.	K	01011
12.	L	01100
13.	M	01101
14.	N	01110
15.	O	01111
16.	P	10000
17.	Q	10001
18.	R	10010
19.	S	10011
20.	T	10100
21.	U	10101
22.	V	10110
23.	W	10111
24.	X	11000
25.	Y	11001
26.	Z	11010

16 8 4 2 1

1. Count from 0 to 26 by **shading the boxes** corresponding to a 1.

Do you see the pattern?

2. Below (or on another piece of paper) **write your name in binary code**, (or write a message). Then write each letter in Binary Code with 0s and 1s (or empty & shaded, or use beads, sequins, etc.)

Write the Letters of your name

... then in Binary Code 1s & 0s or shaded 1s, etc.

16 8 4 2 1

Number "Guessing"

	16 8 4 2 1
1	**1**
2	**10**
3	11
4	**100**
5	101
6	110
7	111
8	**1000**
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111
16	**10000**
17	10001
18	10010
19	10011
20	10100
21	10101
22	10110
23	10111
24	11000
25	11001
26	11010
27	11011
28	11100
29	11101
30	11110
31	11111

16	**8**	**4**	**2**	**1**
17	9	5	3	3
18	10	6	6	5
19	11	7	7	7
20	12	12	10	9
21	13	13	11	11
22	14	14	14	13
23	15	15	15	15
24	24	20	18	17
25	25	21	19	19
26	26	22	22	21
27	27	23	23	23
28	28	28	26	25
29	29	29	27	27
30	30	30	30	29
31	31	31	31	31

Translate these **Binary numbers** into Base 10:

128	64	32	16	8	4	2	1	
				1	0	1	0	=
			1	0	1	0	0	=
		1	0	1	0	0	0	=
		1	1	0	0	1	1	=
		1	0	0	1	1	0	=
	1	1	1	0	1	1	1	=
	1	0	1	0	1	0	1	=
1	1	0	0	0	1	1	0	=

Translate these Base 10 numbers into Binary:

			128	64	32	16	8	4	2	1
8)	12	=								
9)	48	=								
10)	96	=								
11)	192	=								
12)	225	=								

13) Is this binary number even or odd? 1101100011000101101001110101110001010

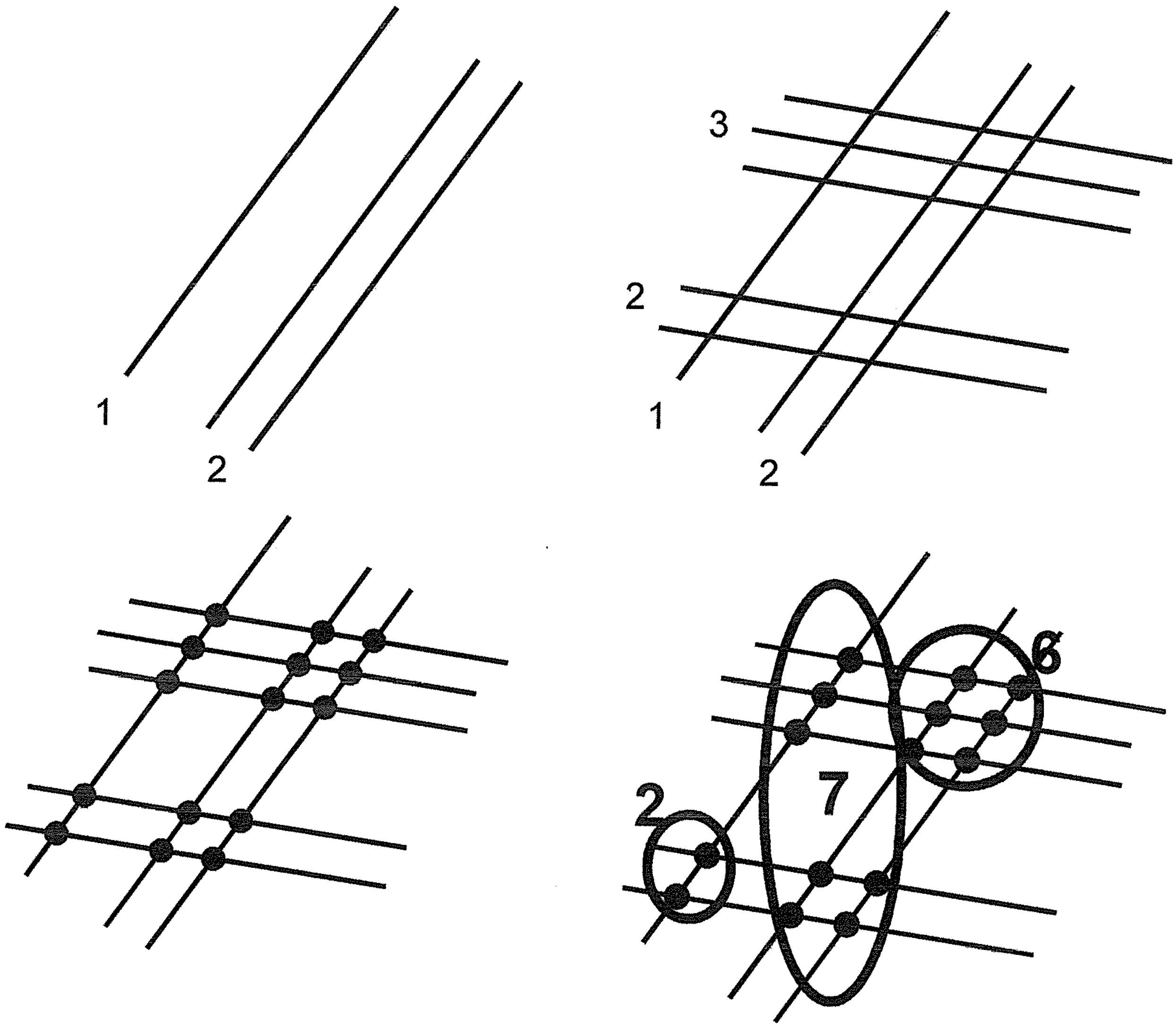
14) How can you easily *double* it?

15) How can you easily multiply it by *four*?

There are only 10 types of people: those who understand binary and those who don't.

Multiplying is really Weaving!

12 x 23 = ?

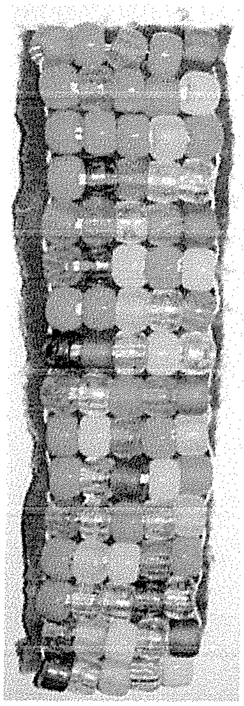


12 x 23 = 276

Try your own multiplication weave!

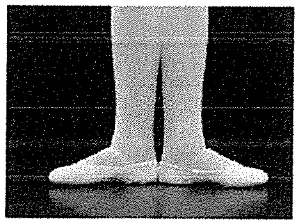
Homework?

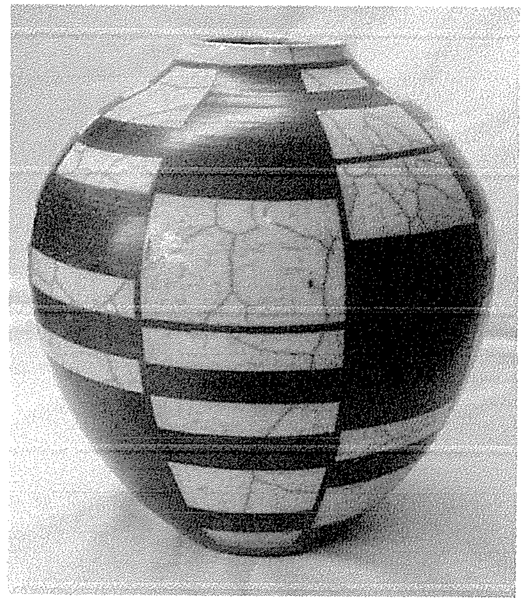
Design or create (in any media) an original exploration of "polarity."



Create a message disguised as a design?

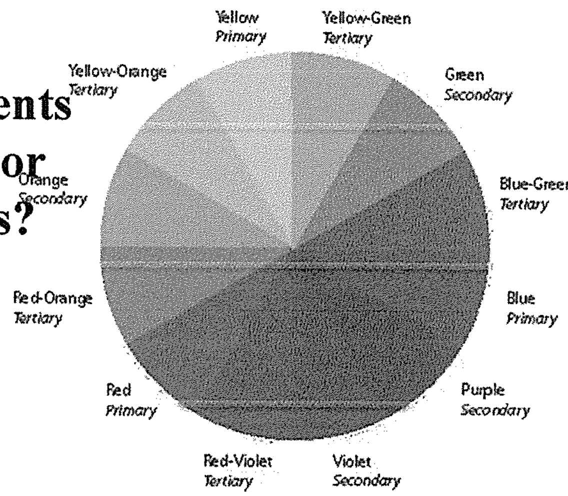
A series of photographs?



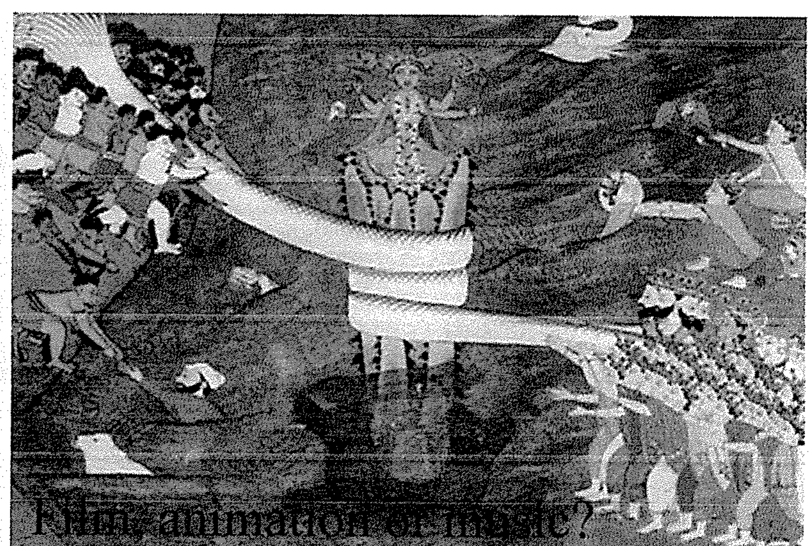


Playing with polarity in textiles or fashion?

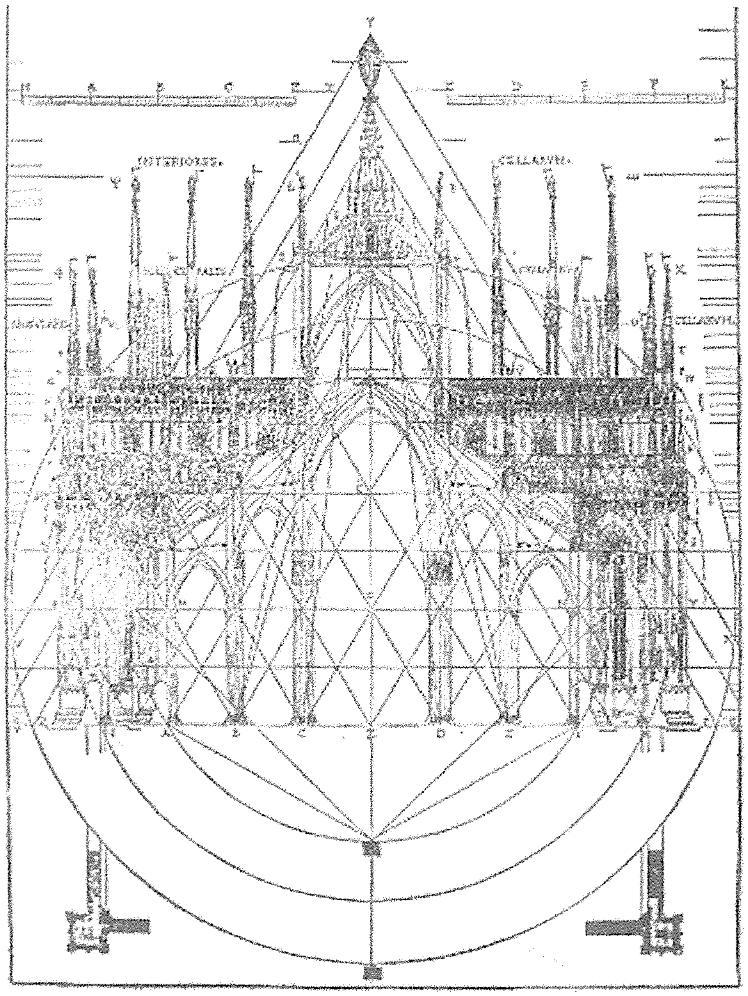
Experiments with color tensions?



Illustrations involving polarity?



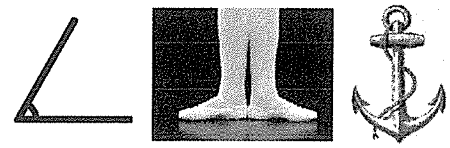
Ad Triangulum Symmetry



Name:

27 [redacted]

What's So Great About Triangles?

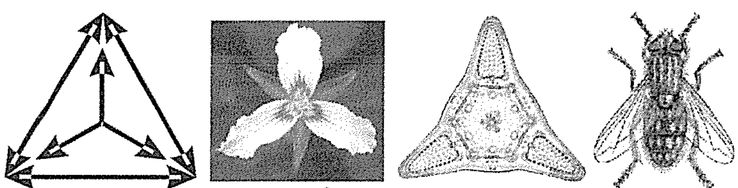


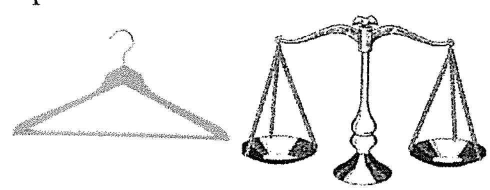
Where does the word "angle" come from?
The "ANG" or "ANK" sound in a word is a clue that it is *bent*, like an angle, ankle and anchor!

All triangles have three corners and three sides.
It's the simplest shape having an inside *and* corners!
The triangle's claim to fame is that it solves four problems:

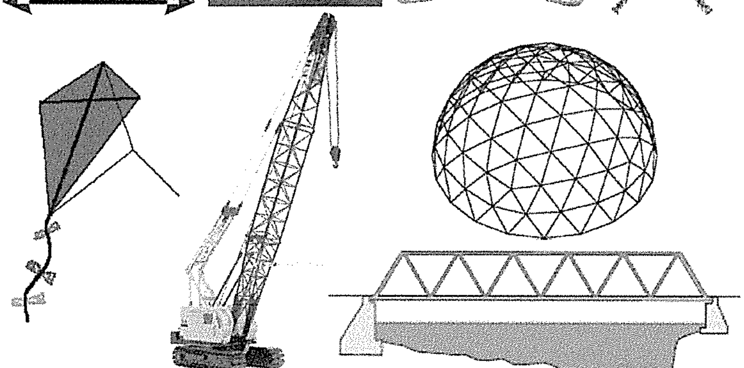
How to be small but very, very strong.
How to balance when standing still.
How to enclose the smallest inside by using the *most* to surround it,
(making the triangle the opposite of a circle).
How to be whole: everything needs three parts, a beginning, middle and end, to be complete.
How to repeat and cover a surface leaving no gaps or overlaps.

A flower, microscopic plant and a fly each enjoy the triangle's strength and balance in different ways.



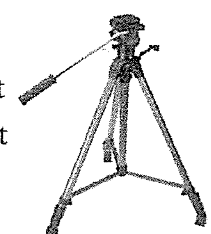


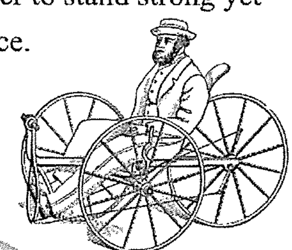
A clothes hanger and scales show how opposites can be made to balance by a neutral third point above.

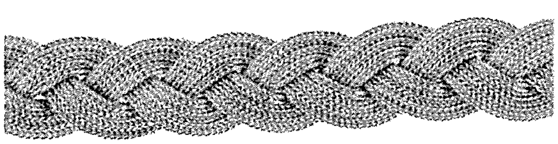


Kites, cranes, bridges and domes use triangles for great strength with the fewest materials and least weight.

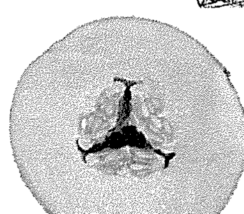
A tripod and tricycle only need three legs, the fewest number to stand strong yet balance.





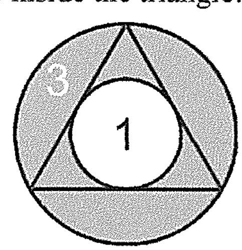


Three is a way that different parts become one complete whole: One strand of hair just dangles, two will untwirl. But three strands weave into *one braid*! When three work together as one, they become complete and very strong.



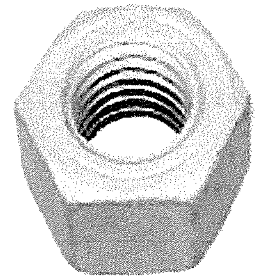
Cut across a melon and you're likely to find a "triangle" inside a big circle. The circle provides the most space, food and protection for the tight triangle of valuable seeds at its center.

Curious fact: The rim of a circle surrounding a triangle has an area *exactly three times* the area of the circle inside the triangle!



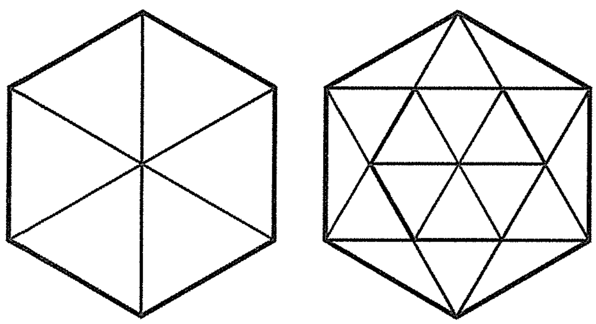
What's So Great About Hexagons?

Every hexagon has six corners and six sides. When they're all equal, it's called a "regular" hexagon. The star inside is called a "hexagram."



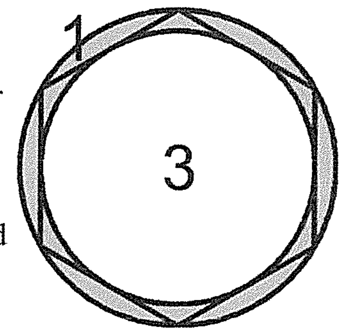
A hexagon solves four problems:

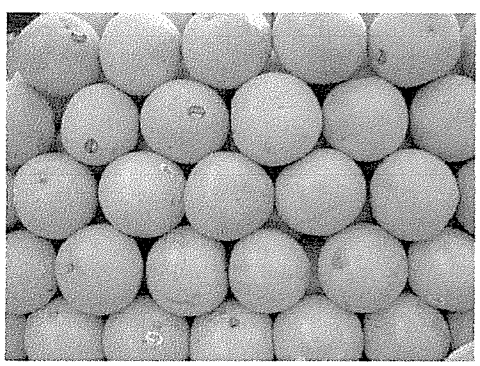
How to be strong.
How to balance while standing still.
How to approximate a circle's benefits by using straight lines.
How to pack the most into the smallest space.



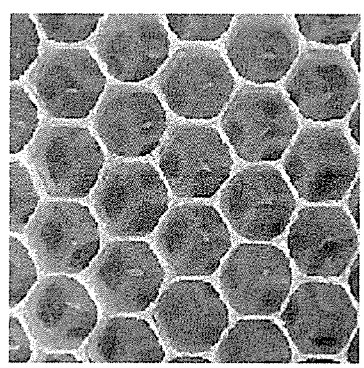
Hexagons are strong because they're supported by triangles.

The area of a circle inscribed inside a regular hexagon is exactly 3 times the area of the rim made by the circle around the hexagon.



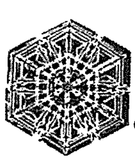


Arranging circles or spheres as six-around-one packs the most into a compact space, stable and self-supporting.

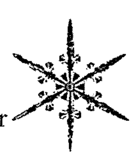


The wax cells of a beehive are hexagons arranged six-around-one, packing the most into the least space. Three-corner joints make it strong to hold lots of heavy honey.

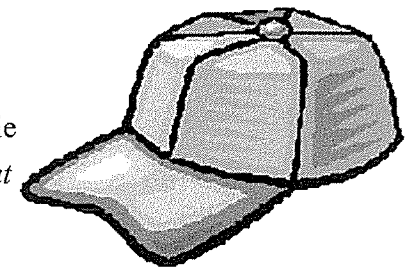
Look closely at six-petaled flowers and you'll see that they're actually two types of petals.



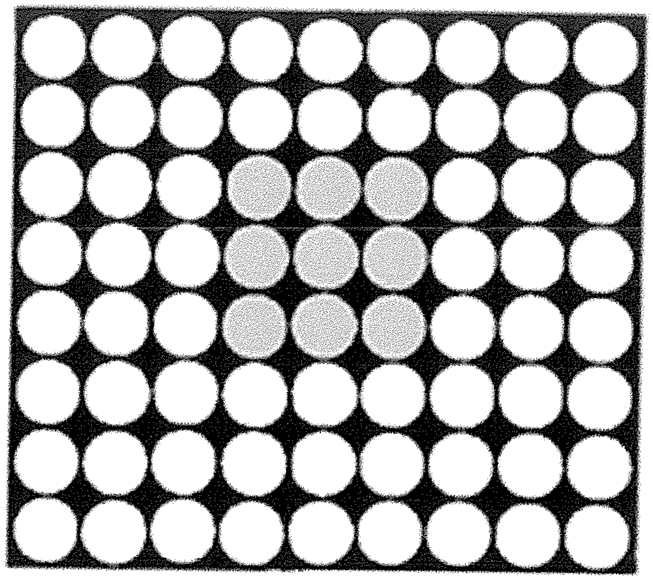
Snowflakes range from flat hexagon plates to hexagram needles and everything between. Their shape tells you about the air's pressure, temperature and humidity. Colder weather makes needles, less cold makes flakes.



A baseball cap is a circle made of six *straight-cut* triangles.



8-around-1
Square



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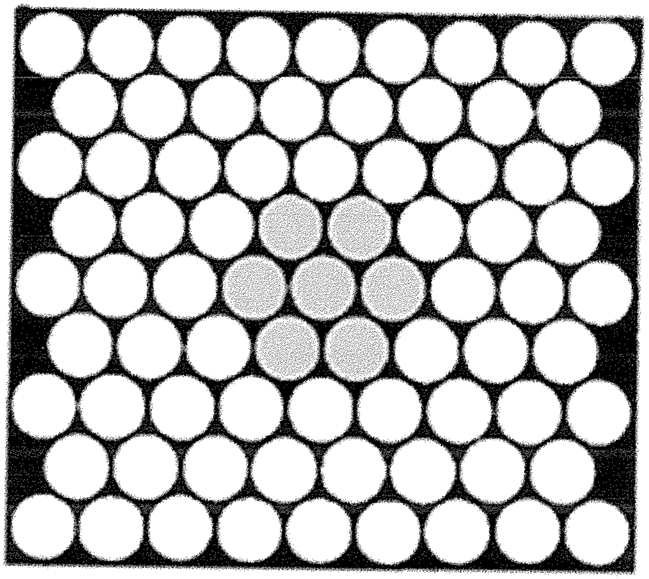
Six is superior for *Close-Packing*

6-around-1
Hexagon (Triangles)
Getting *more* in the same space.



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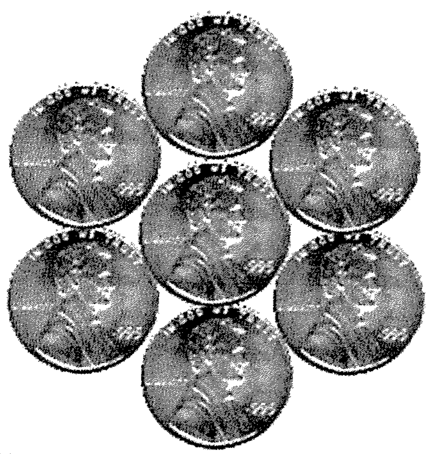
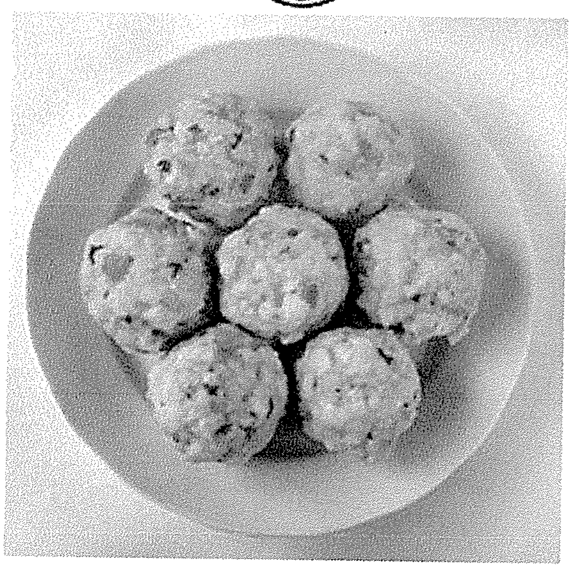
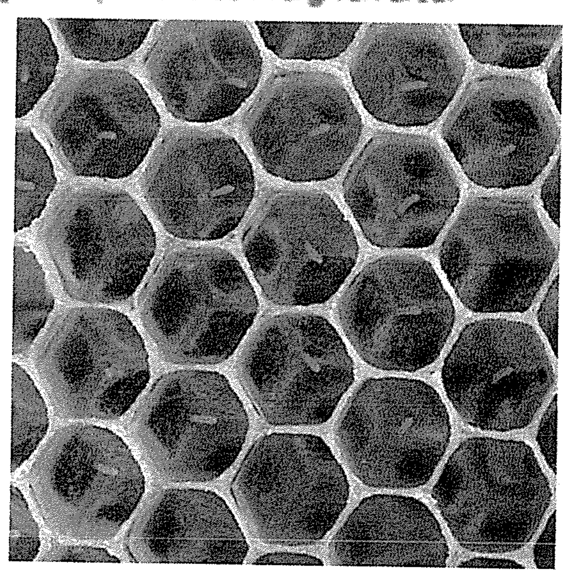
1.4 Comparison of square and triangular packings of equal circles in a given area.

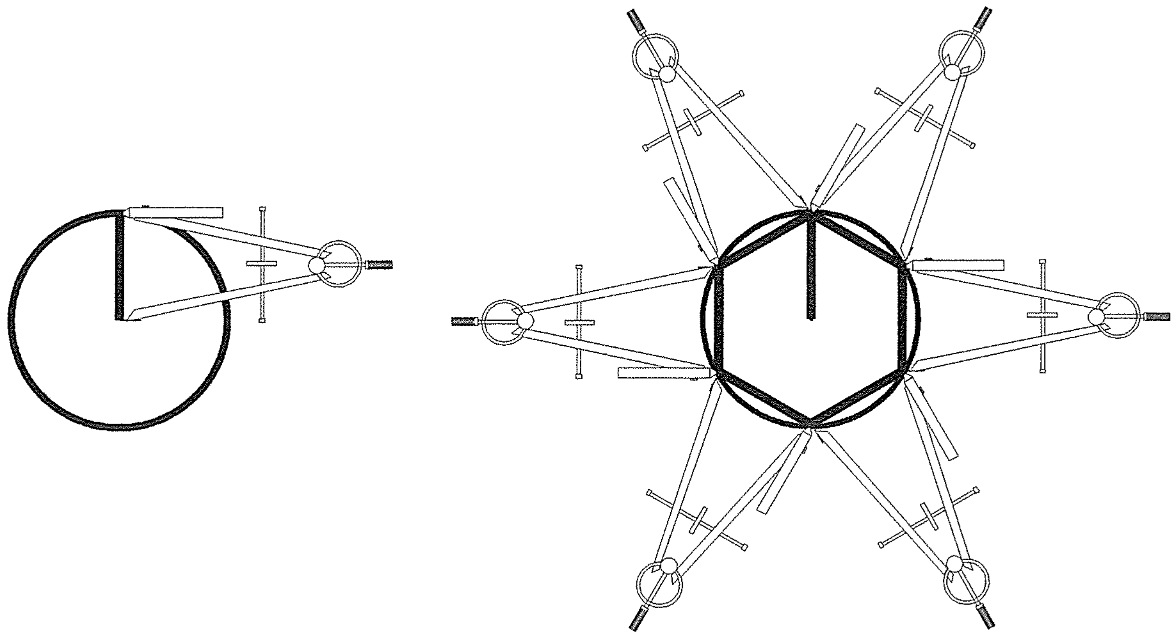






Construct a Hexagon two different ways

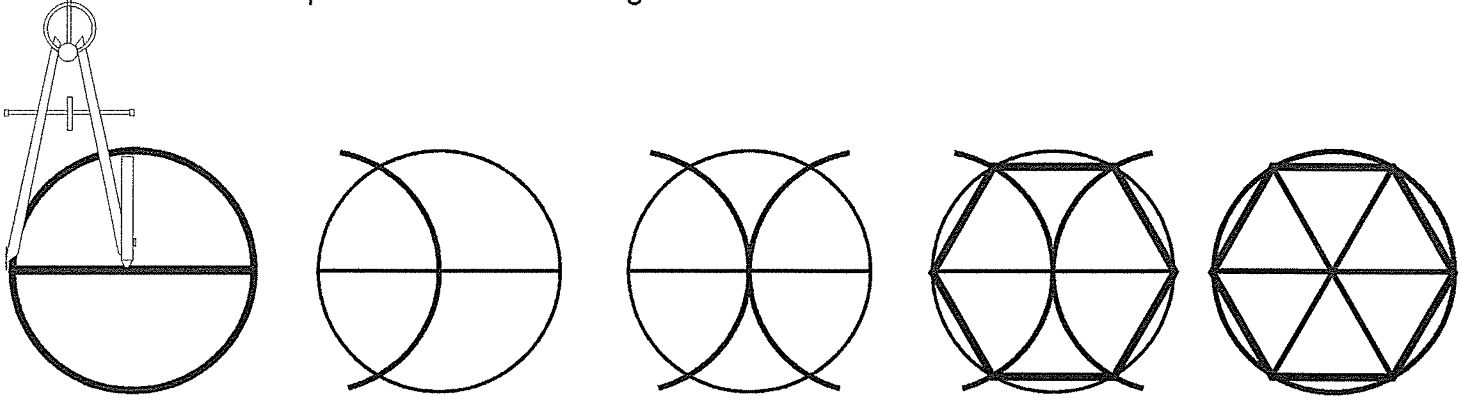
(on the opposite blank page)



Turn a circle. Place the compass point at the top of the circle.
"Walk" the radius around the circle.
It should reach the beginning point at the sixth step.

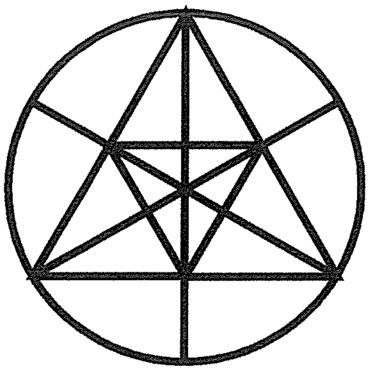
If the last step doesn't exactly reach the beginning, repeat the process in the opposite direction. The actual point is half way between them.

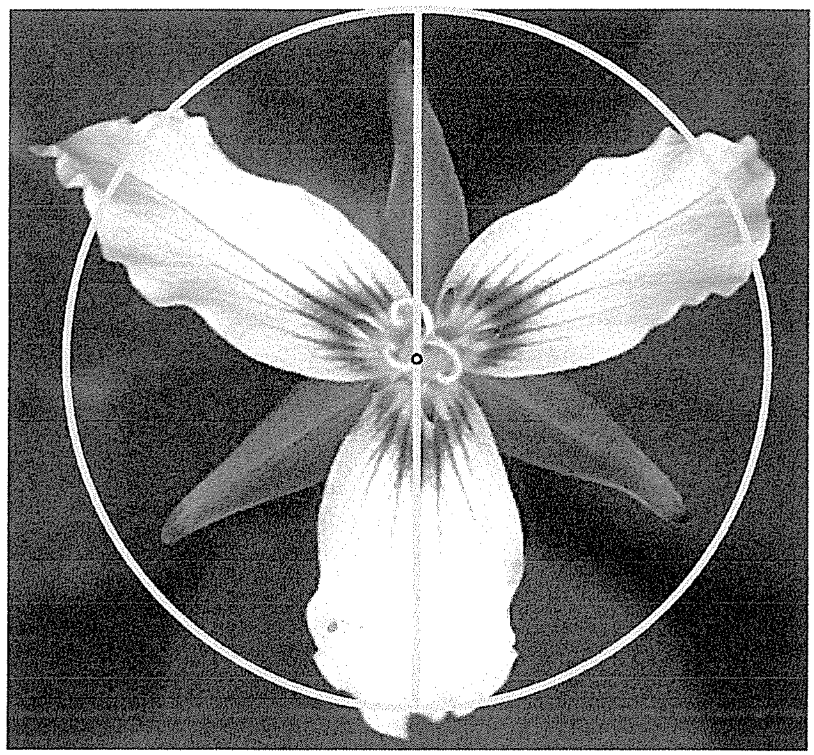
Connect the six points to make a Hexagon.

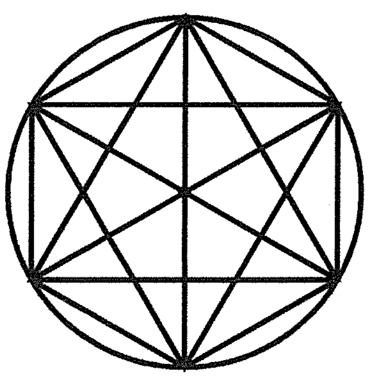


Turn a circle and draw its diameter through the center point made by your compass.
Place the compass at one end of the diameter and make an arc. Notice where it crosses the circle.
Do the same from the other end of the diameter.
Connect the six points to make a Hexagon.
Draw its diameters to show six triangles.
Are all the sides and diameters *equal*?

Is one method more accurate? If so, which?







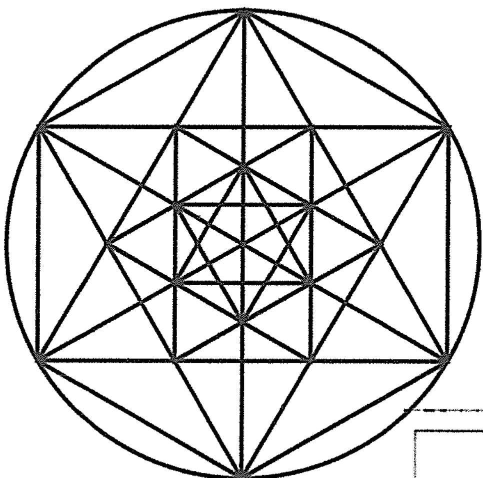
Ancient Chinese “Pi Disc”

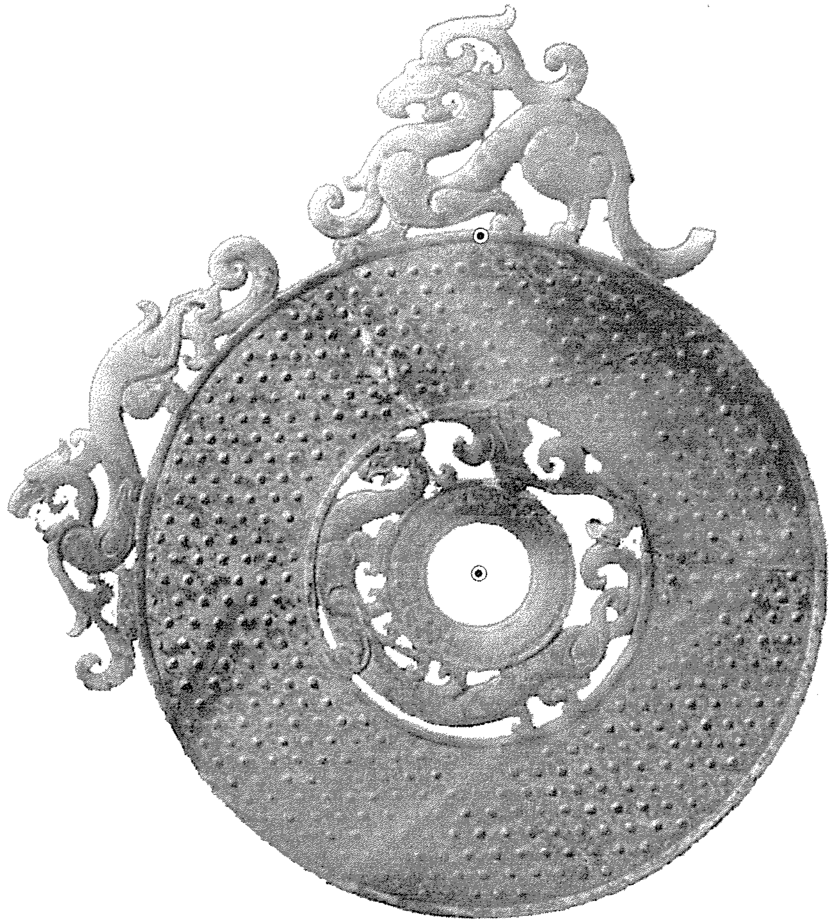
and

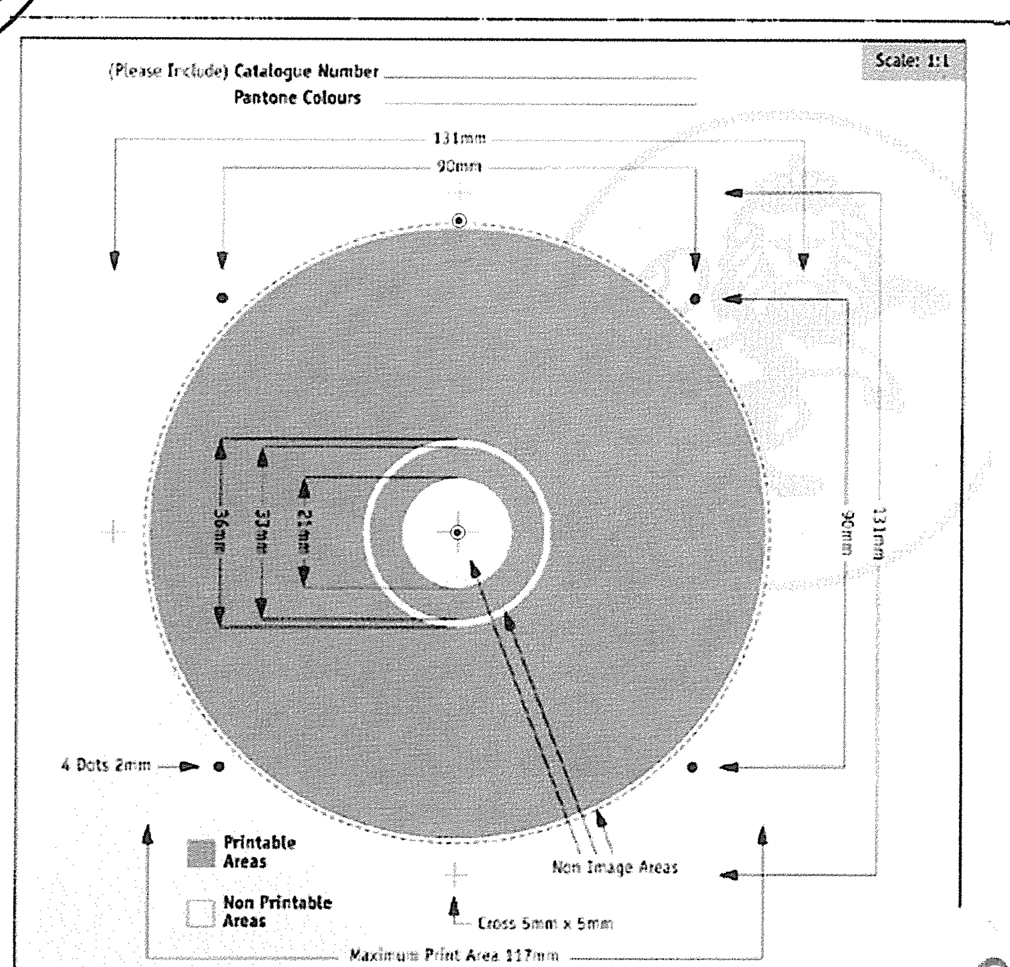
Modern CD disc

Use the center and top points given to construct a hexagon subdivided into hexagrams as shown below.

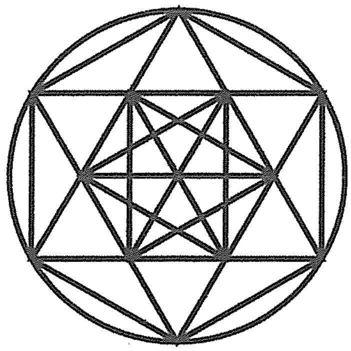
Timeless idea;
Different expressions.

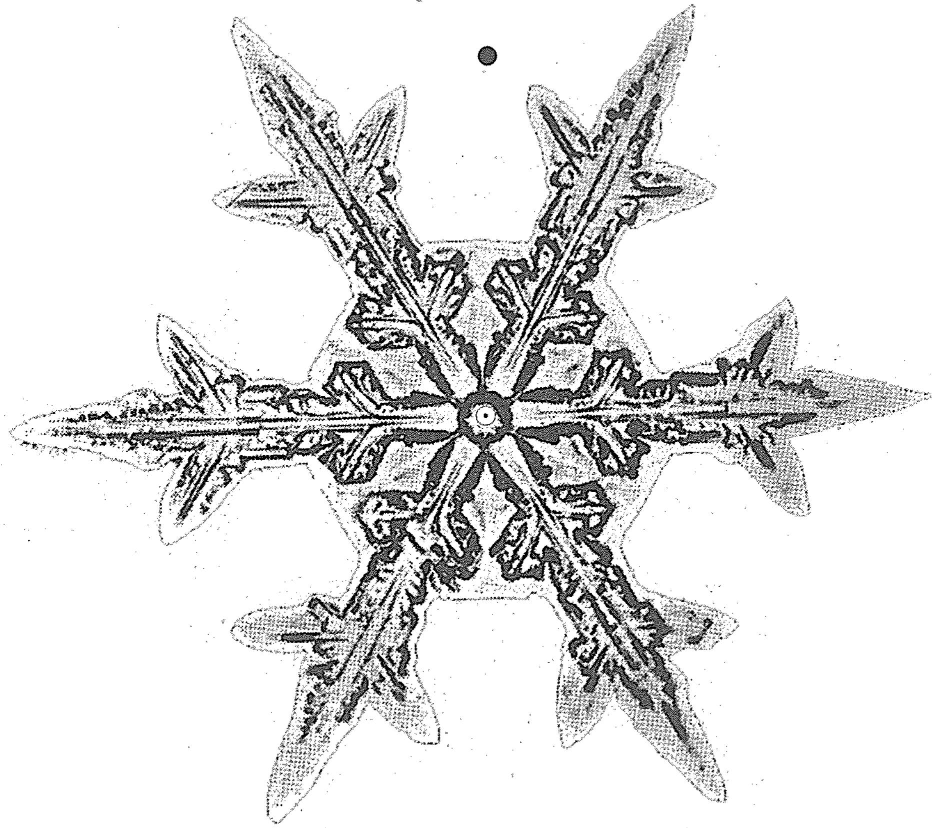


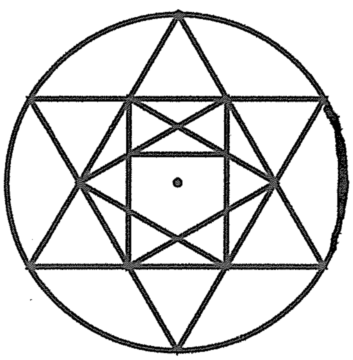




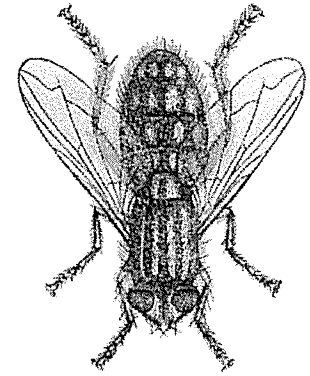
CD







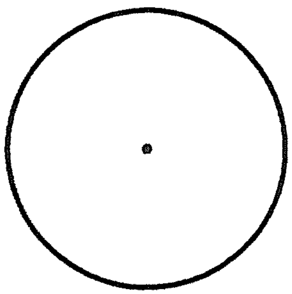
Draw an Insect Face!

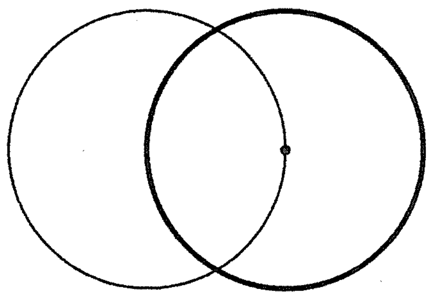


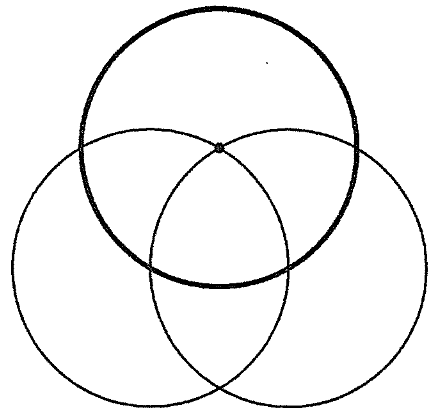
Use your compass and follow these steps by turning *the same size circle.*

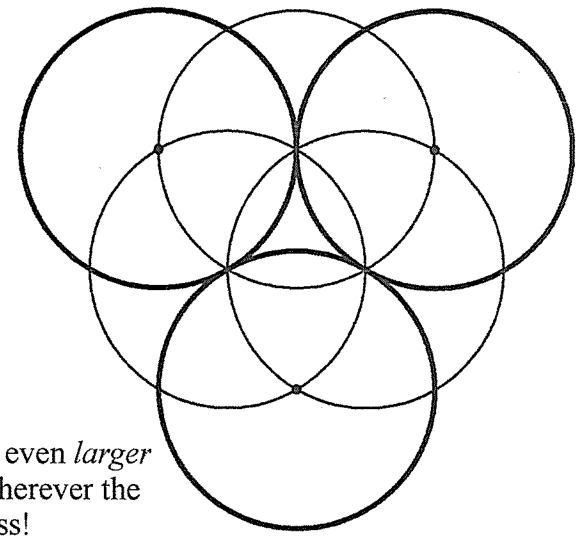
Do you see an insect, or an insect's face in the geometric construction?

Draw (or paint) it! and invent your own insect!

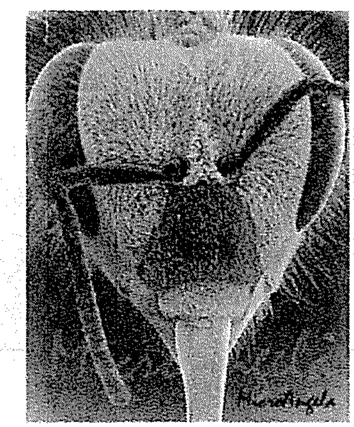


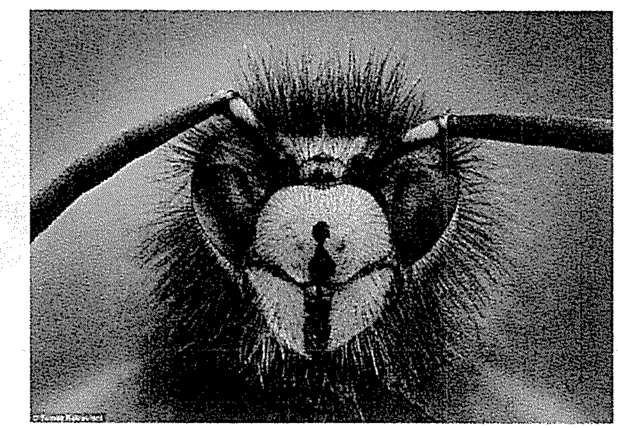


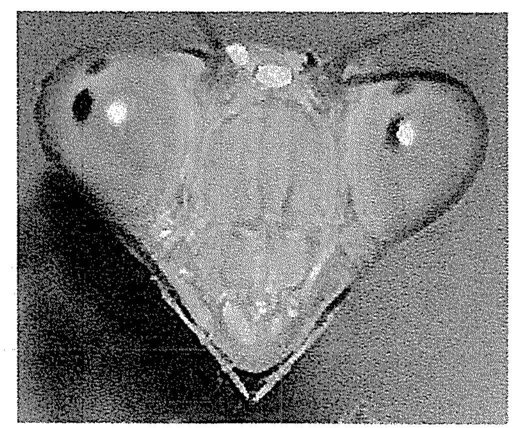


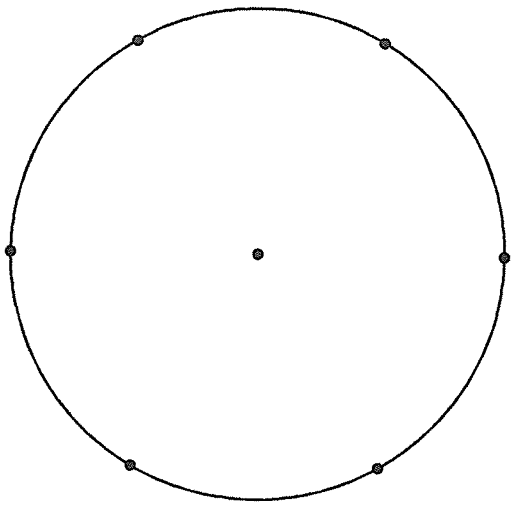


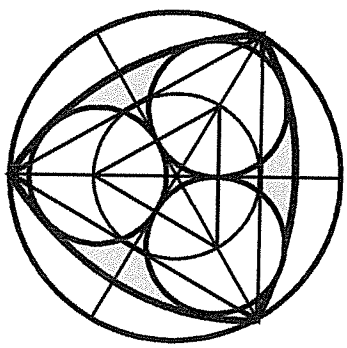
You can make this design even *larger* by turning new circles wherever the other circles cross!

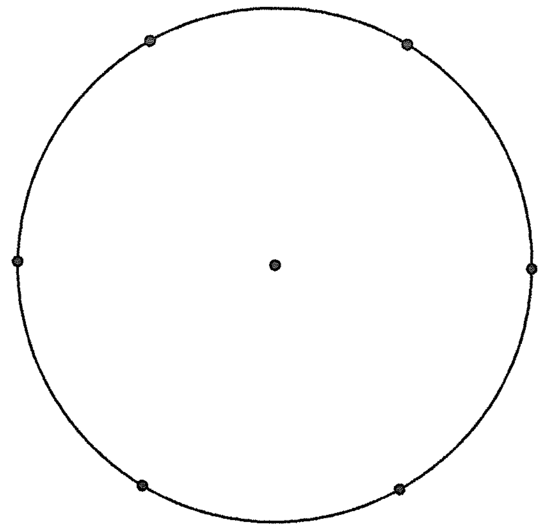


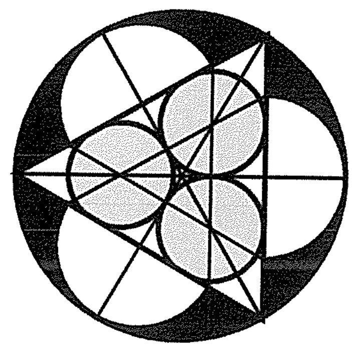


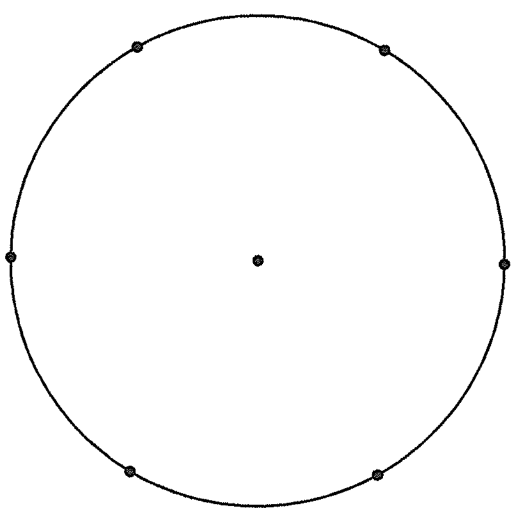


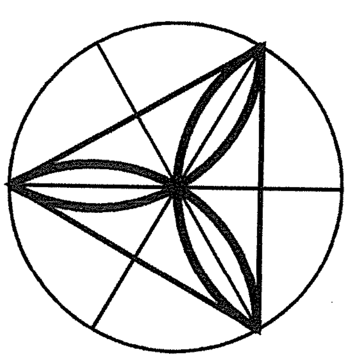


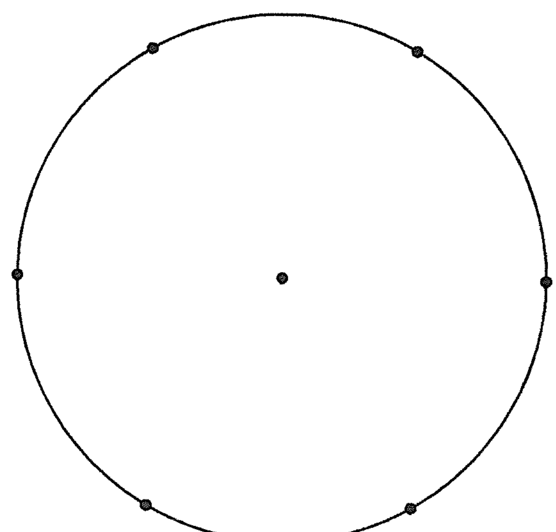


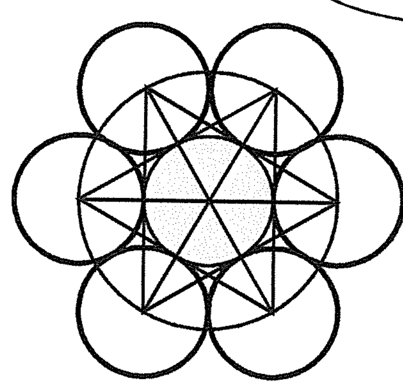








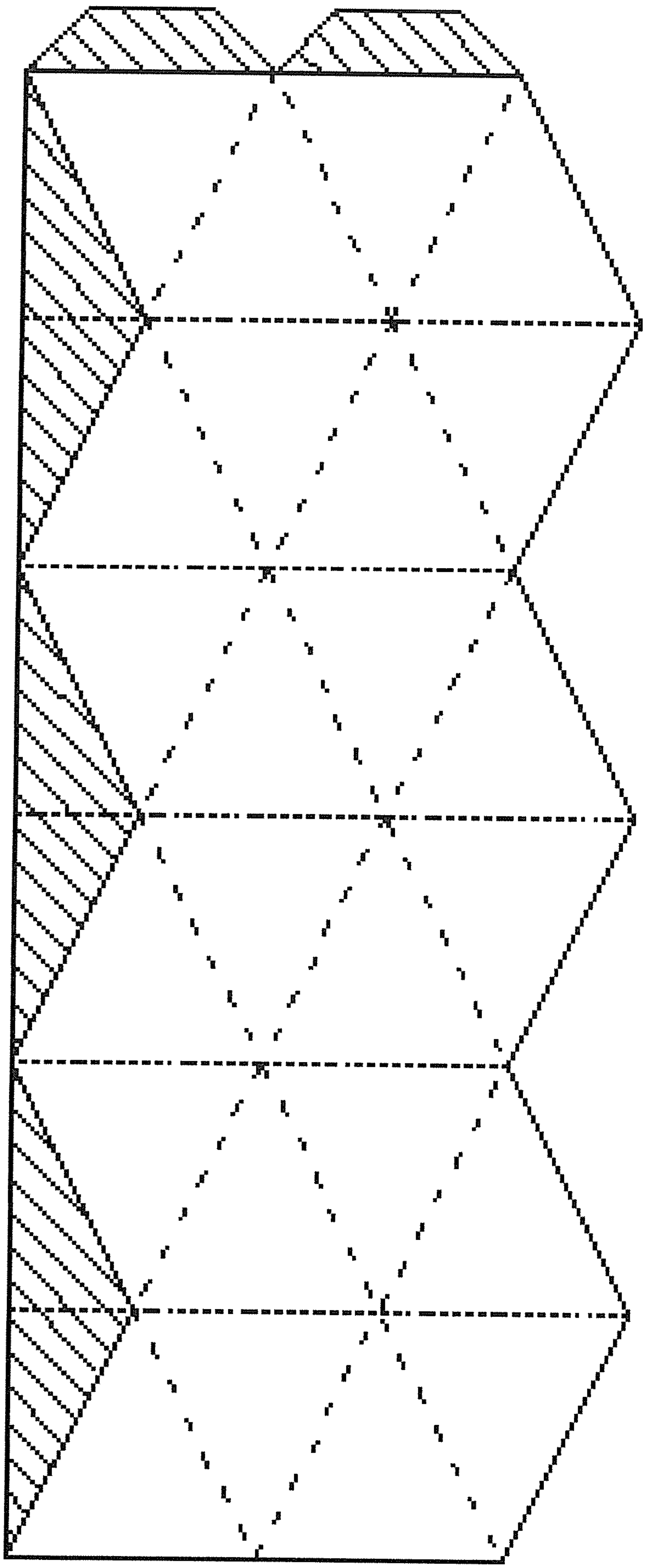


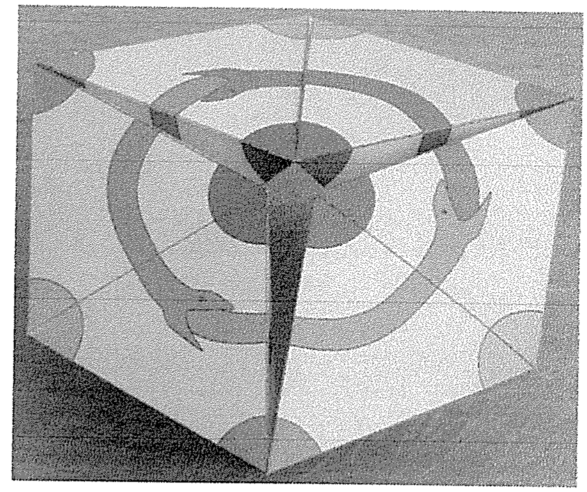


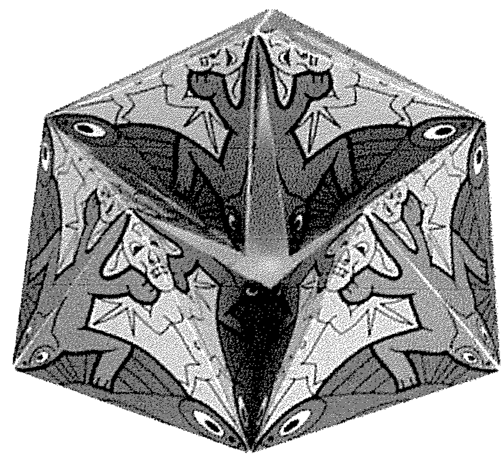
See if you can reproduce each pattern in the circle next to it.

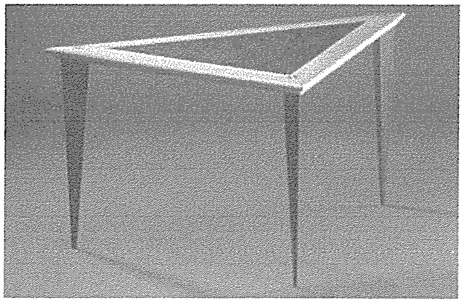
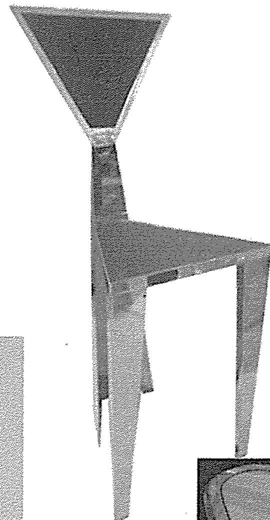
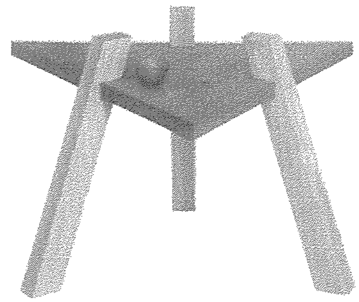
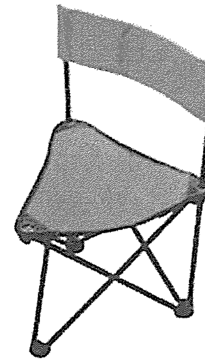
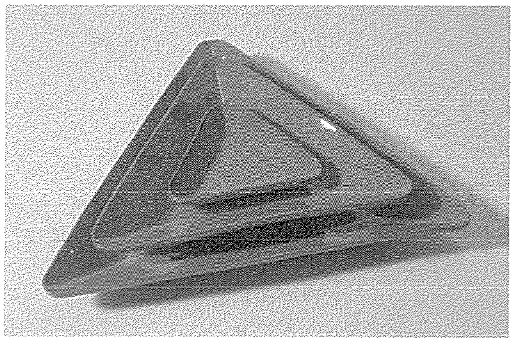
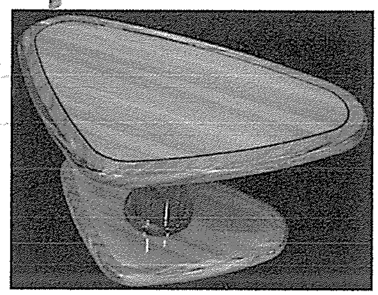
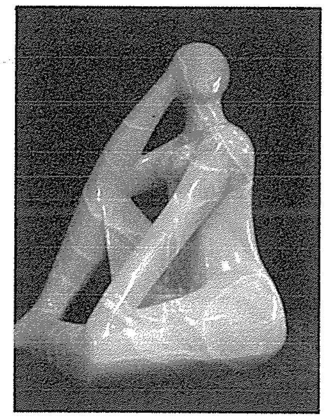
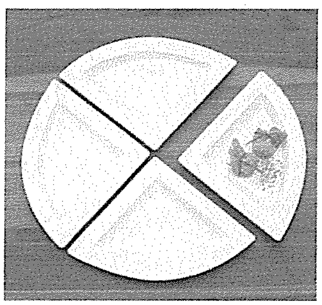
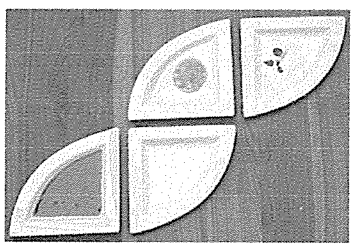
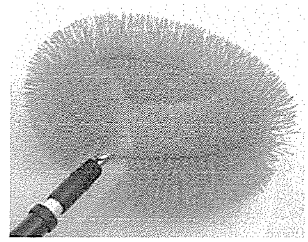
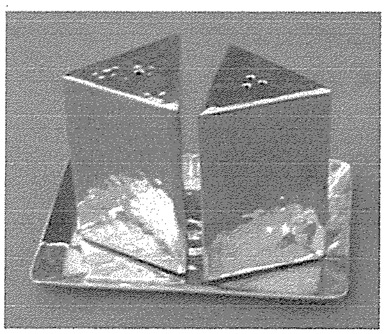
Kaleidocycle

Enlarge and use stiffer paper.

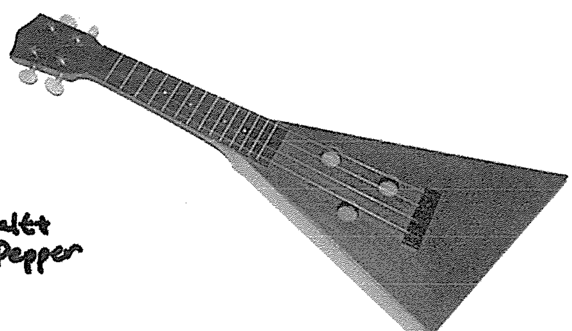




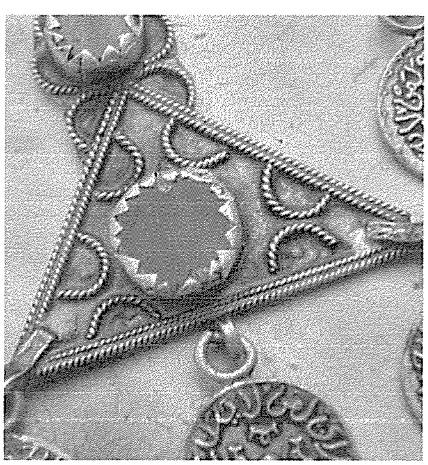
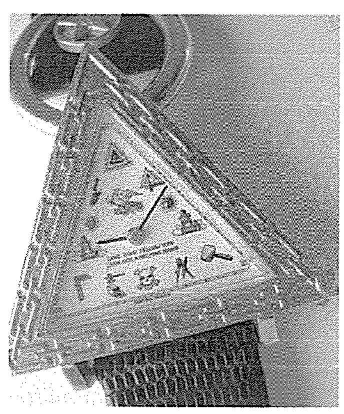


Salt+ Pepper




Bike Bag

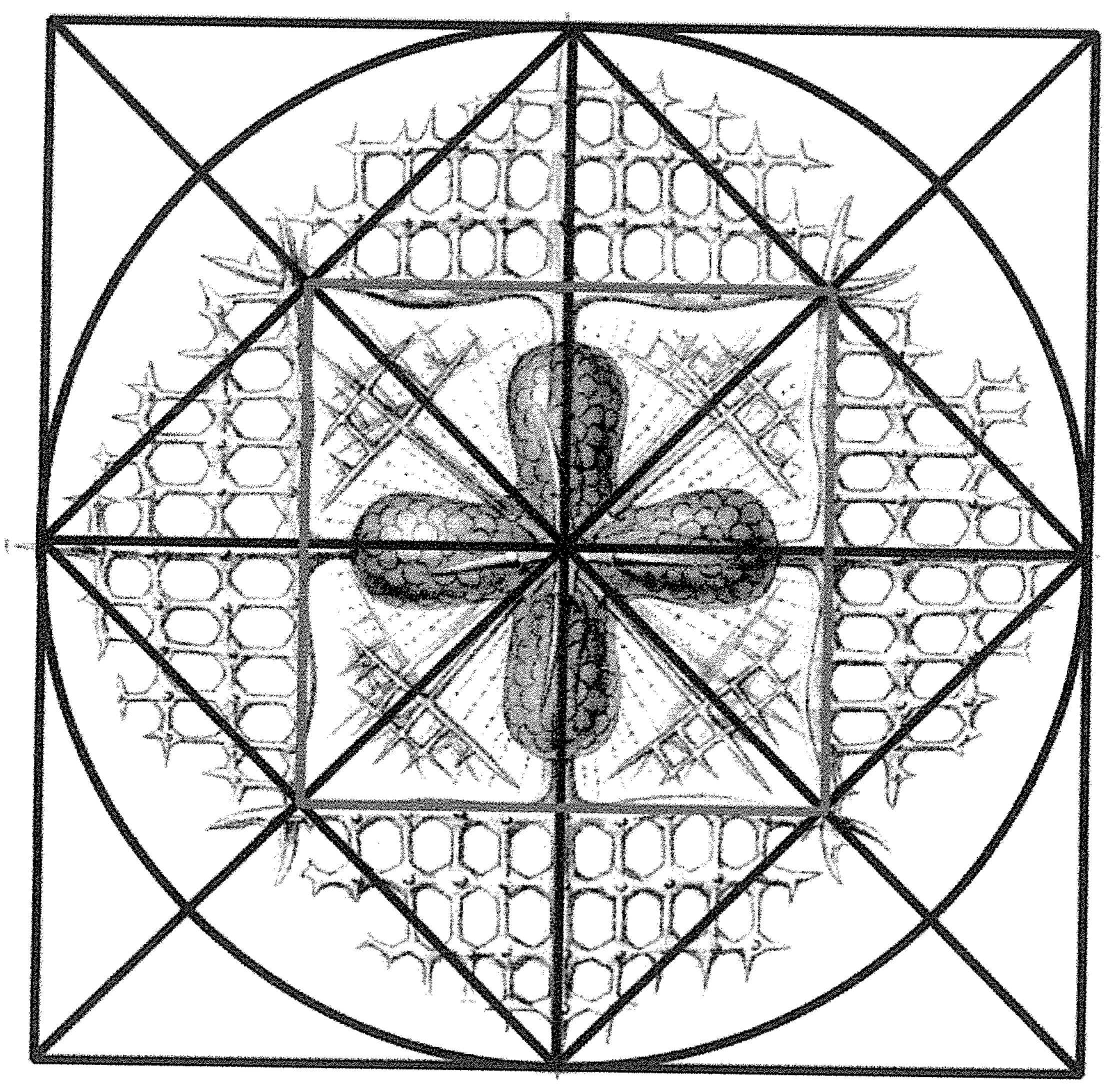




Teapot

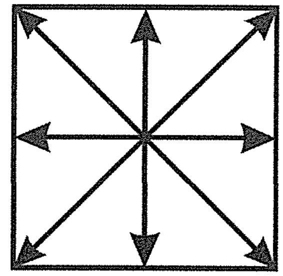
Ad Quadratum Symmetry

Part 1

Squares



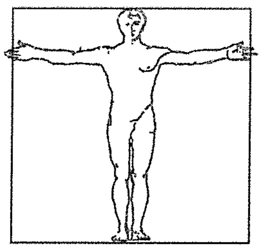
What's So Great About Squares?

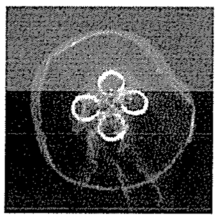


Every square has four equal sides and four corners at "right" angles.

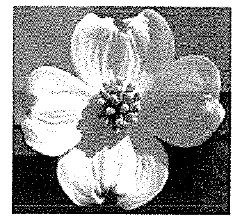
A triangle balances opposites, and a square does too. But a square has *two* pairs of opposite sides and *two* pairs of opposite corners, and so specializes in solving this problem:

How can opposites, as well as *pairs* of opposites, balance in equality and fairness?

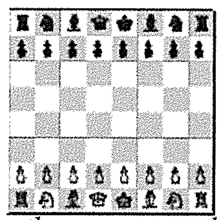


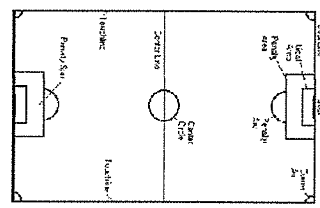


A jellyfish floating freely and the open dogwood flower both balance pairs of opposites by the number four and the square.



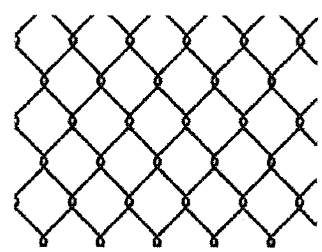
When our height equals our arm span, we fit into a square.

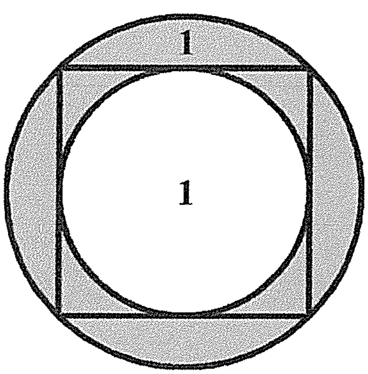




We "square off" against opponents on the squares and rectangles of board games and sports fields. This way, both sides begin with equal opportunities, "fair and square".

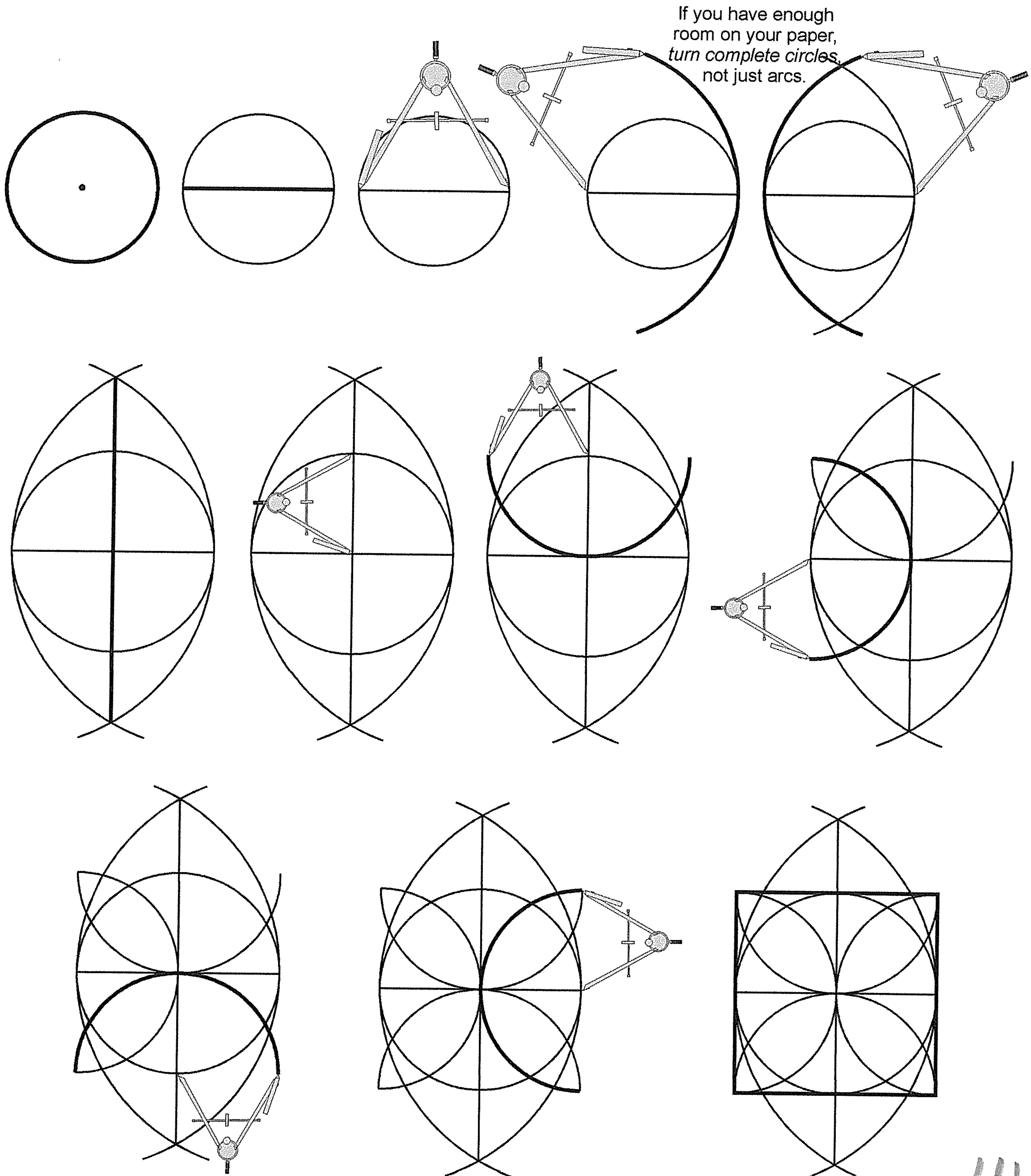
A square also provides balance to a circle, dividing it's area into equal halves! The shaded rim has the same area as the white circle it surrounds, an idea used in many plates and elsewhere.





Squares "tessellate" or tile to fill space with no gaps or overlaps, like a checkerboard or chain-link fence.

Construct a Square Around a Circle



Subdivide A Square

If we construct a Square around a Circle then we already know where the midpoints of the four sides are. We can use them with the diagonals to subdivide the Square into smaller Squares all sharing the same center. We only need a straightedge and pencil.

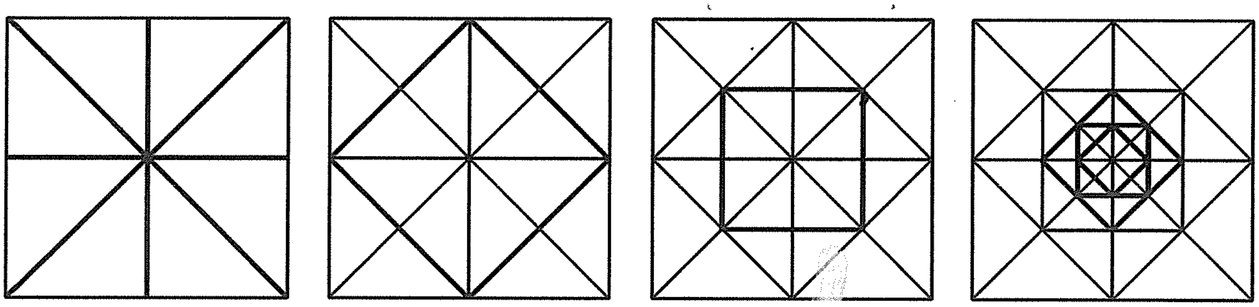
(1) Construct a Square around a Circle. Draw its diagonals and also the lines connecting the midpoints of its opposite sides.

(2) Connect the midpoints of the sides to draw a tilted Square.

(3) Connect the points where the diagonals cross this tilted Square to make a smaller Square.

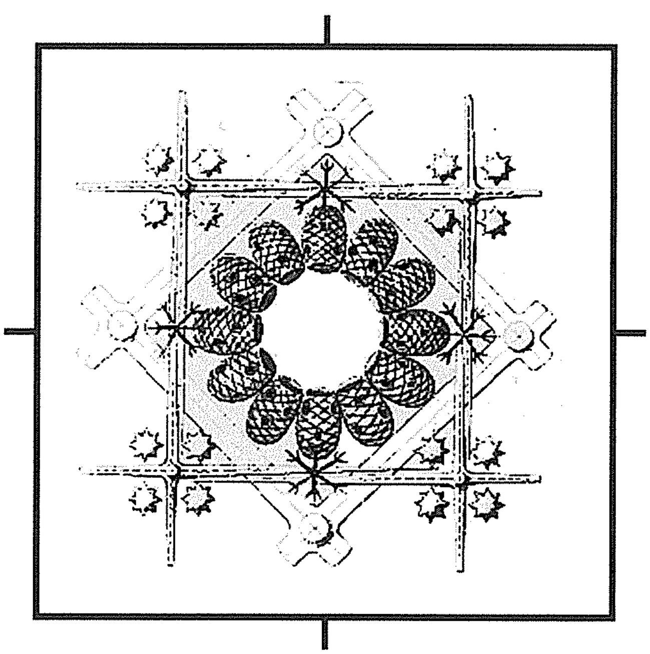
(4) Draw a new Square wherever the diagonals or midpoint lines cross the smallest Square. Do this as small as the point of your pencil allows.

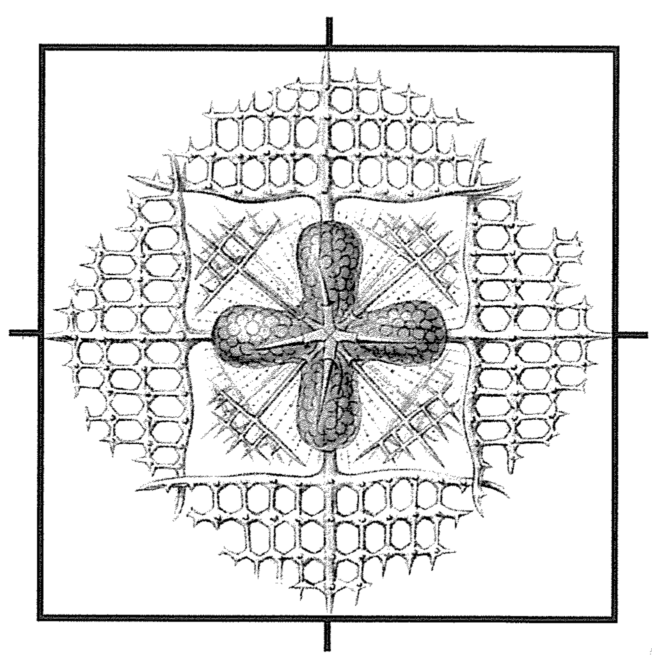
1 2 3 4



Subdivide These Squares as much as needed to reveal its design.

Microscopic **Radiolarian** Skeletons

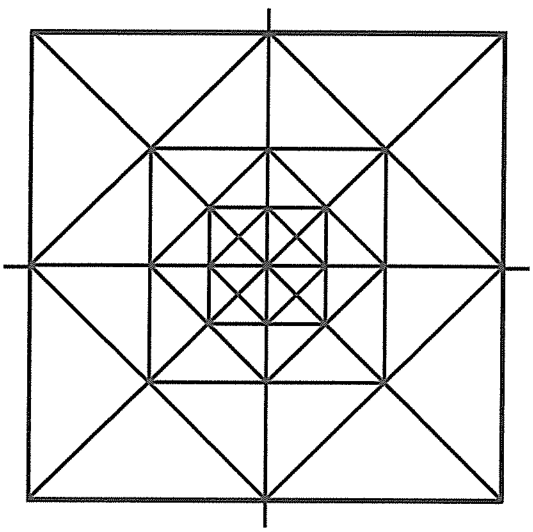




Byzantine dome

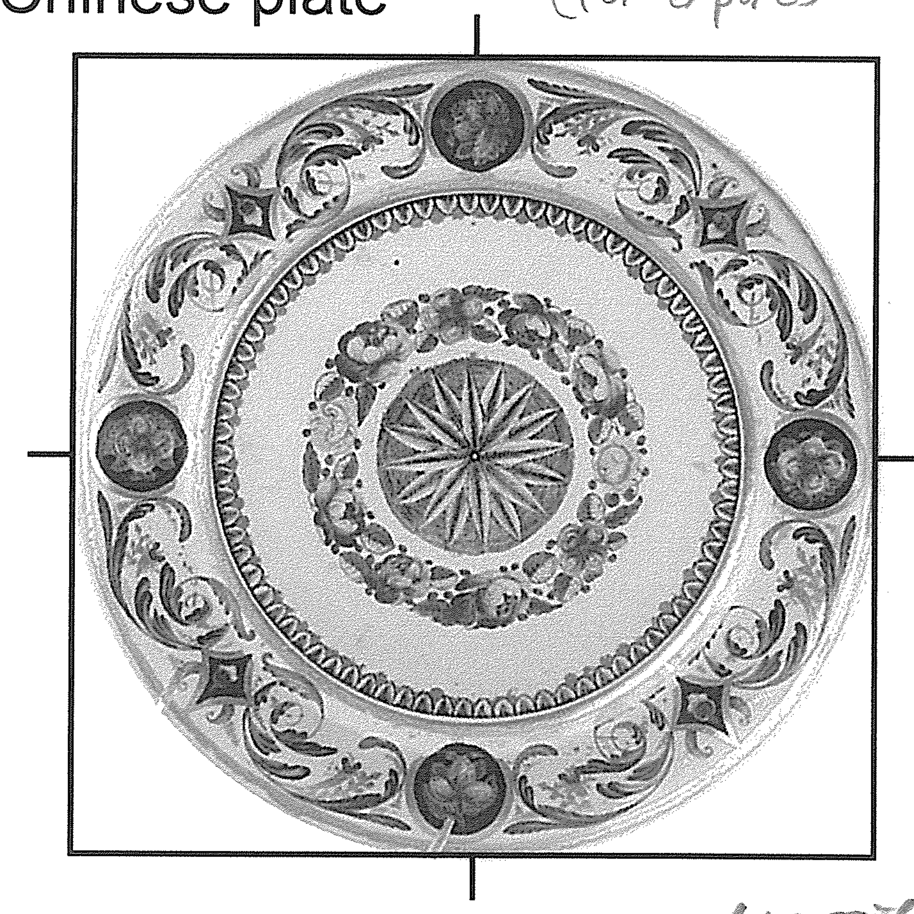
Do this geometric construction on each image.

Notice how it guides their composition.



Chinese plate

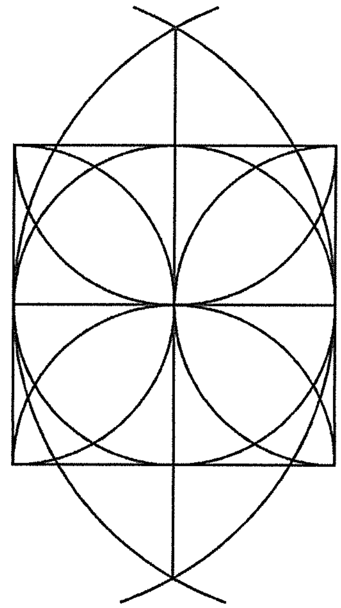
(for export)

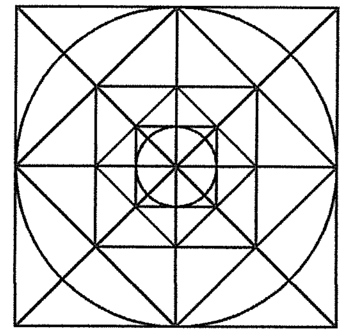


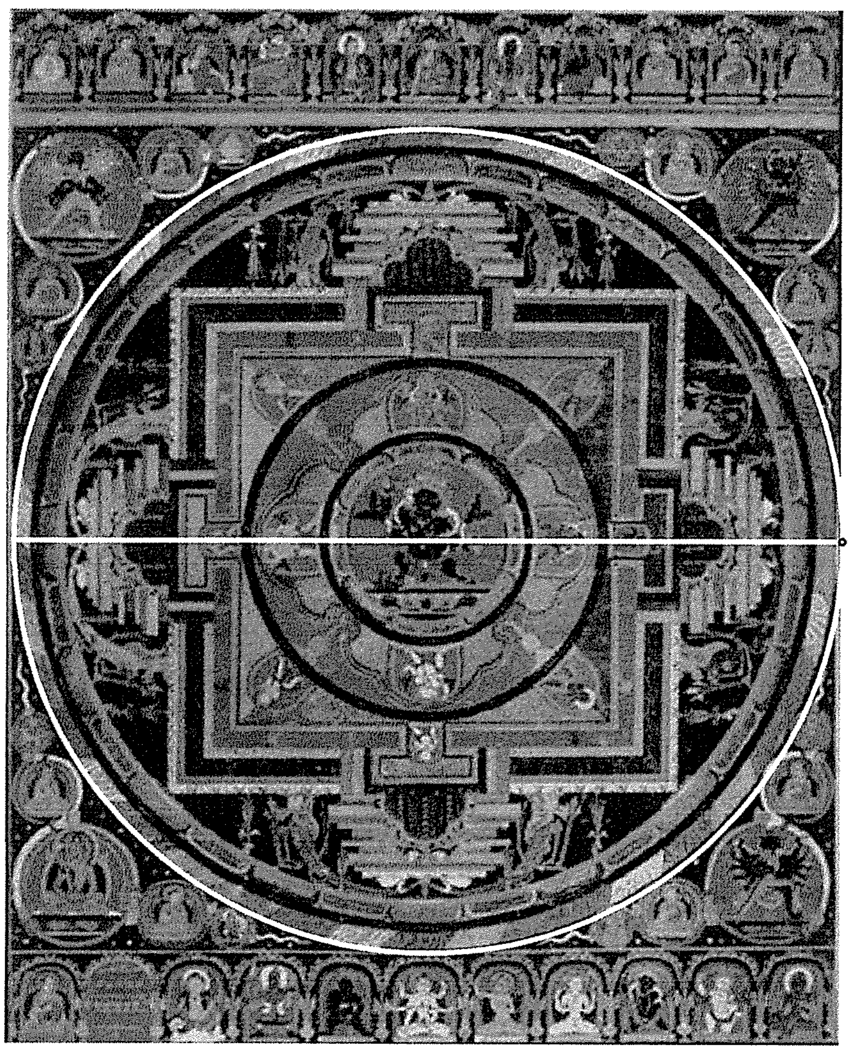
Buddhist Mandala

Given this circle and diameter drawn on the mandala, first construct an "almond" and square.

Then draw the eight-fold geometry as shown to see how it was designed.

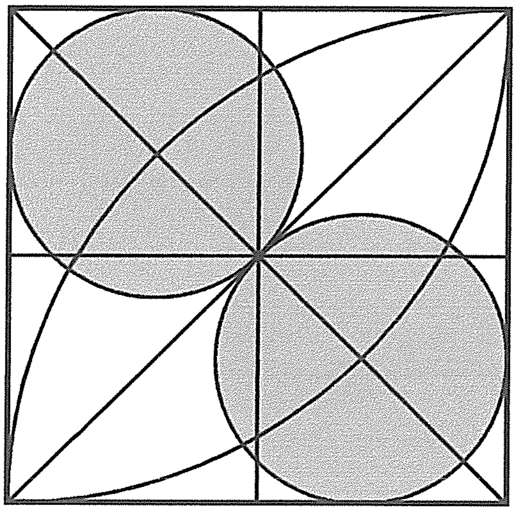






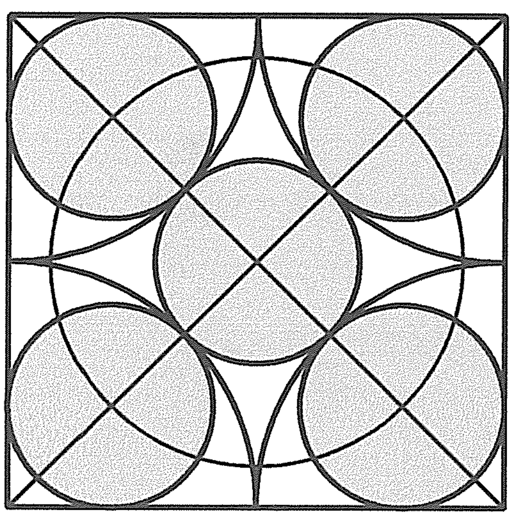
Can you figure out how to fit these circles in the boxes?

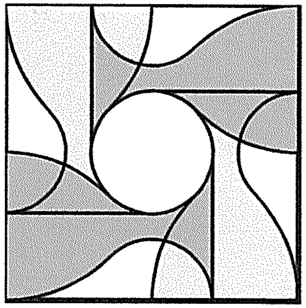
Hint: First find the center point of each circle. What is their radius? Then draw the circles.



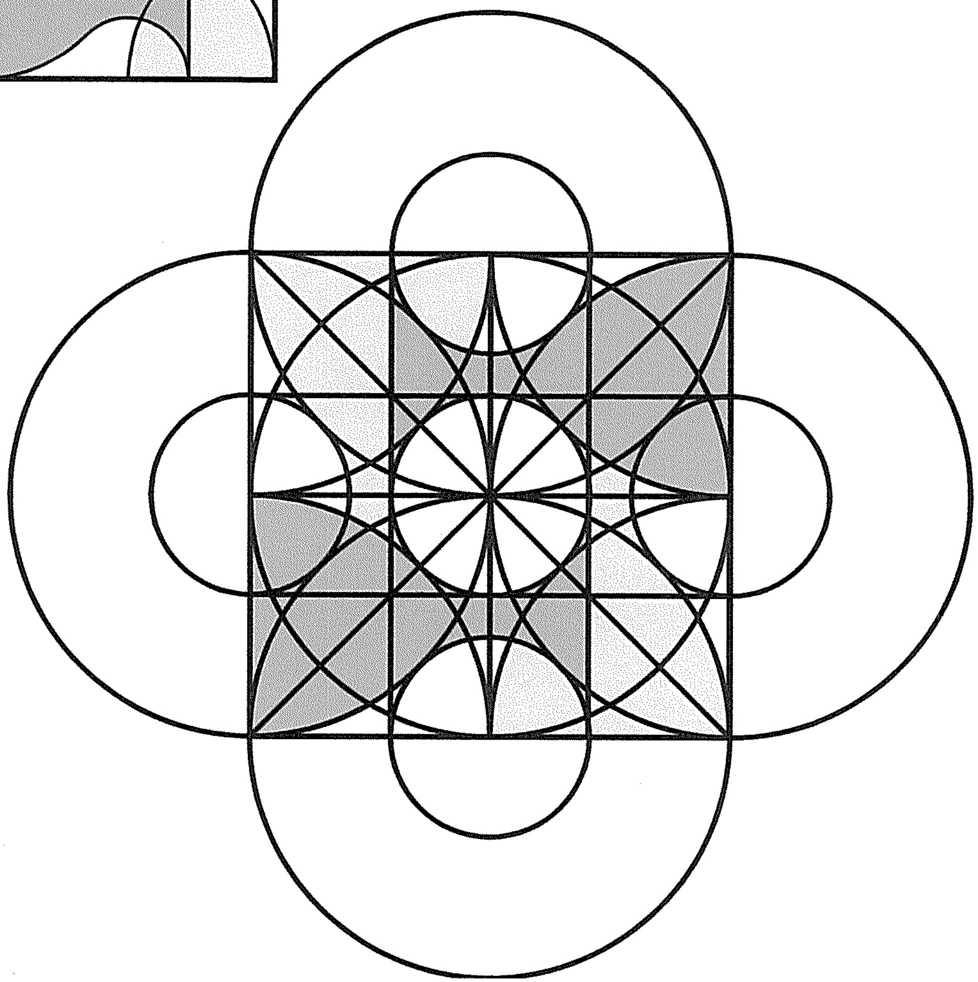
All five circles are the same size.

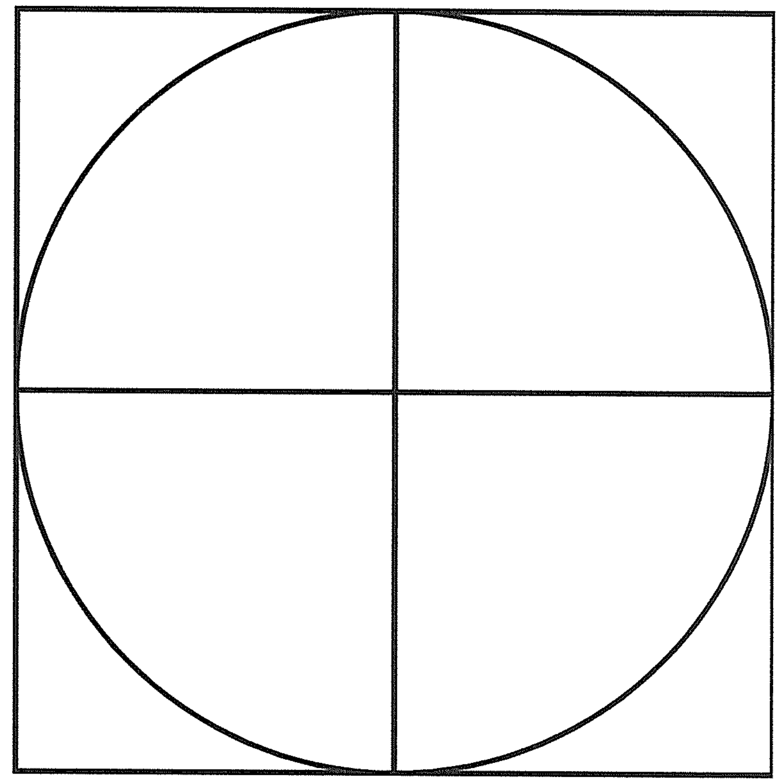
Hint: The central circle must be drawn first. What determines its size? How are the centers of the outer circles found?





Rotating Goblets

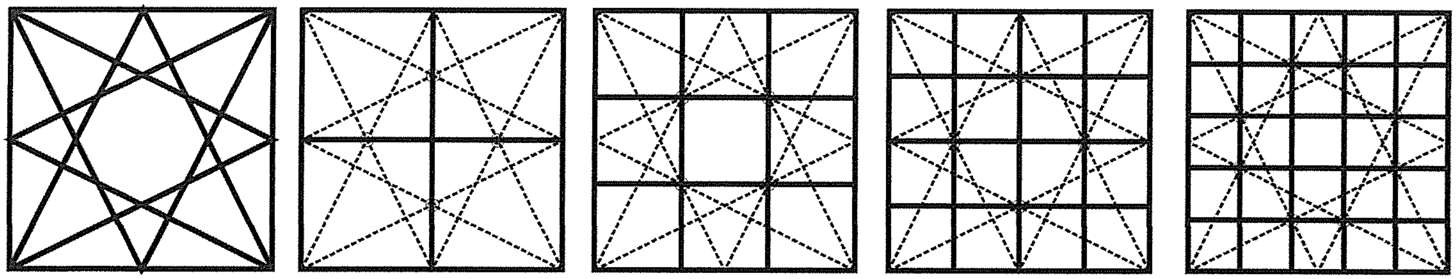




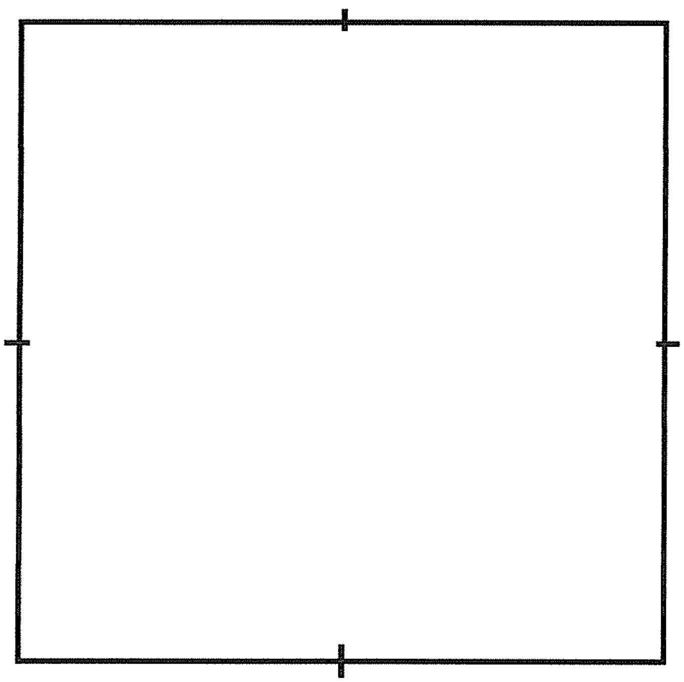
Dividing any rectangle into halves, thirds, fourths or fifths.

Given the centers of each side, draw the **Starcut Diagram**.
Then simply connect its different crossings with straight lines.

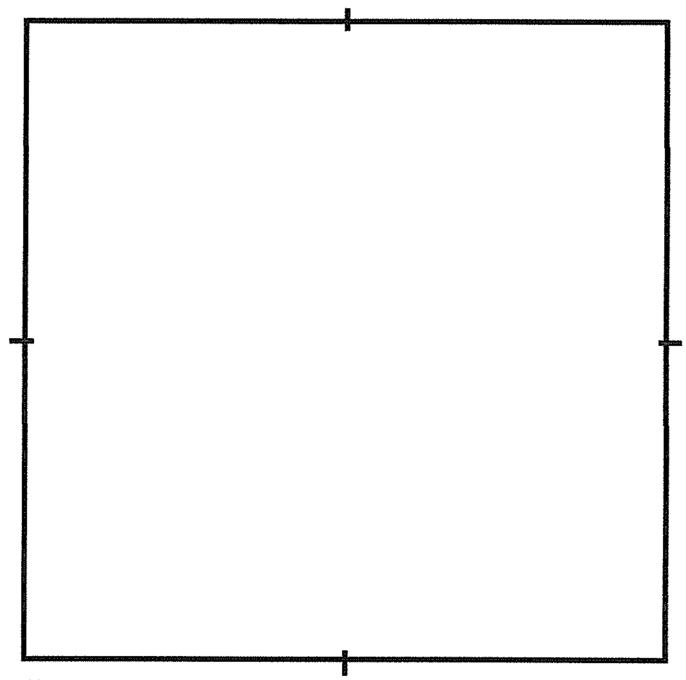
Starcut Diagram 2x2 3x3 4x4 5x5



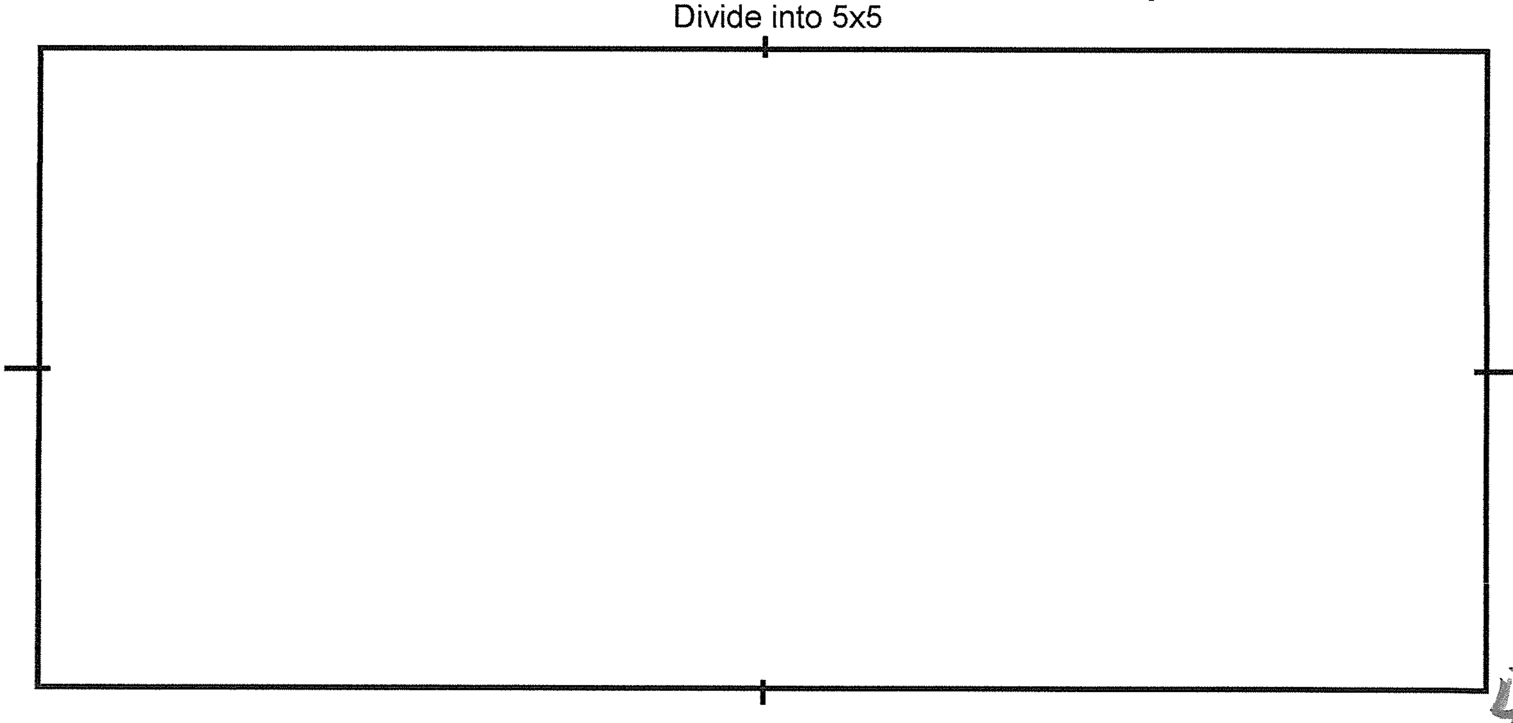
Divide into 3x3



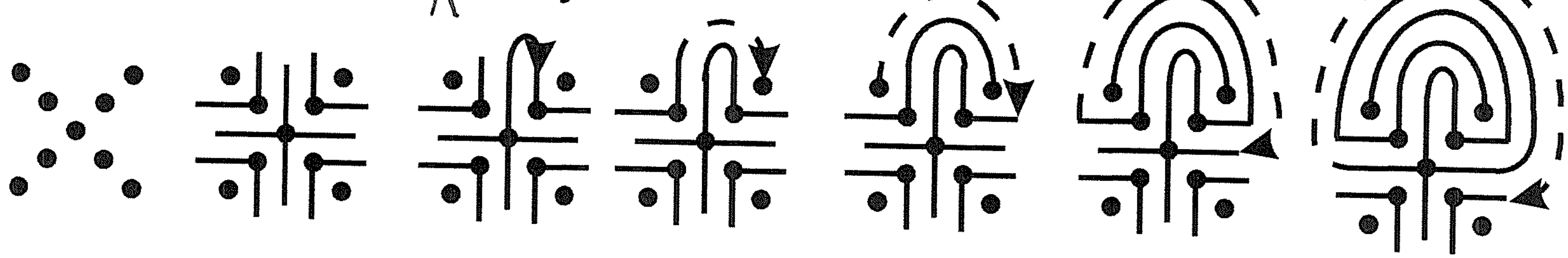
Divide into 4x4

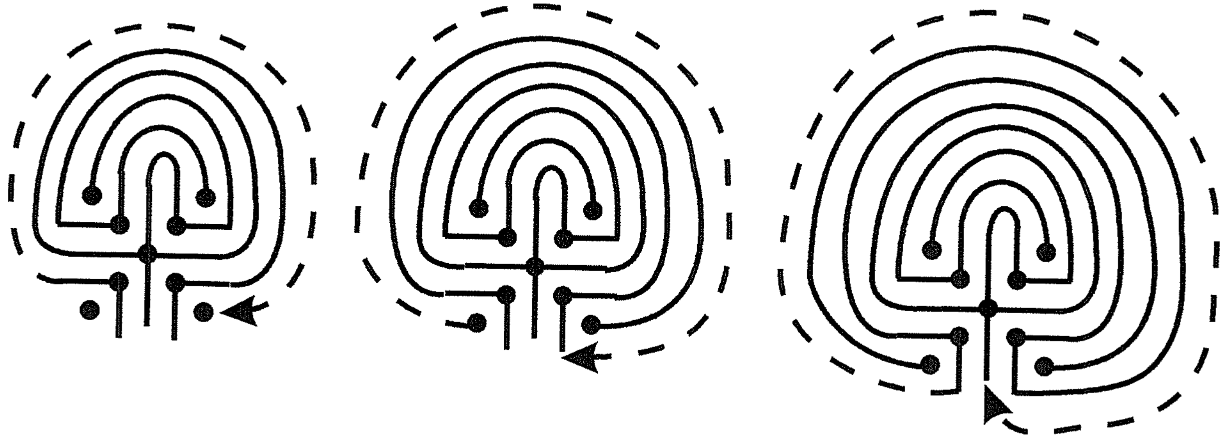


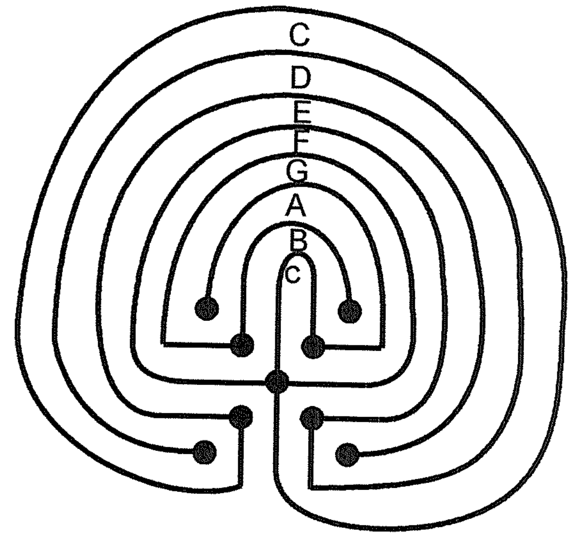
Divide into 5x5

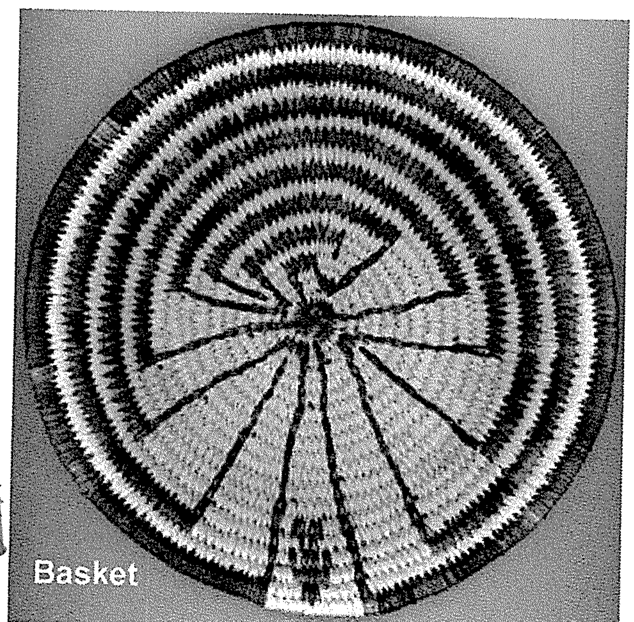


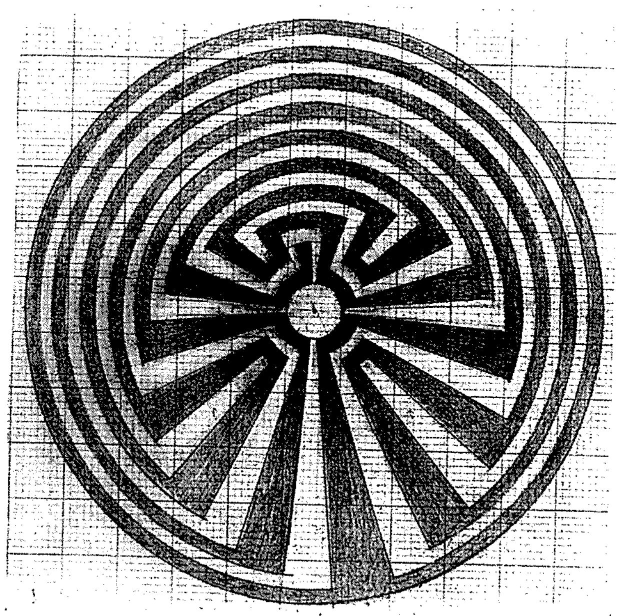
How to draw a Minoan Labyrinth









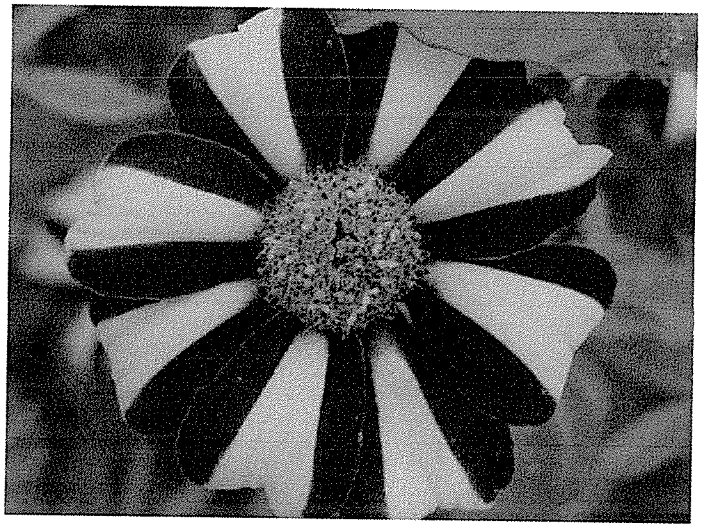


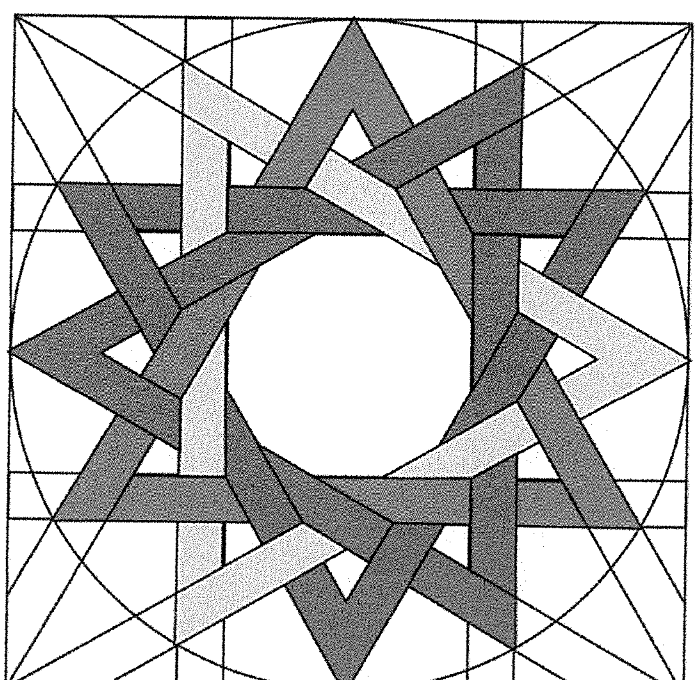
Stylize your labyrinth, shaping the lines into a recognizible object, like these Native American Indian "Spider" and "Thunderbird" designs.

Ad Quadratum Symmetry

Part 2

8 & 12

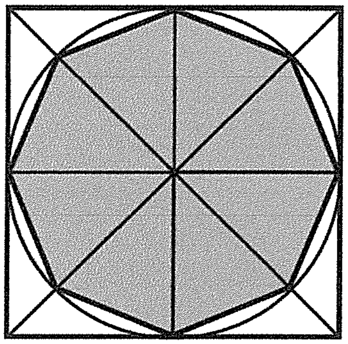
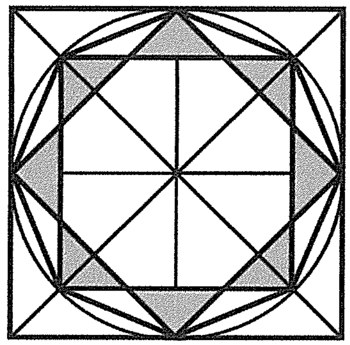
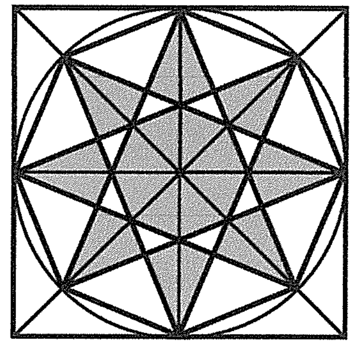


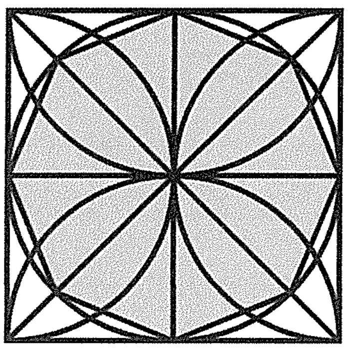


What’s So Great About Octagons?

An eight-sided figure is called an octagon. When it’s sides and angles are equal it’s a “regular octagon.”

An octagon contains two octagram stars.

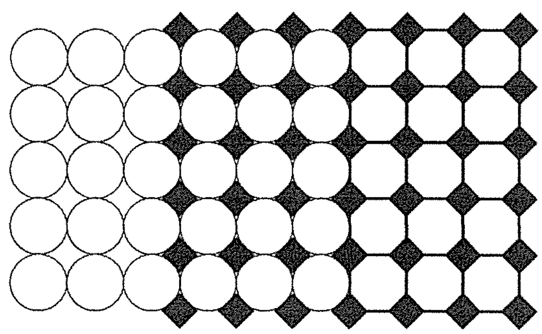




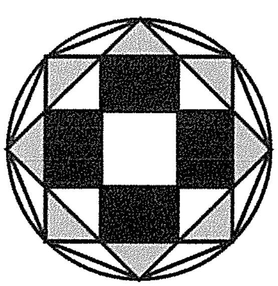


Because the octagon emerges along with the geometric construction of the square, they share similar mathematical and other properties.

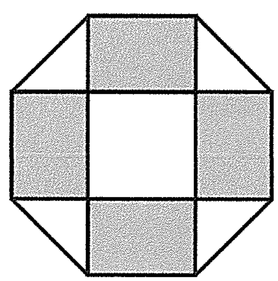
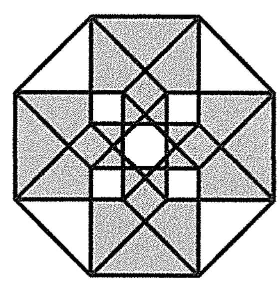
Squares and octagons solve similar problems involving balancing (pairs of) pairs of opposites.

Octagons and squares combine to solve the problem of covering a surface. Circles arranged in square formation leave gaps between them. But octagons *plus* squares together “tessellate” and tile leaving no gaps or overlaps.



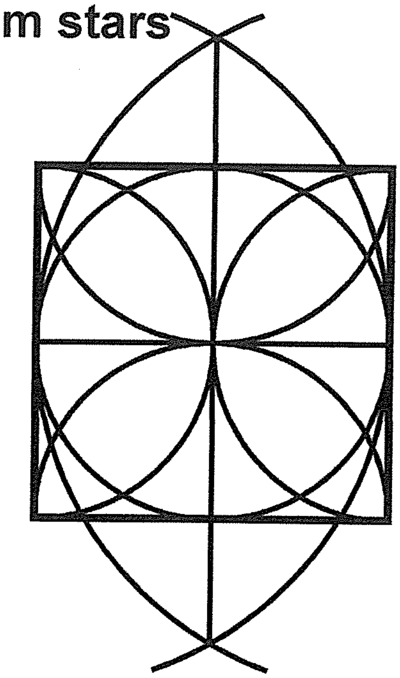


The points at the eight corners of an octagon provide opportunities for many harmonious connections among them.

Because a regular octagon is like a square that’s been quarter-turned as a circle, thus partaking of both, it symbolizes their intersection, the space between the “heavenly” circle and “earthly” Octagonal compositions of art and domed architecture are symbolic acknowledgments of being situated at the crossroads between the heavenly and earthly realms, and observed by both.

Construct an Octagon and its two Octagram stars

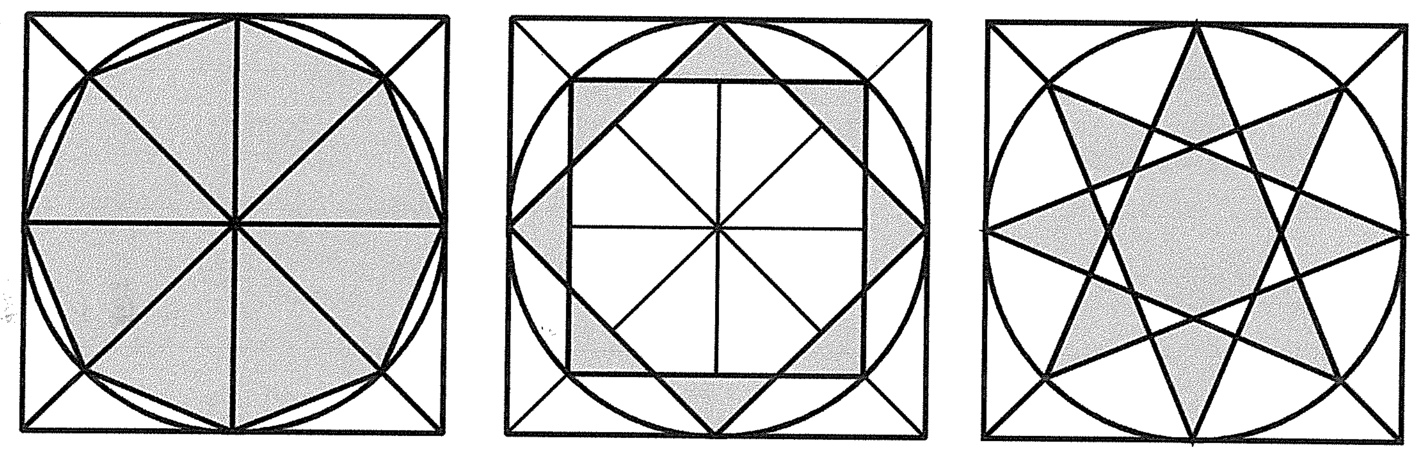


Start by constructing a square.

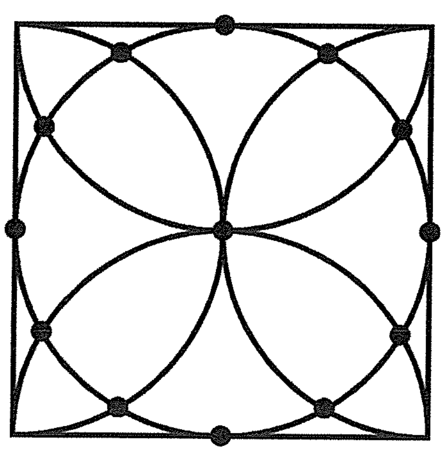
Draw diagonals in the square to find 8 points around the circle.

Draw the Octagram stars seen below.

To construct an Octagon and Octagrams:



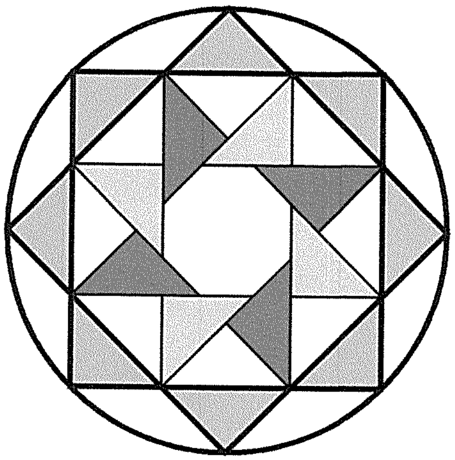
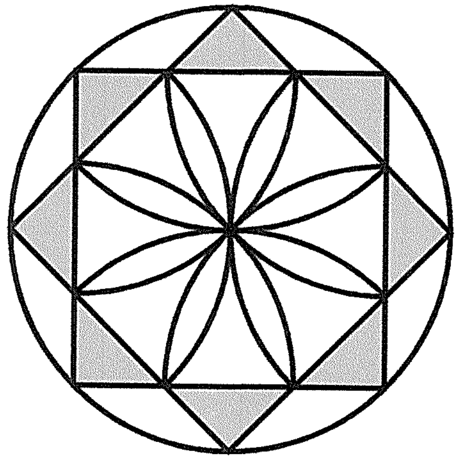
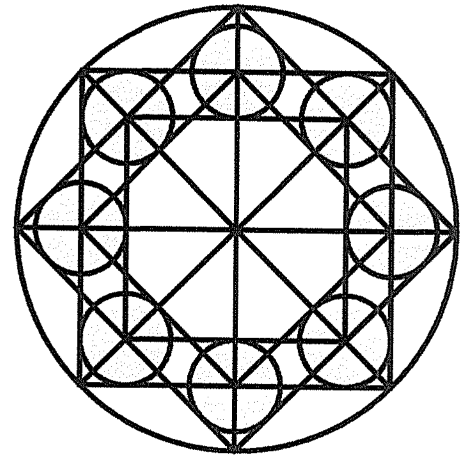
To construct 12 points equally-
spaced
around a circle:

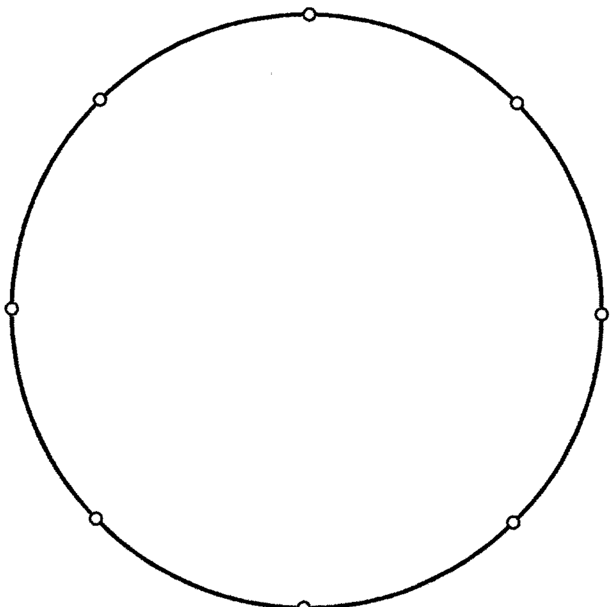
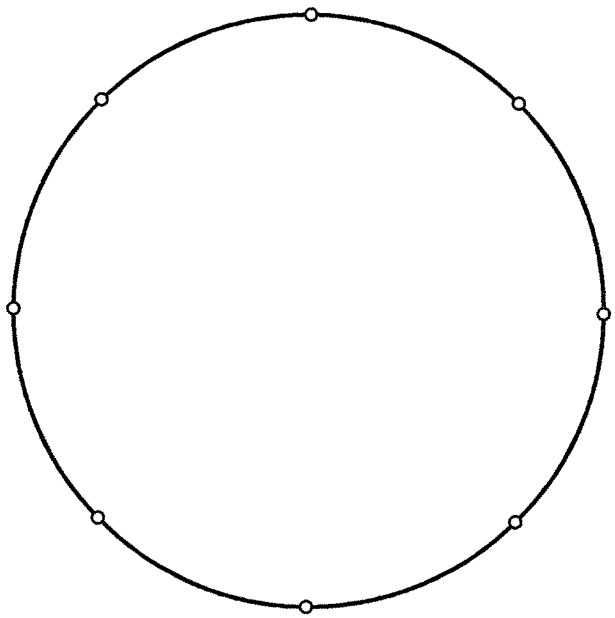
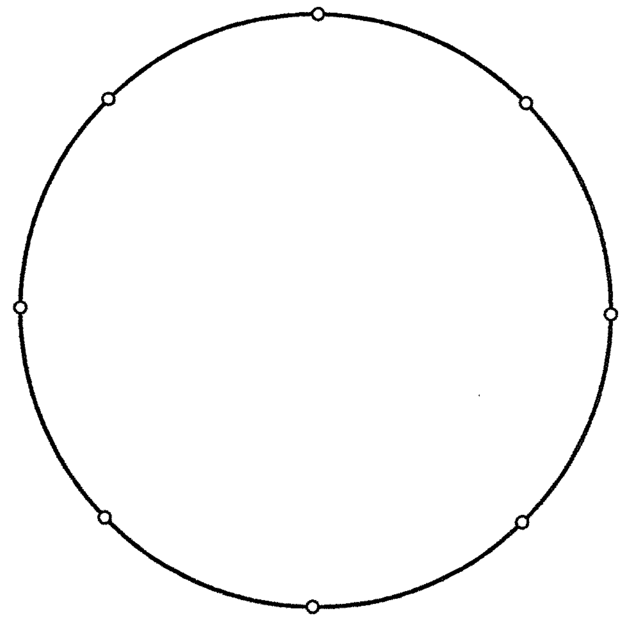


To find the 12 points around a circle,
they're already in the square construction.

How many regular stars can be found
using 12 points? Draw one or more.

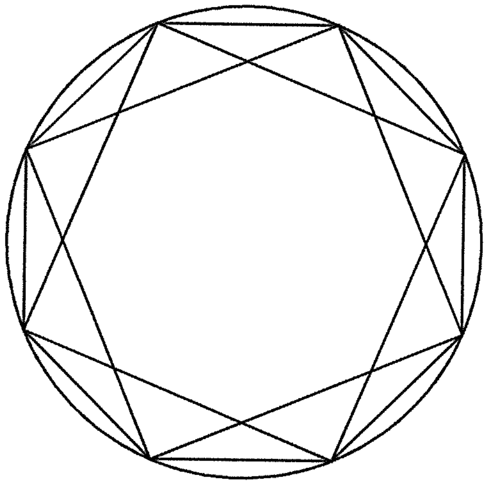
Reproduce these octagonal designs in the circles below them.

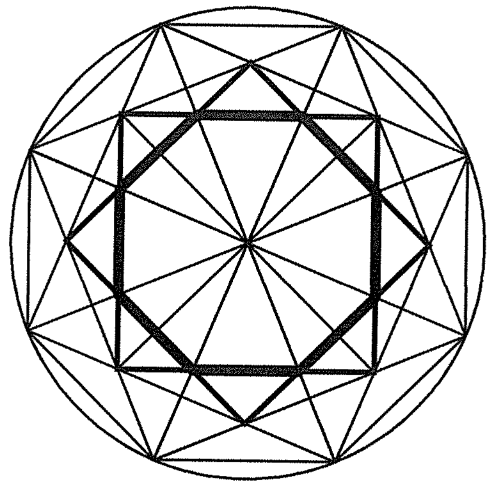




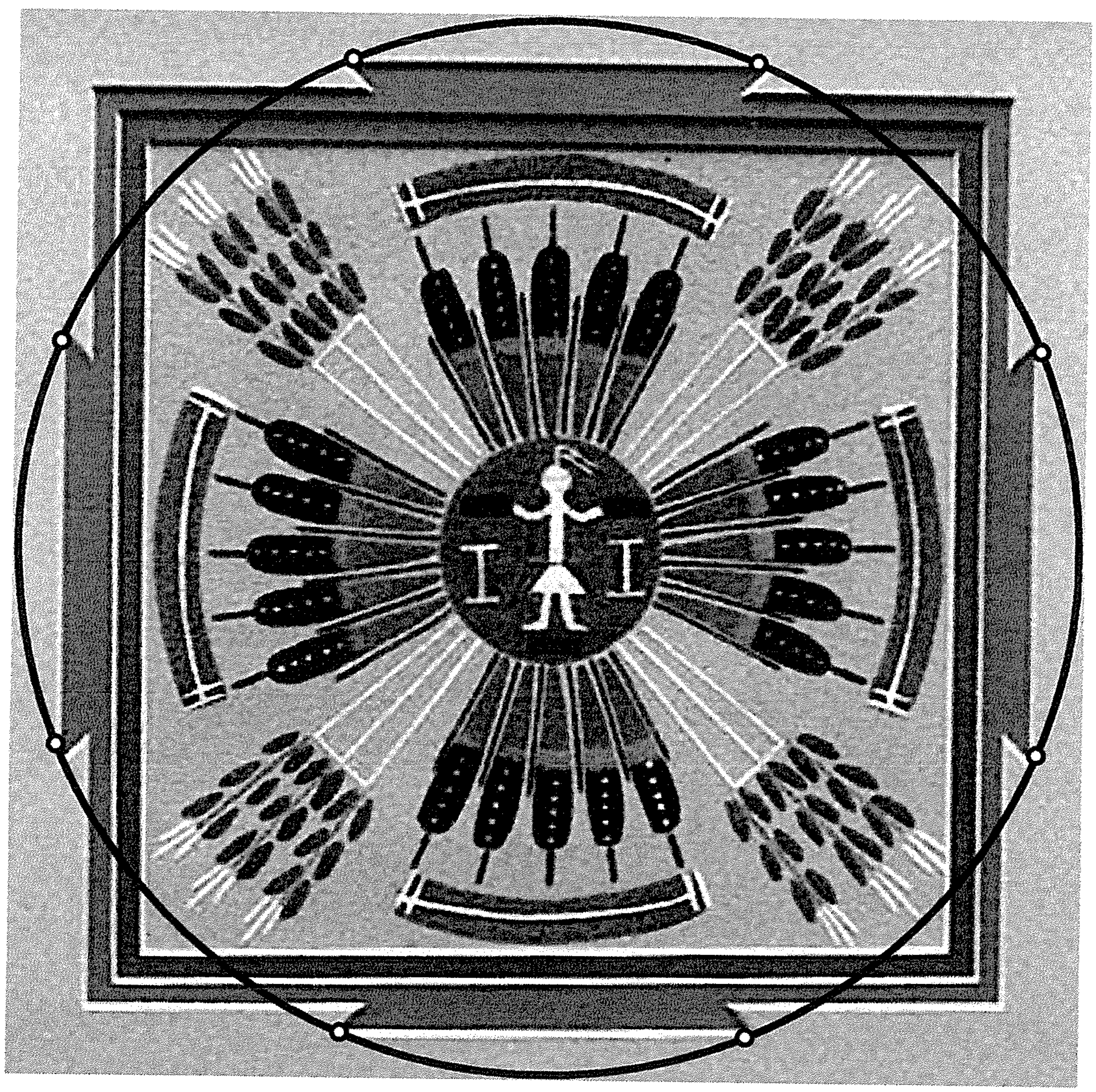




Native American Sandpainting

Use the 8 points around the circle to draw this construction over the painting.
Do you see how the lines guide the painting?







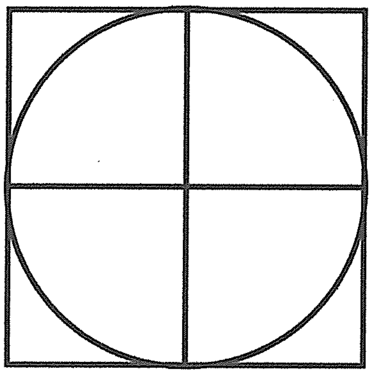
Navajo Sand Painting
12 points around a circle

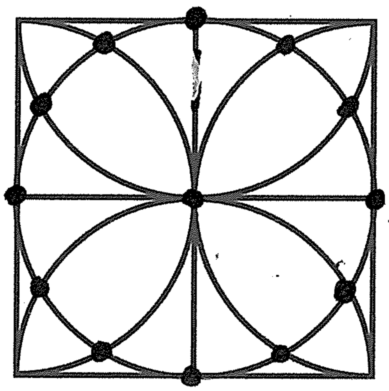
When you constructed the square, you made four arcs, like petals, which met at the square's corners. Along with the 4 points at the middle of each side, the arcs cross the circle at 8 points to make a total of **12 points equally spaced around the circle**.

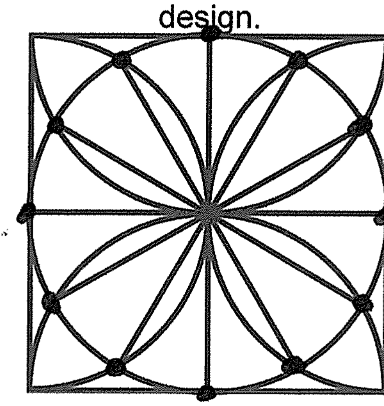
A square and quartered circle have been drawn on the Navajo sandpainting below.

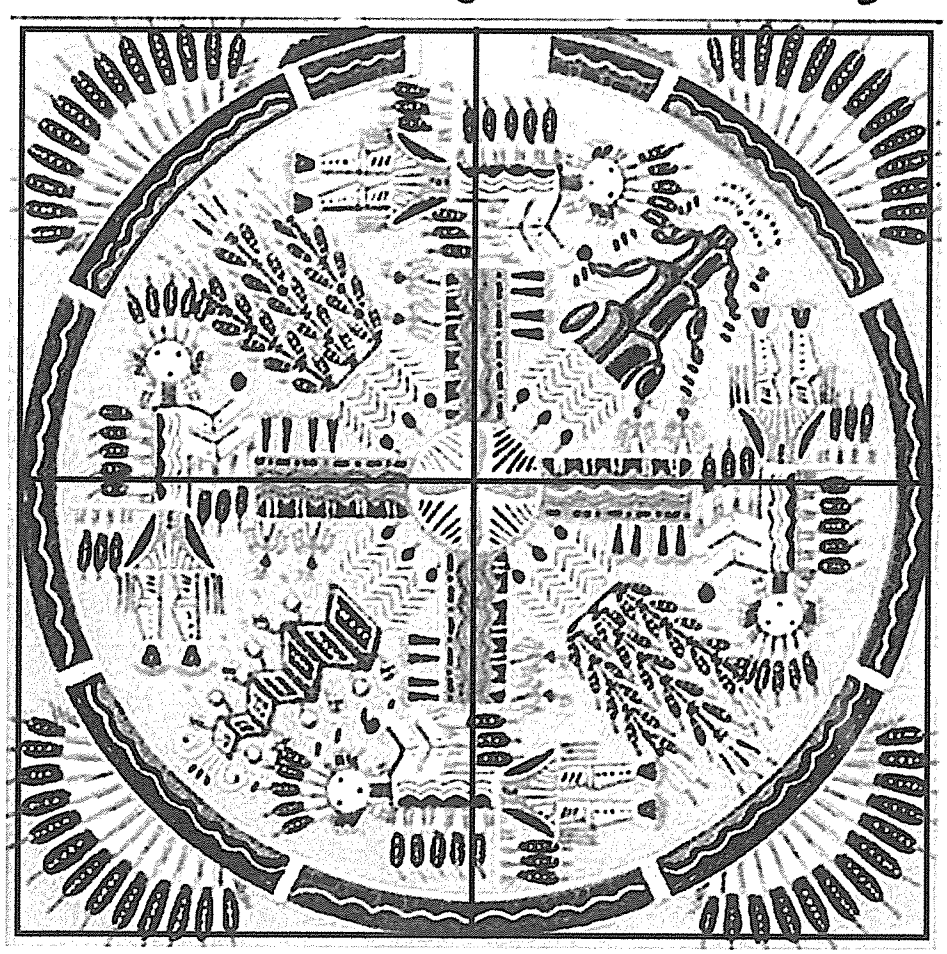
Construct the four petals, and identify the twelve points around the circle.

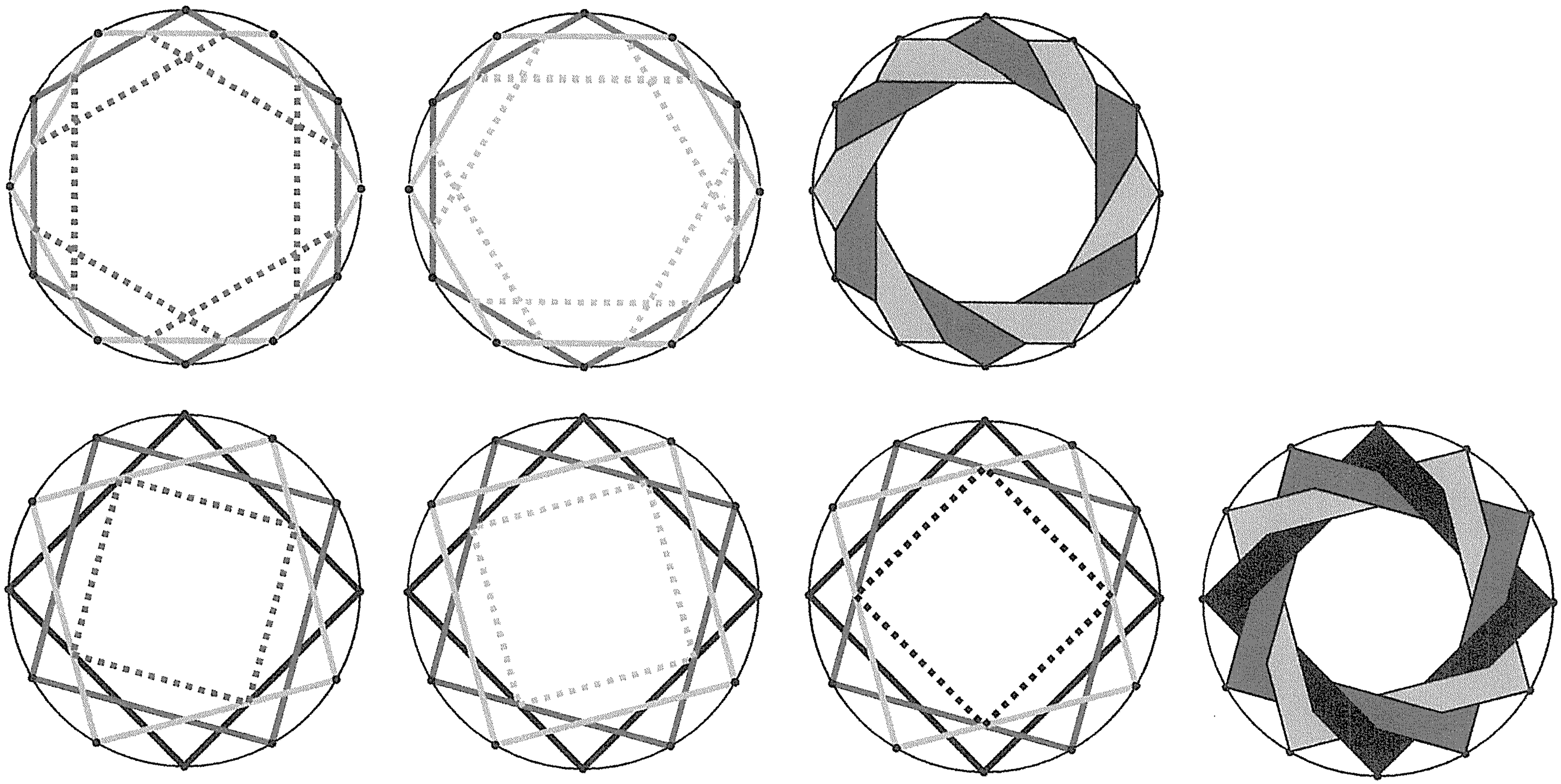
Draw 6 diameters of the circle as shown. Notice what they reveal about the painting's design.

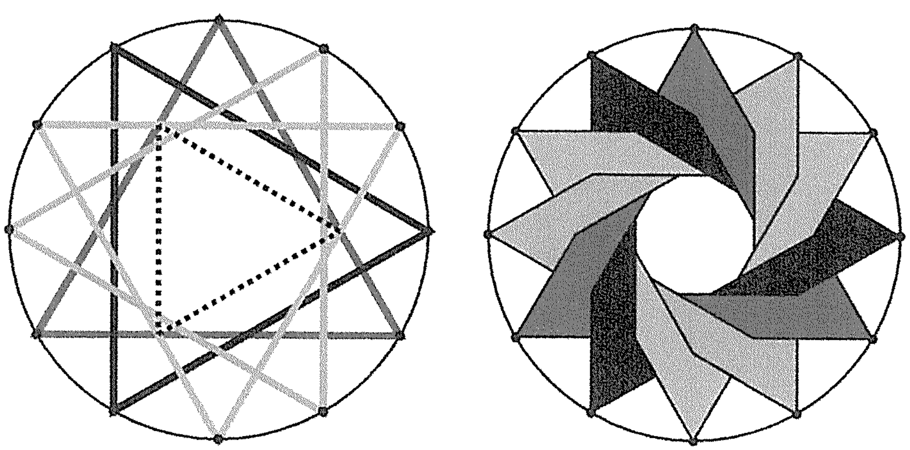








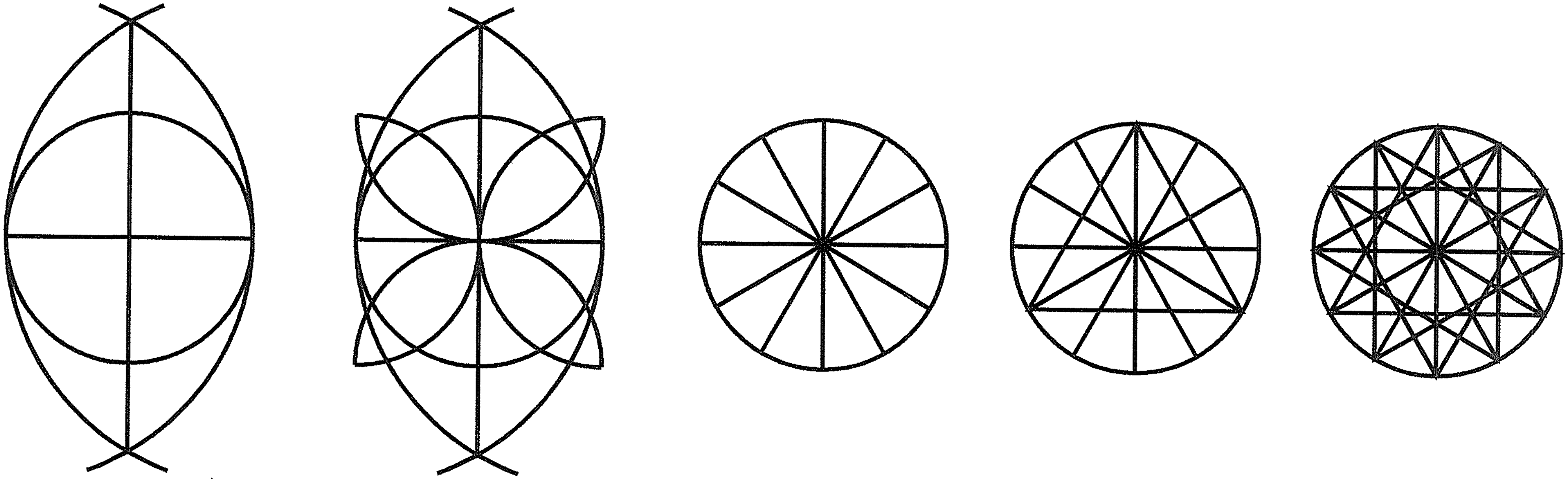


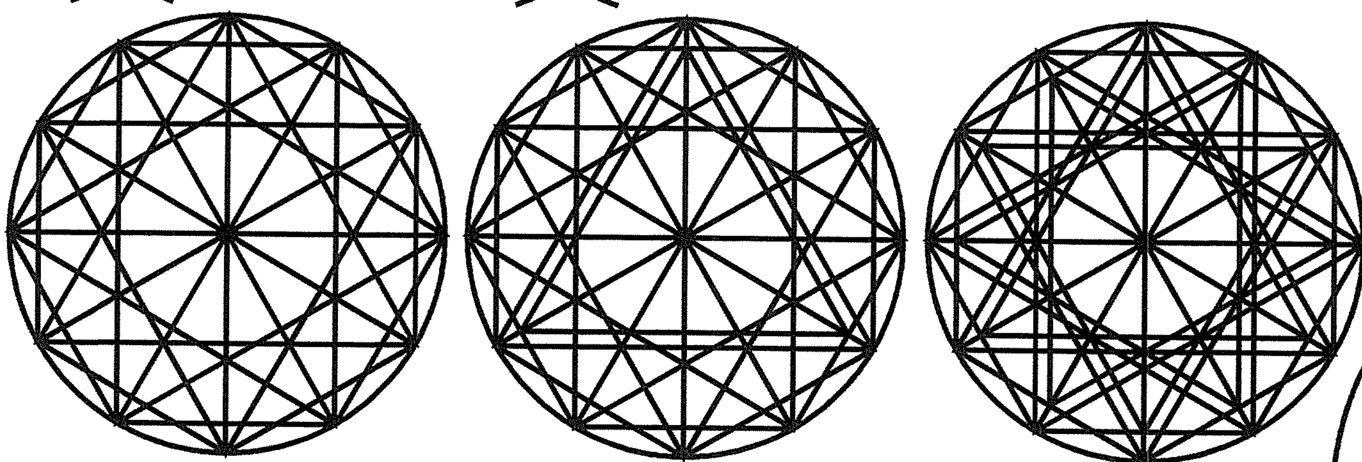


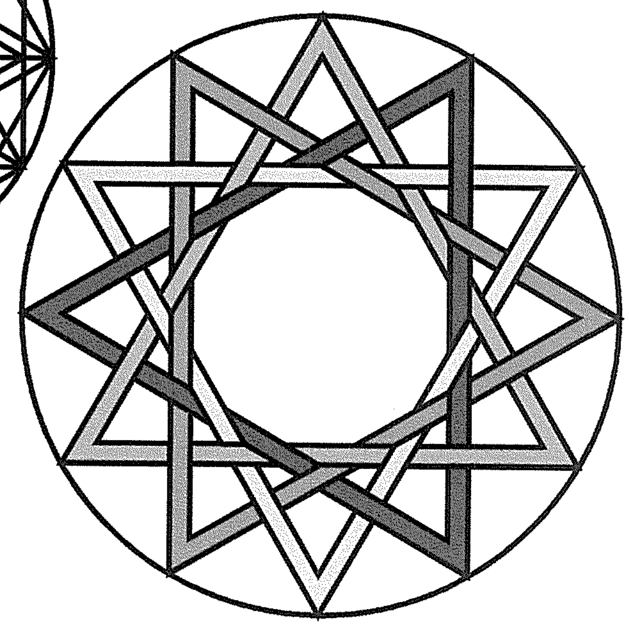
Weaving...

Two Hexagons
Three Squares
Four Triangles

Start with 12 points around the circle

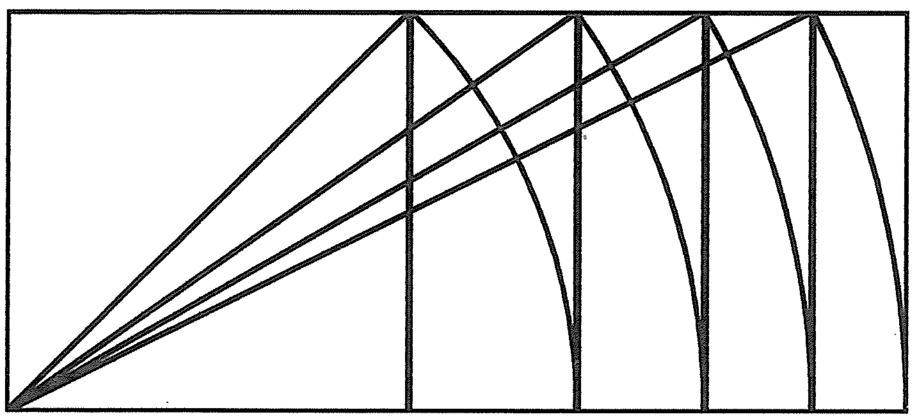






Weaving Four Triangles

Root-Rectangle Symmetry

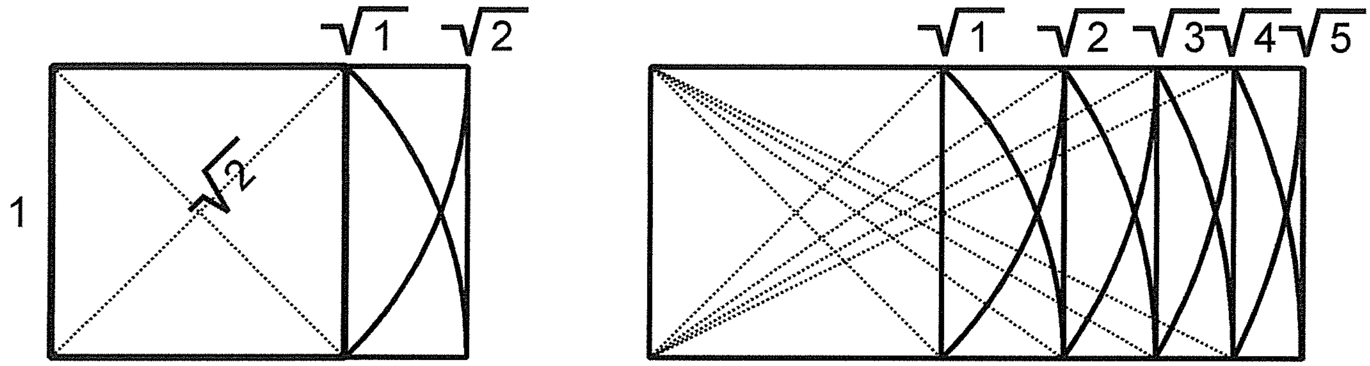


Name:

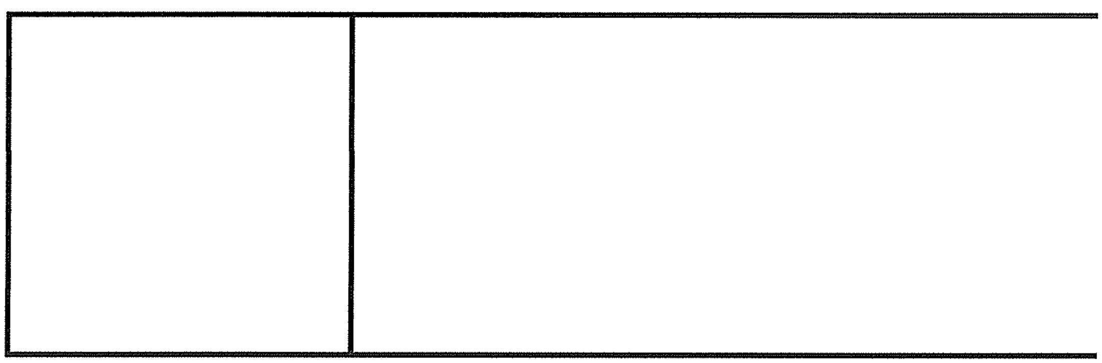
57

Construct *Square-Root Rectangles* from a Square

Proven by the Pythagorean Theorem



Swing your compass to construct the first five Root Rectangles, starting with the Root-1 (Square) below.



Values

$\sqrt{5}$ = 2.236

$\sqrt{4}$ = 2.000 = Double Square

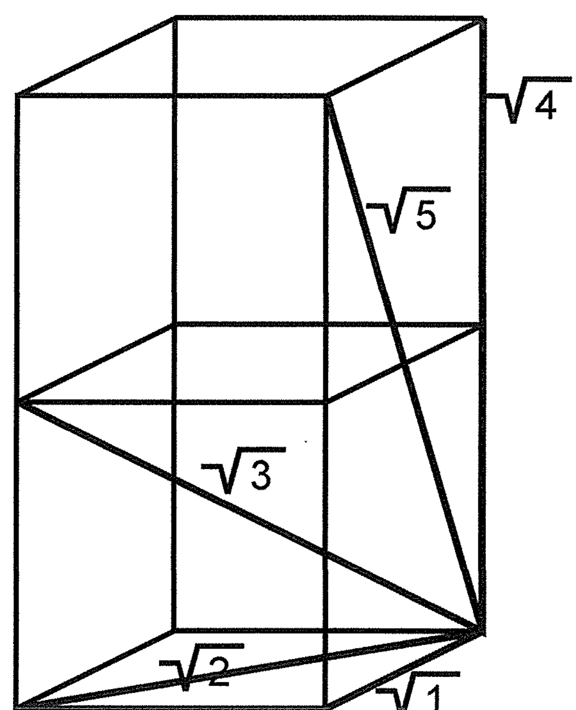
$\sqrt{3}$ = 1.732

$\sqrt{2}$ = 1.414

$\sqrt{1}$ = 1.000 = Square

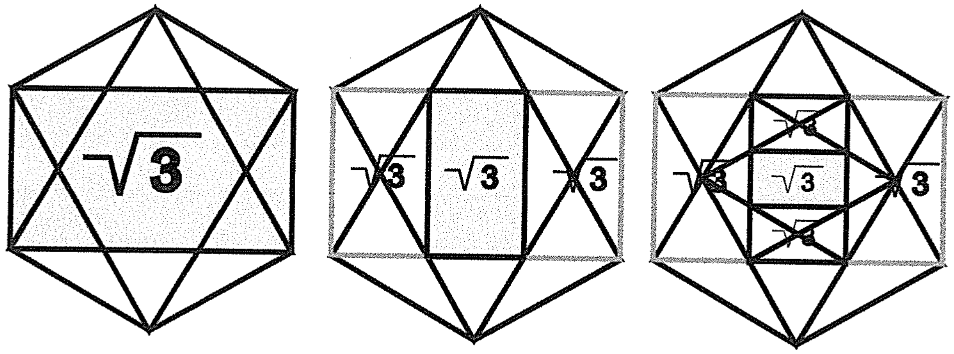
Root-Rectangle proportions can also be found in the basic structures of 3-dimensions.
Here, they're found in a double-cube.

Where's the Root-6?



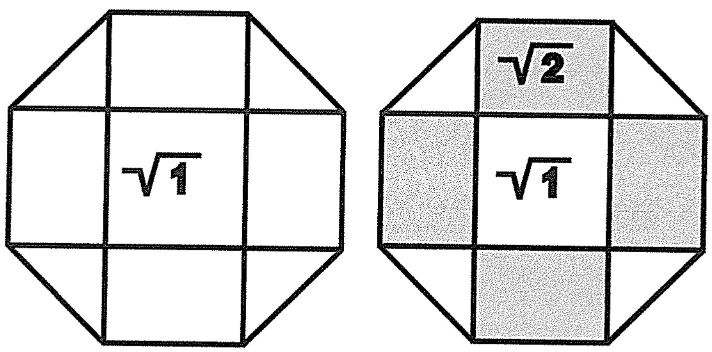
Root Rectangles appear *within* many shapes, including...

Hexagons



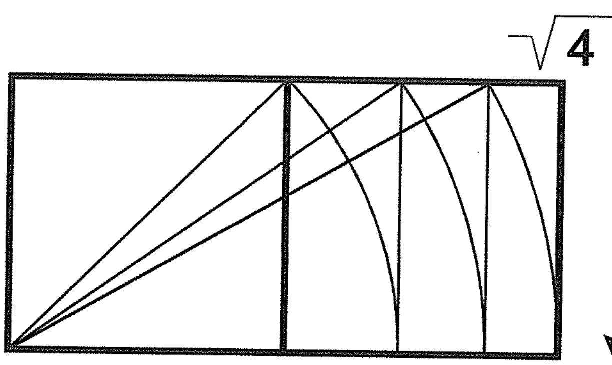
Each Root-3 Rectangle can be divided into three more Root-3 Rectangles.

Octagons

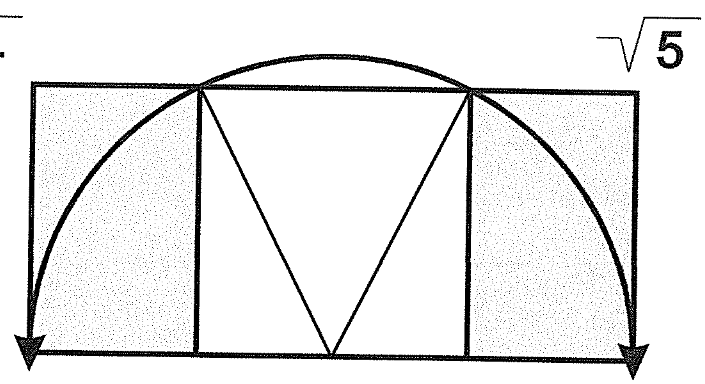


Within an Octagon are four Root-2 Rectangles around a square.

Squares



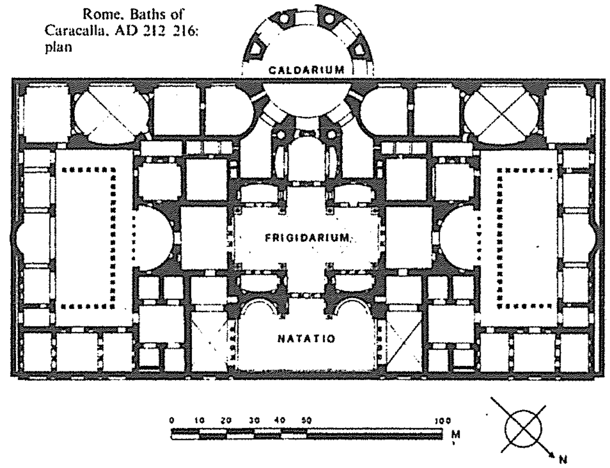
A Root-4 Rectangle precisely equals two Squares (two Root-1 Rectangles)!

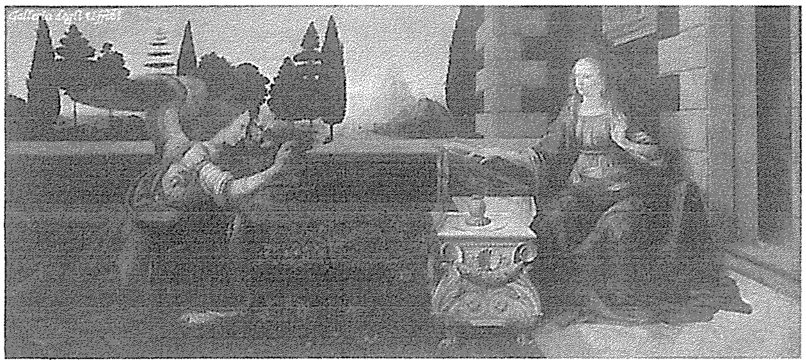


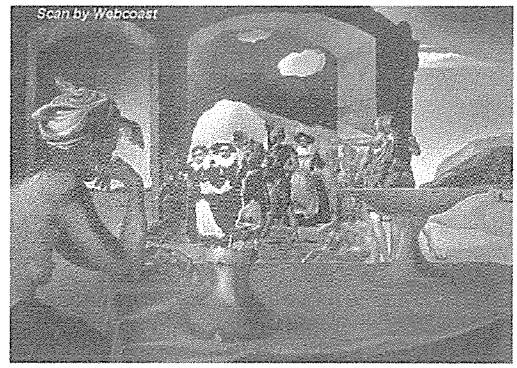
A Root-5 Rectangle can also be made starting with a central Square (a Root-1 Rectangle). (The shaded side-rectangles are Golden Rectangles.)

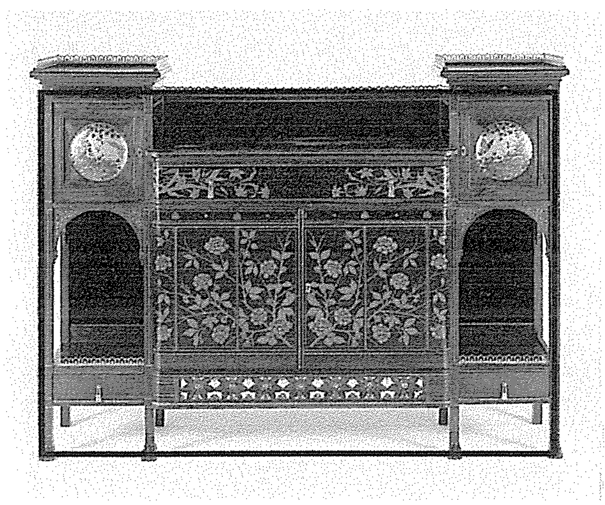
What is the Root Rectangle?

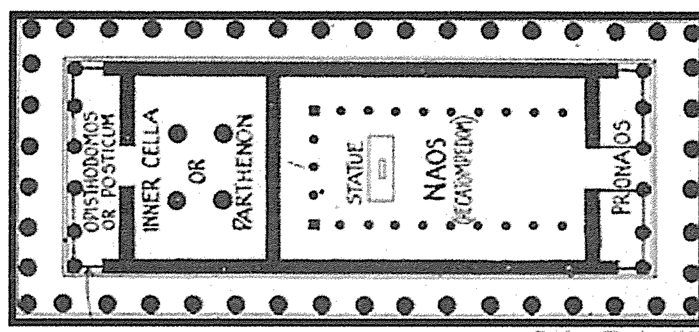
Next to each, identify which Root Rectangle has been used in its design.



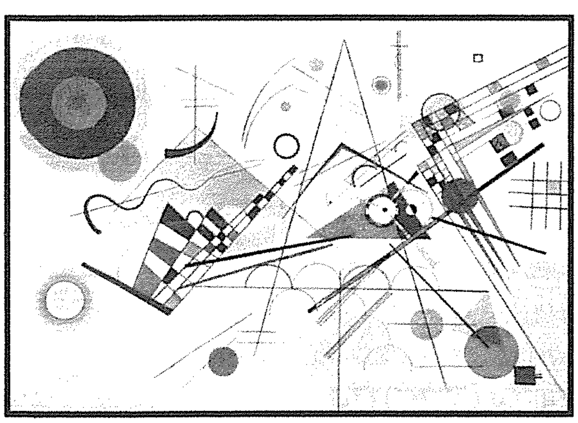


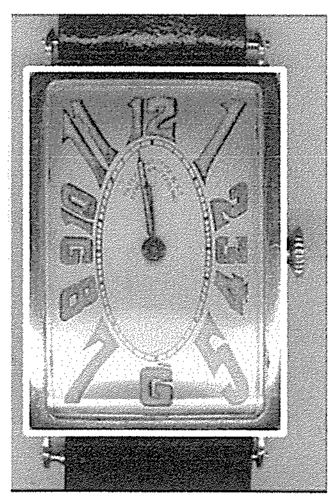






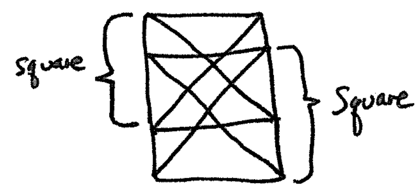
Banister Fletcher 1905





60

This floor tile from the Medici Library is framed in a White $\sqrt{2}$ Rectangle.



Construct squares from its top and bottom.

Draw the diagonals in both squares.

Open the compass to each diagonal and turn both arcs at each end to prove that this is a square-root of 2 rectangle.

What do the diagonals guide the size of?

What do the arcs show us?

Draw a square from the bottom of the drawing.

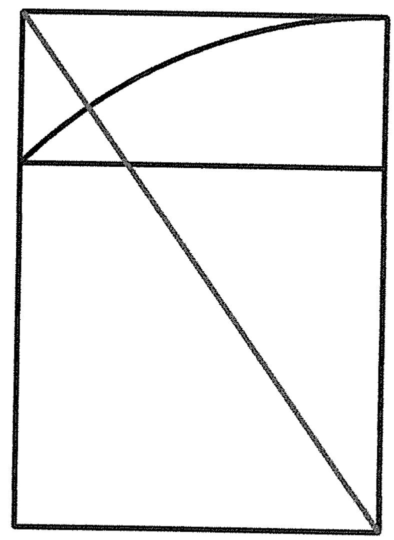
Make an arc to see that it's a root-2 rectangle.

Draw one diagonal as shown to see how it guides the woman bending.

Drawn by Jay Hambidge. Half-tone plate engraved by H. C. Merrill

WEIGHING THE BABIES AT AN INFANTS' MILK STATION IN NEW YORK

Jay Hambidge

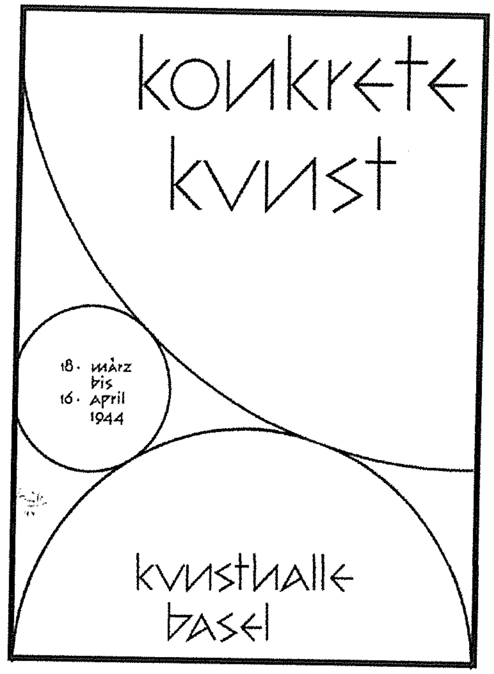


Root 2 Rectangle

***Type* Construction**

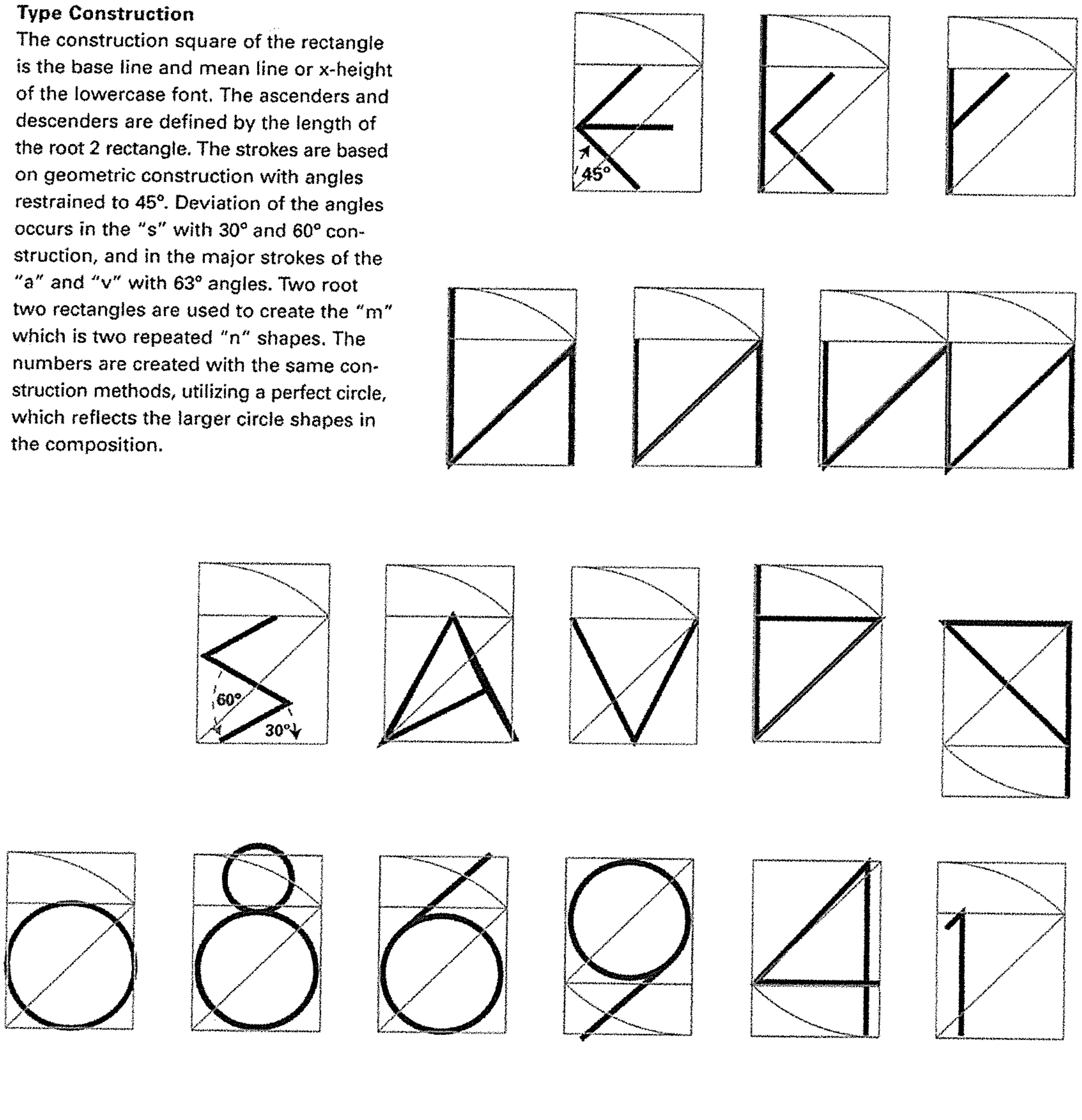
Each letter is based on the *same proportion* as the ***whole poster.***

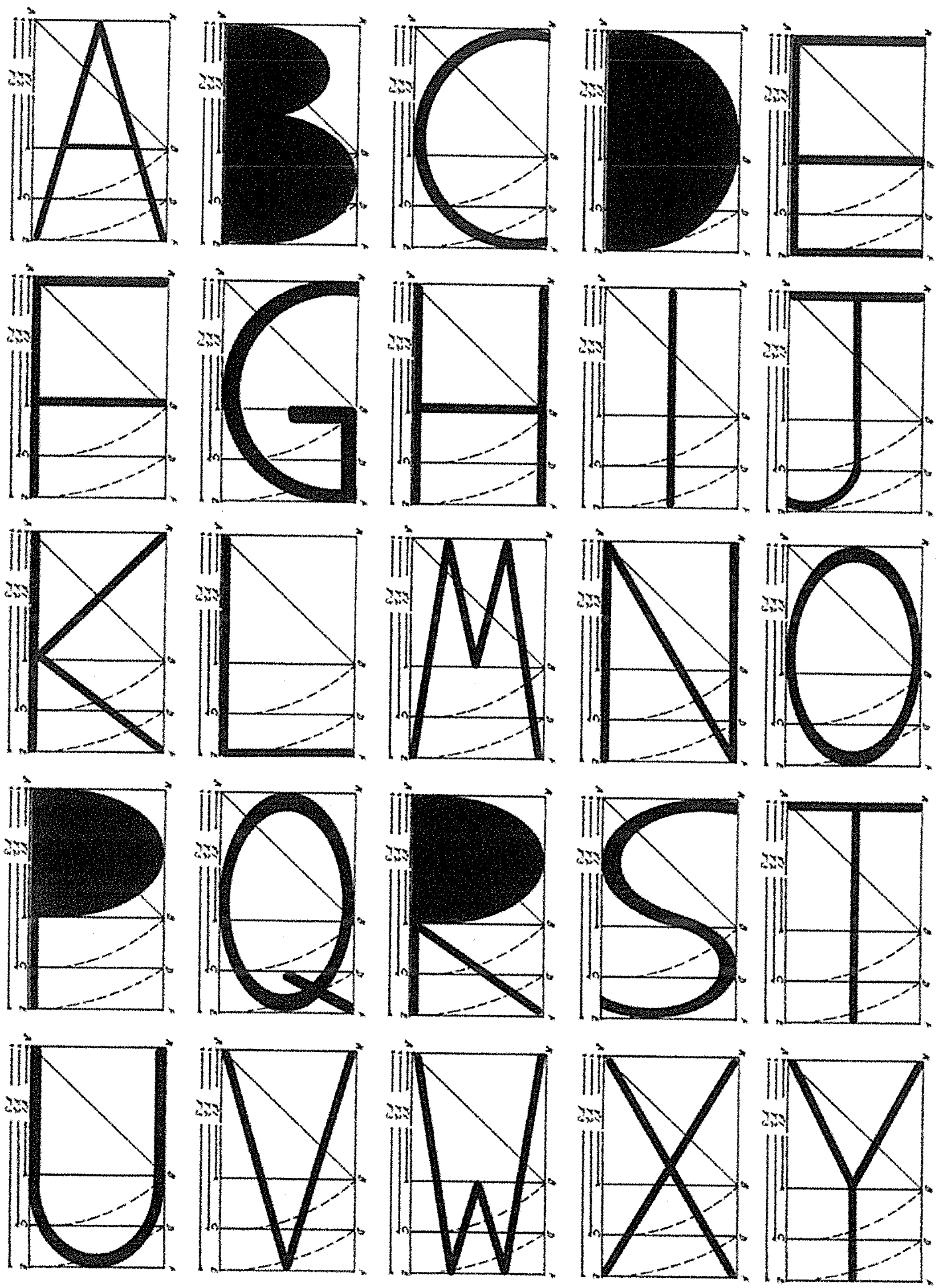
This can be done using *any* Root Rectangle.

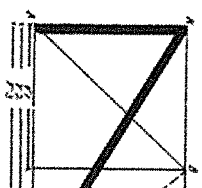


Type Construction

The construction square of the rectangle is the base line and mean line or x-height of the lowercase font. The ascenders and descenders are defined by the length of the root 2 rectangle. The strokes are based on geometric construction with angles restrained to 45°. Deviation of the angles occurs in the "s" with 30° and 60° construction, and in the major strokes of the "a" and "v" with 63° angles. Two root two rectangles are used to create the "m" which is two repeated "n" shapes. The numbers are created with the same construction methods, utilizing a perfect circle, which reflects the larger circle shapes in the composition.







Root-3 Rectangle Typography

Leecie Suyeda

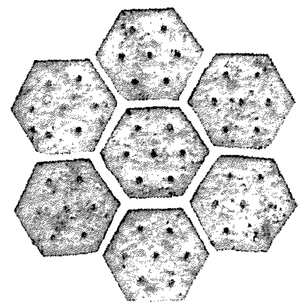
Tessellation

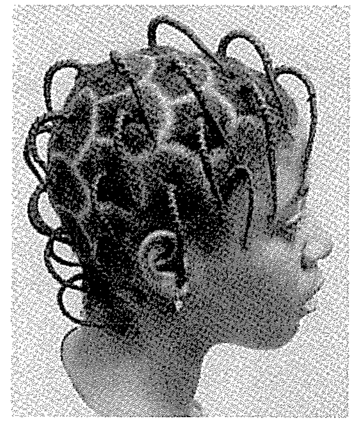
"Periodic Tiling"

"Space-Filling Motifs"

A shape interlocks with its replicas to **fill the plane** with *no gaps or overlaps.*

Crystals, molecules, Islamic patterns, floortiles, brick walls, wallpaper, lace, crochet, quilts, paper towels, mattresses, the art of M. C. Escher, etc.



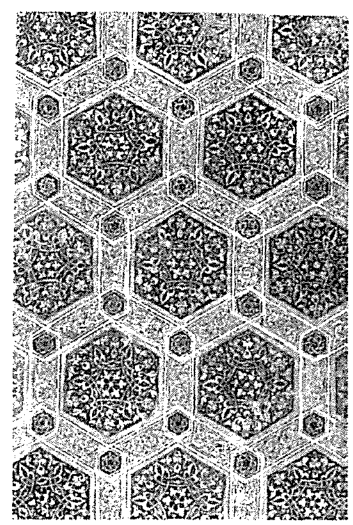


Escher: To make tessellations, and artist needs:

- Knowledge of Geometry
- Imagination
- Artistic Ability
- Tenacity

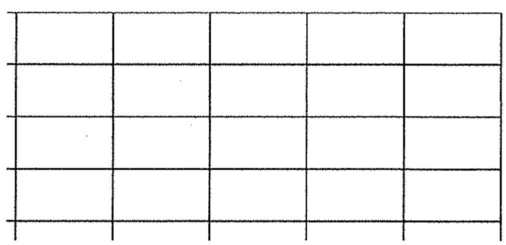
Main requisites for Tessellation (Escher):

1) Plane-filling with no gaps or overlaps
2) Form recognizibility
   - living beings, well-known objects
3) Color contrasts
   - Cells must be colored.
   - No adjacent motifs should be the same color.



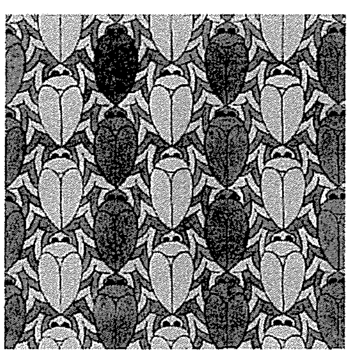
Begin with a space-filling grid (a regular divisions of the plane):

- Squares
- Rectangles
- Parallelagrams
- Triangles
- Hexagons
- ...others

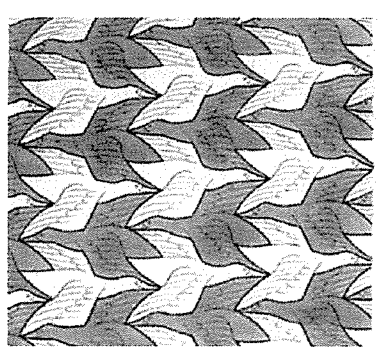


Then transform the lines by shaping and repeating them in a regular fashion to fill the plane:

Glide

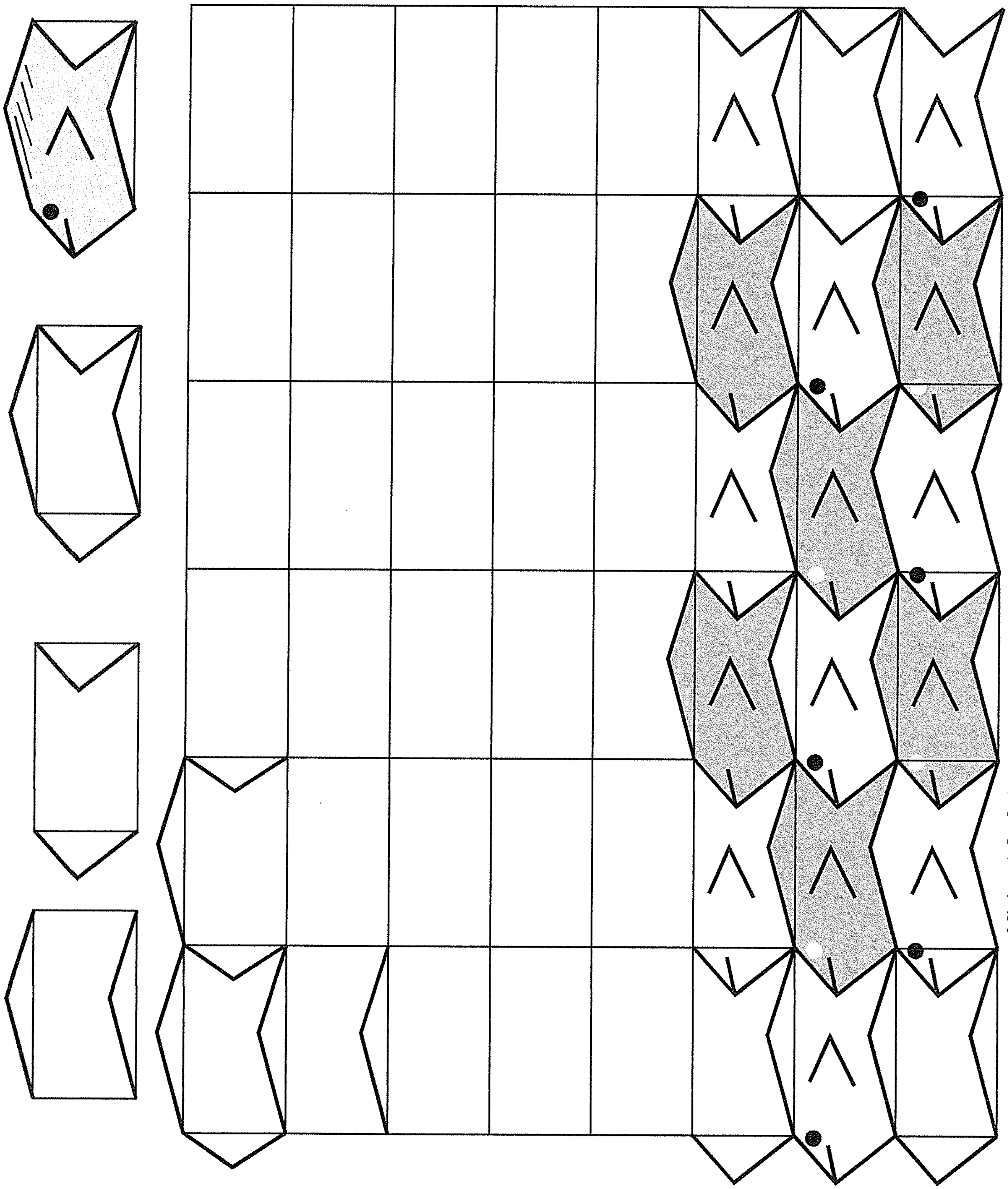


Glide-Reflection

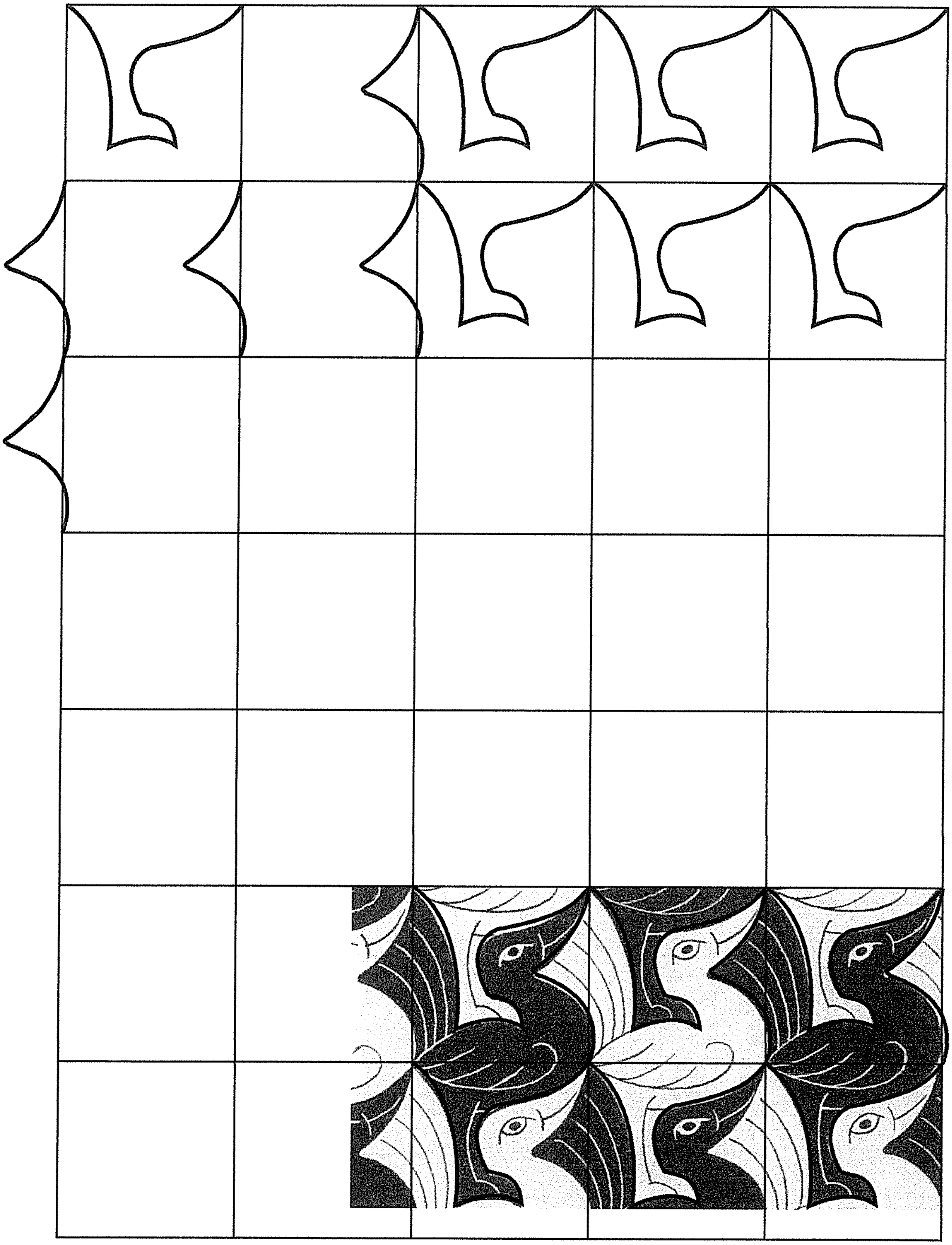


Rotation

64-A

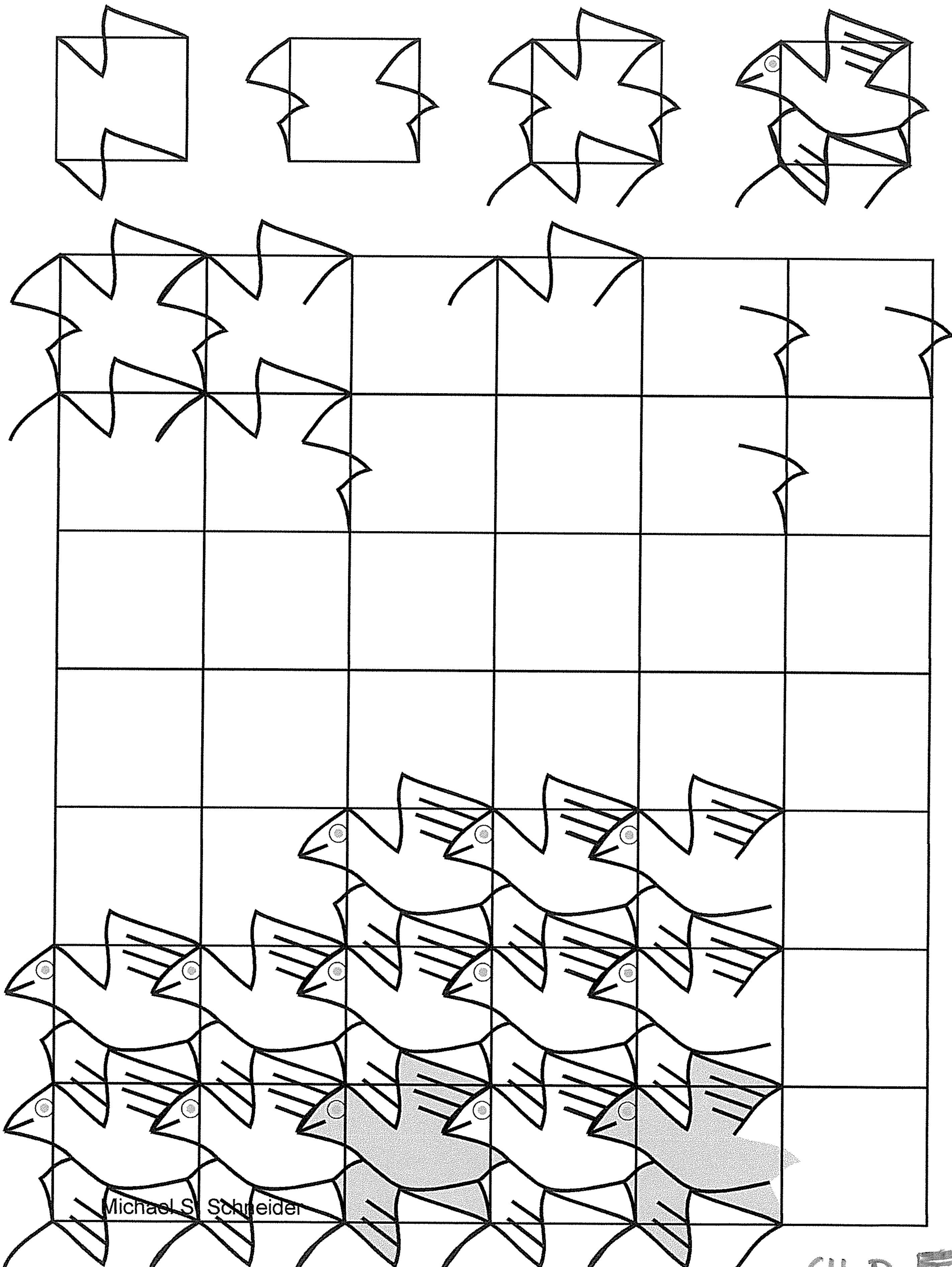


64-B

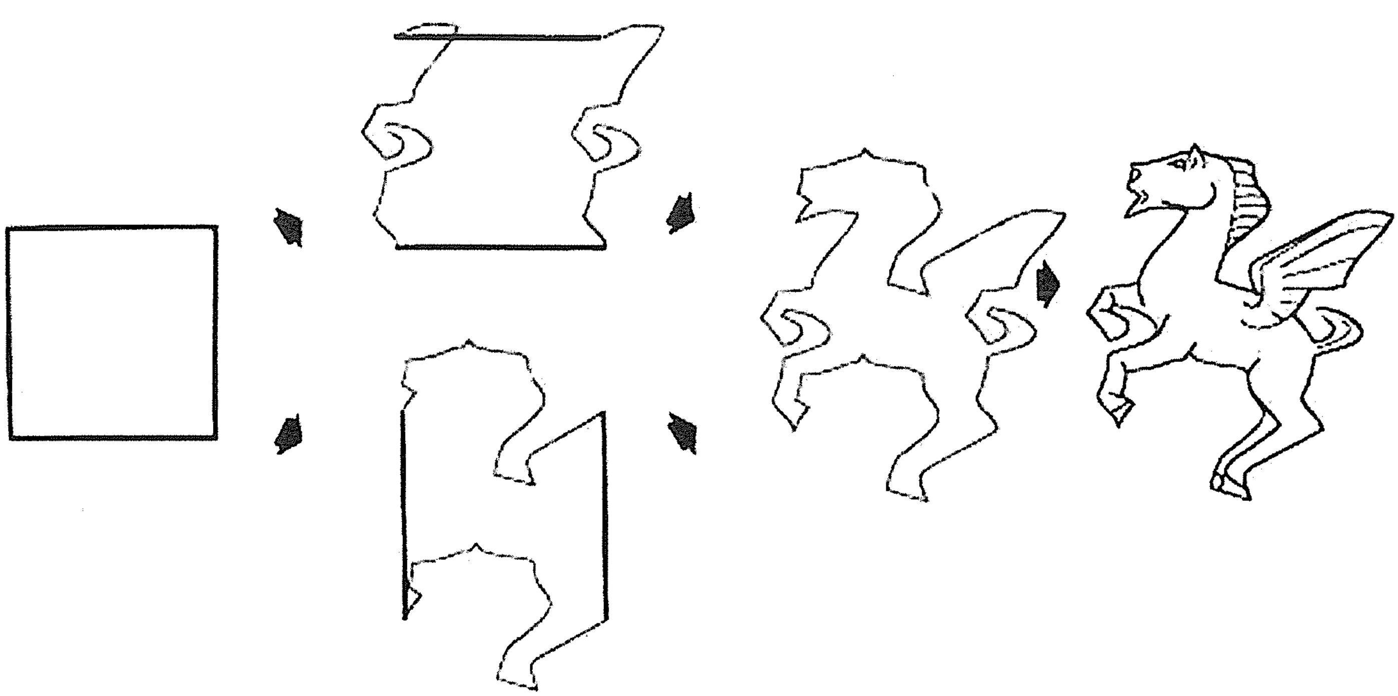


Michael S. Schneider

64-C

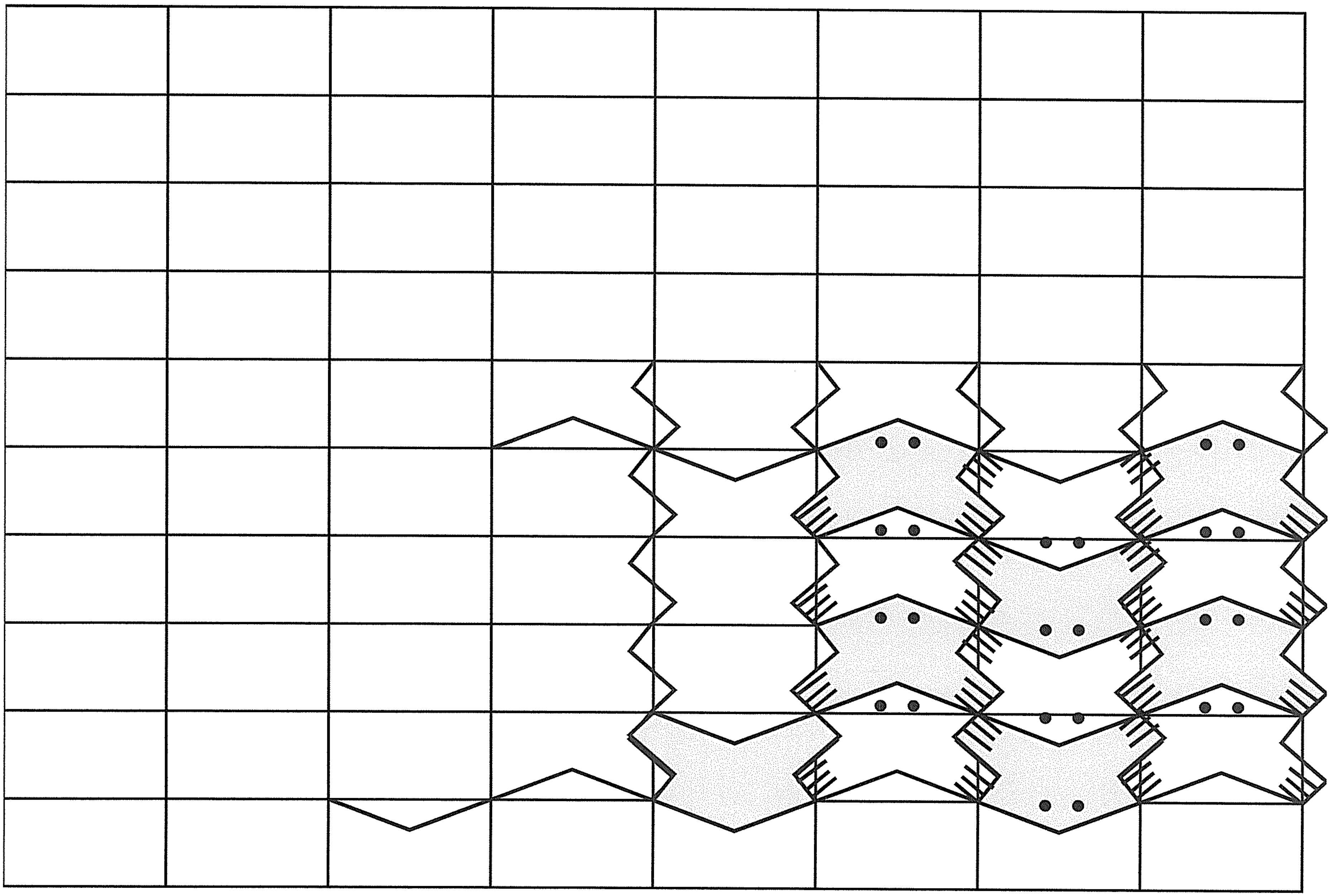


64-D



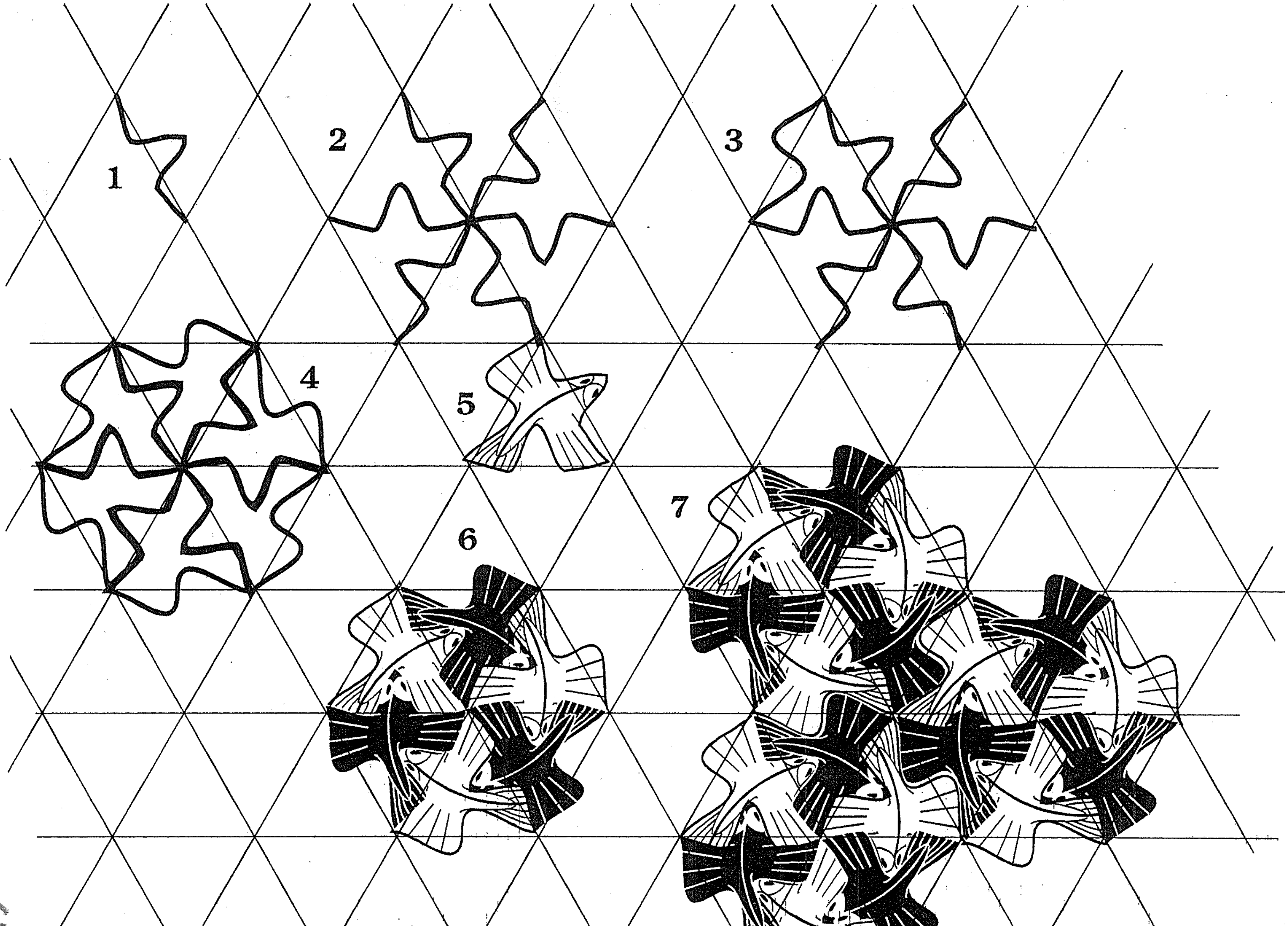
64-E

Glide-Reflection transformation



Continue the tessellation. But change the creature so that it's more interesting.

64-F



(c) 1994 Michael S. Schneider

ROTATION

64-G

Mysteries of Seven
The Heptad

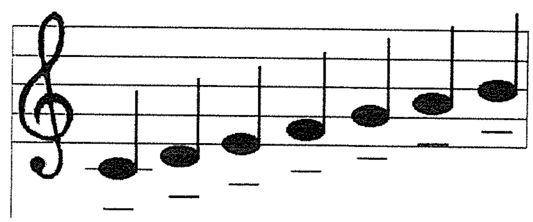
Seven is a "number of mystery" (with 9 and 11).

Seven symbolizes *that which is beyond ordinary earthly life* because it often shows up as ideas and abstractions we cannot hold in our hands.

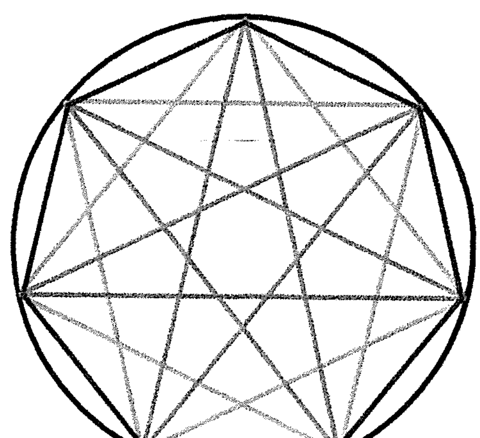
Words associated with 7 include:

Mystery
Spirit
Eternal
Divine
Sacred
Wisdom
Virtue
Philosophy
Transcendental Imagination
Imagination Over Rationality

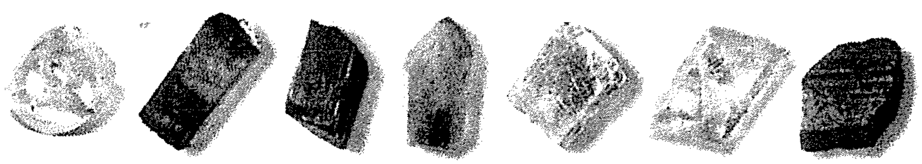
Seven appears in nature and human affairs, including:



Seven colors of visible light (the rainbow)
Seven notes of the diatonic (white keys) musical scale
Seven crystal systems
Seven openings in the head
Seven petaled flowers (Starflower)
Sevens in mythology and religion and fairy tales
Seven days of the week
Seven celestial bodies visible to the eye
Seven shuffles are required to randomize a deck of cards



... and much more

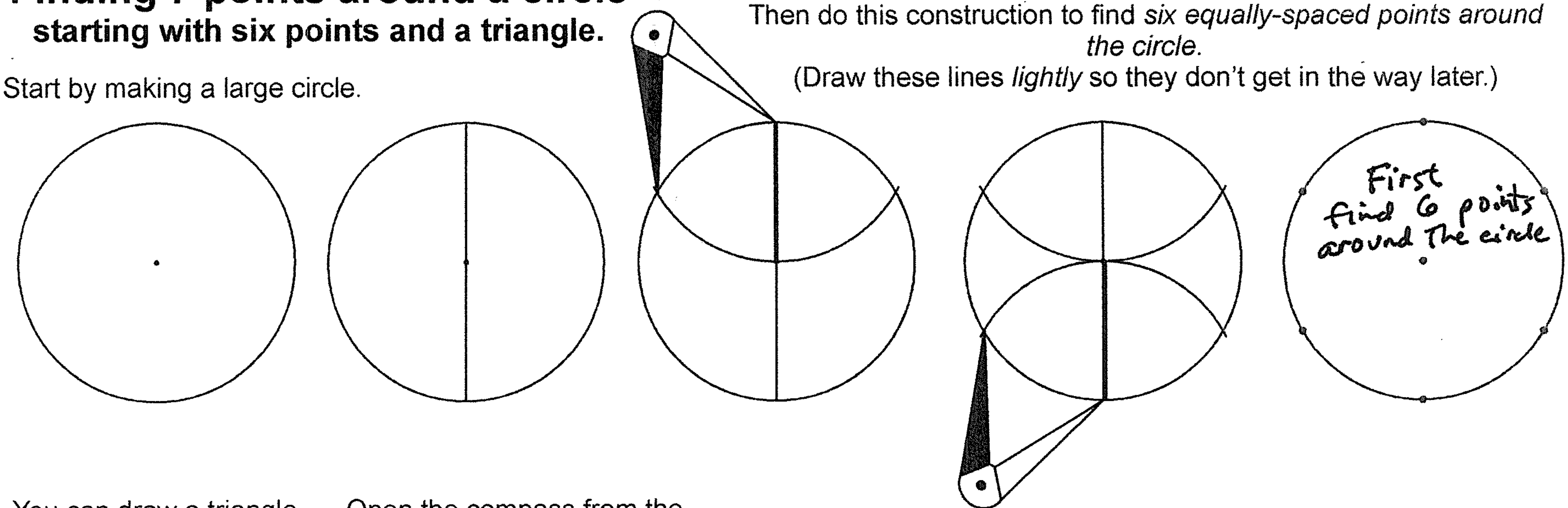


Isometric Hexagonal Tetragonal Trigonal Orthorhombic Monoclinic Triclinic

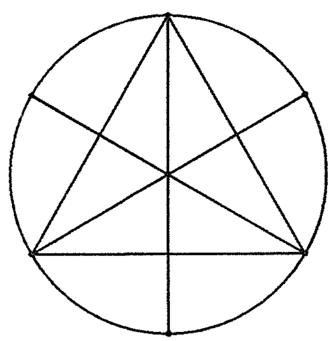
Finding 7 points around a circle
starting with six points and a triangle.

Start by making a large circle.

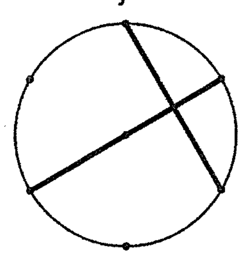
Then do this construction to find *six equally-spaced points around the circle.*
(Draw these lines *lightly* so they don't get in the way later.)



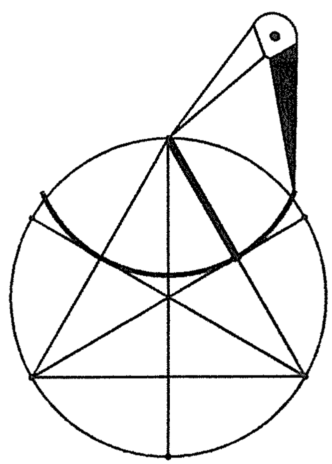
You can draw a triangle and lines across the circle as shown, or just make two lines cross as seen below.



or just

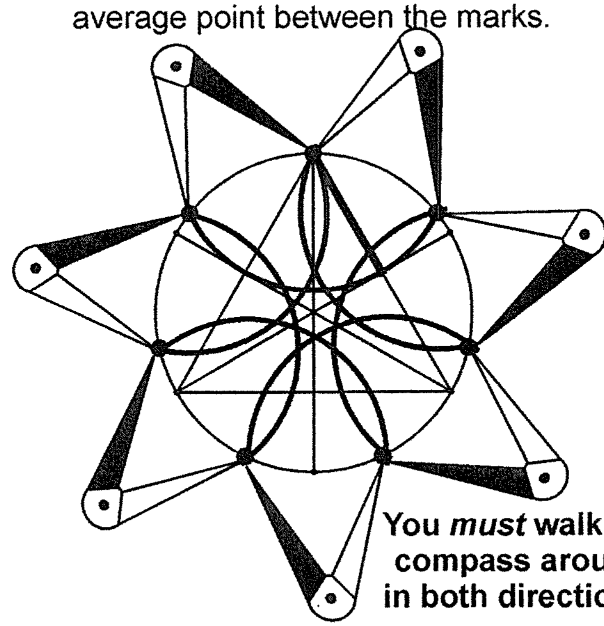


Open the compass from the top of the triangle to the middle of one side, where the two lines cross. Then swing an arc to the circle.



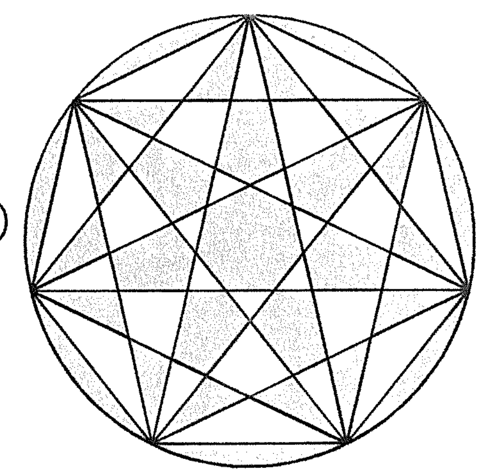
Perfect 7 is impossible to construct. But this compass size shows *approximately* one side of a Heptagon.

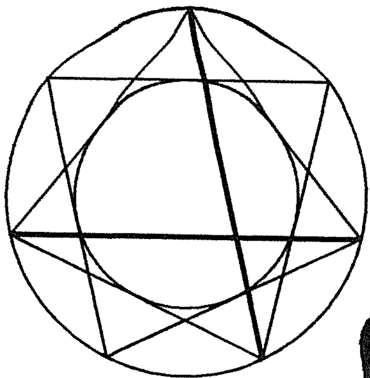
"Walk" the compass around from new point to new point until you arrive back *near* the beginning. Then also walk it around in the *opposite* direction and identify the average point between the marks.



You *must* walk the compass around in both directions!

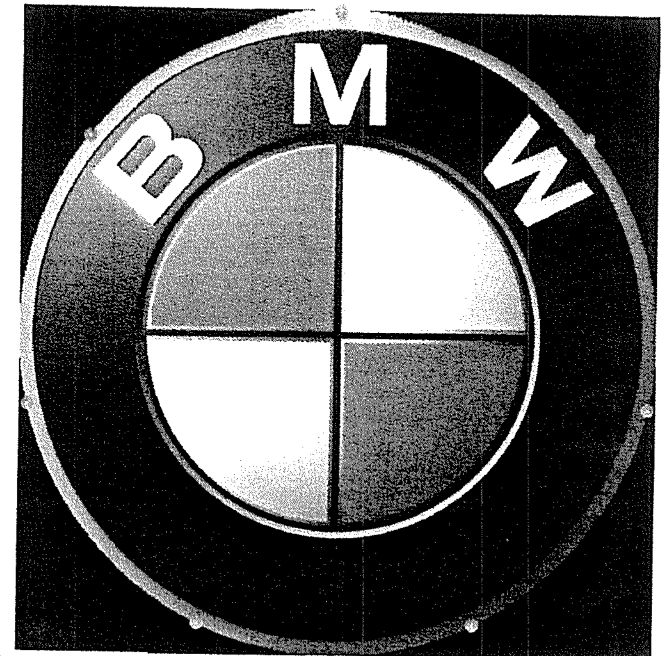
Connect the seven points to make a Heptagon and the two Heptagram stars, and develop the construction even further!

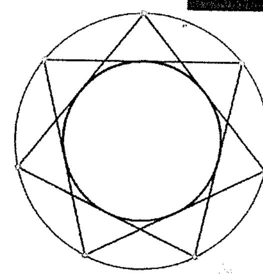


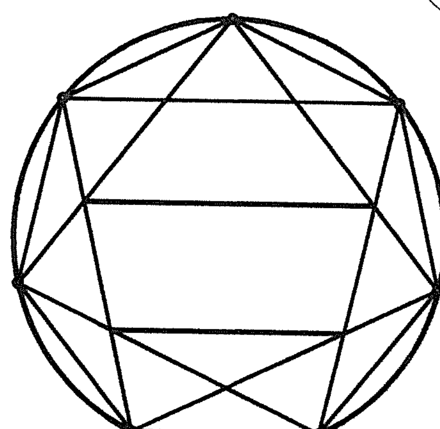


Ancient & Modern

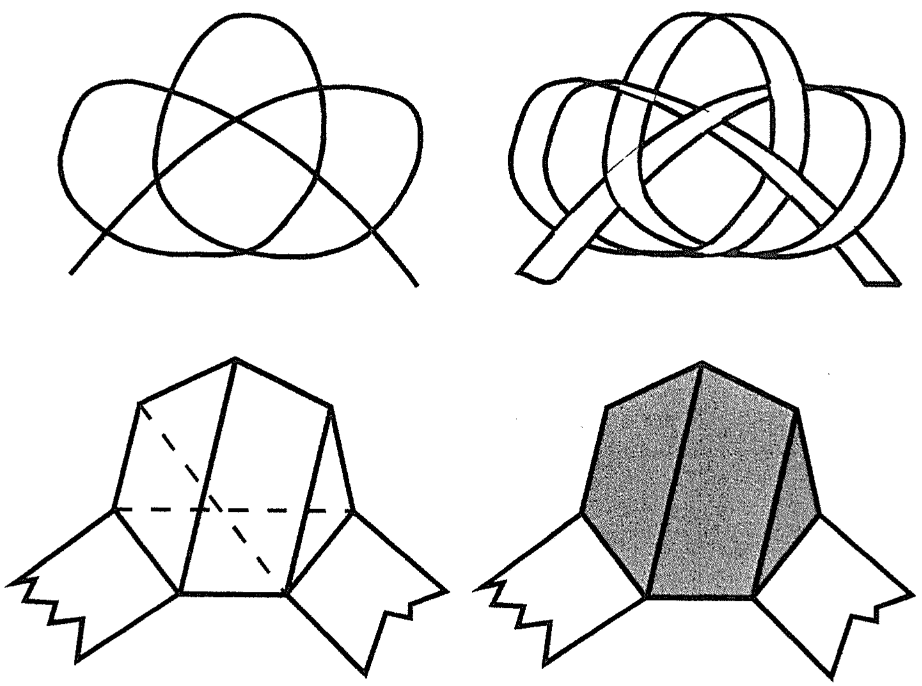
Use the 7 points around each image to draw the geometric pattern seen near it.

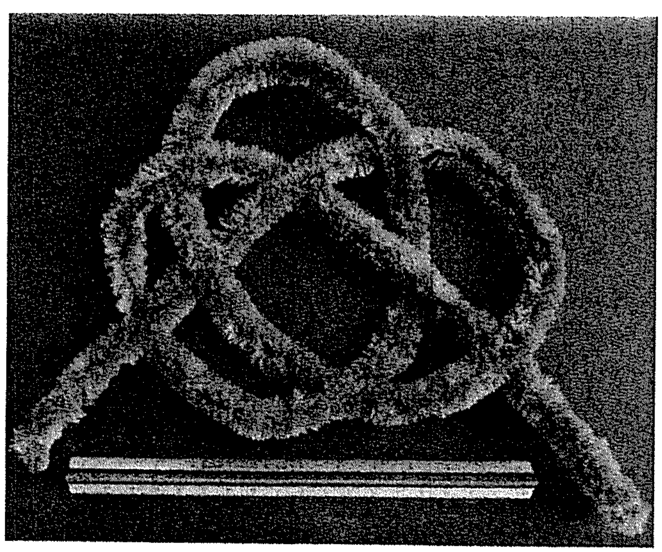




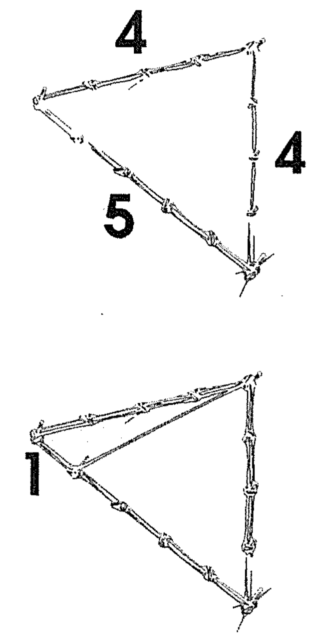


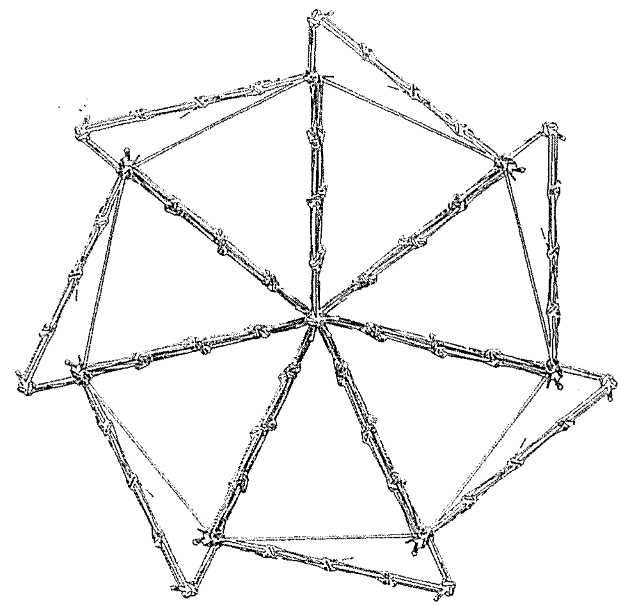
Tying a Heptagonal Knot



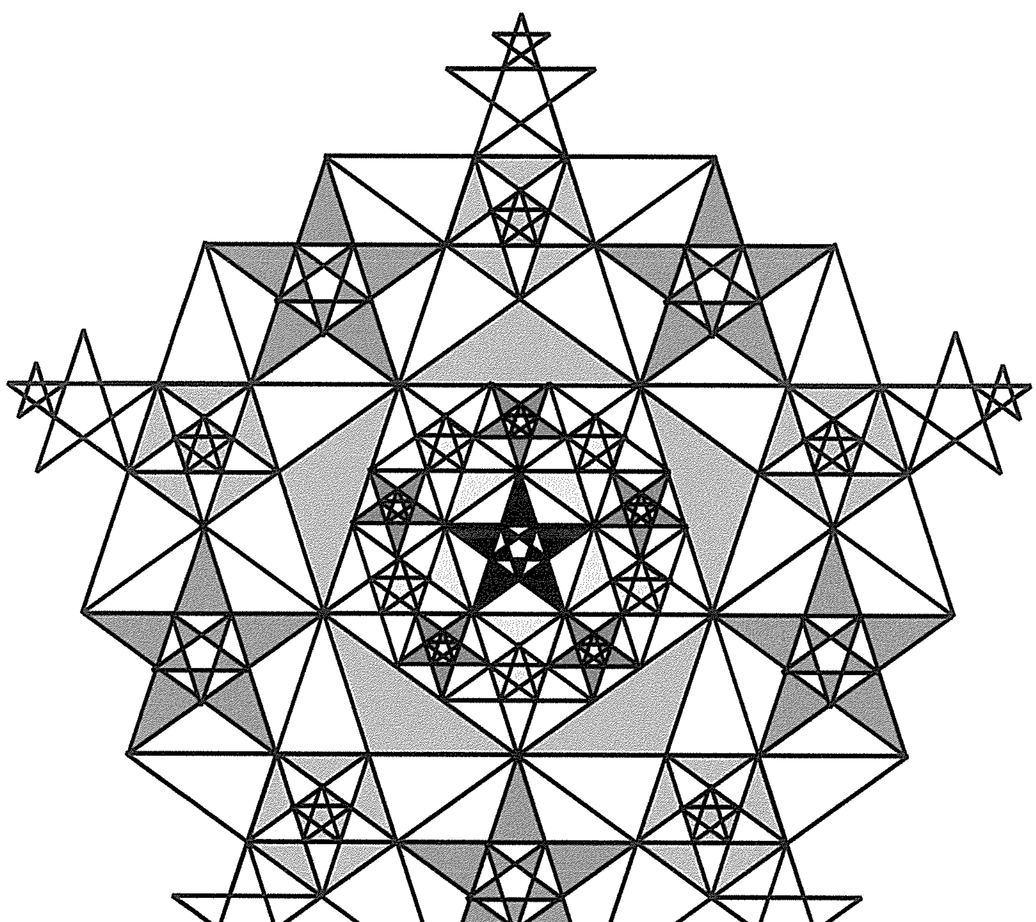


Constructing a Heptagon with a 13-knotted rope





Pentagonal Symmetry



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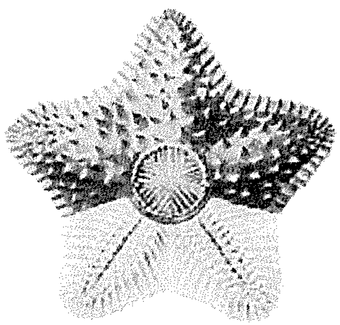
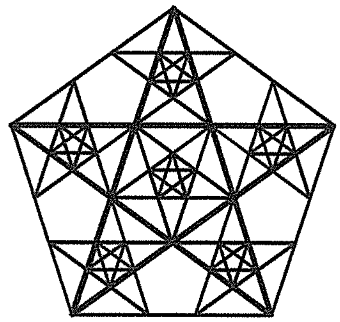
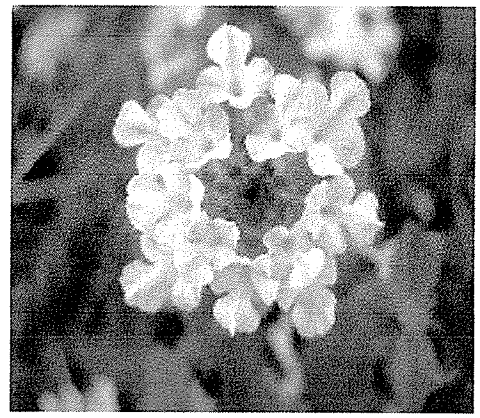
What's So Great About Pentagons?

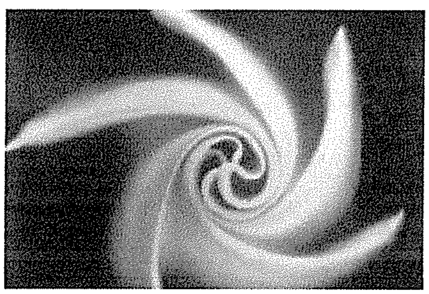
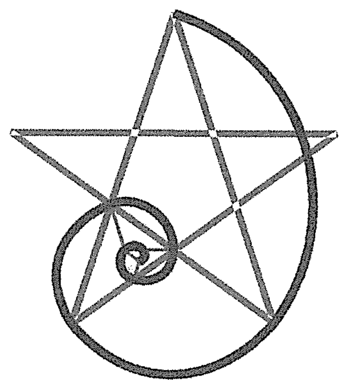
A pentagon has five corners and five sides. When they're all equal, it's called a "regular" pentagon. A regular pentagon solves two problems:

How to balance by repeating (regenerating) the same shape in different sizes so they all fit together.

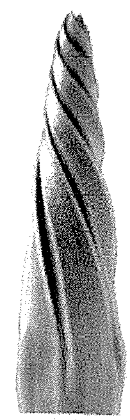
How to balance while moving or growing as a spiral.

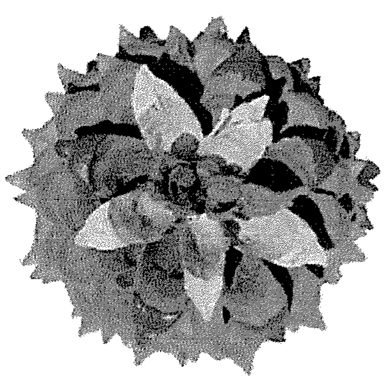
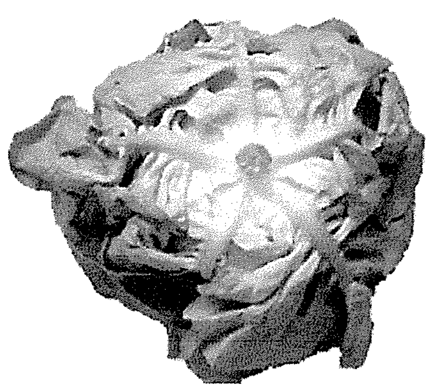
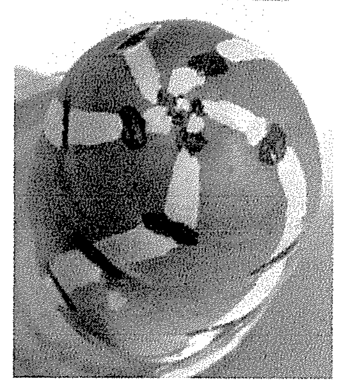




Starfishes and plants regenerate. A starfish can regrow lost arms, and plants with five-petaled flowers have the same shape blooming in many sizes at once, yet they all fit together and the plant balances

When we see five, there may be a spiral unfolding nearby!



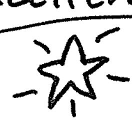
The bottoms of a pinecone and lettuce reveal their "leaves" to be parts of an ongoing, spiraling five-pointed star.

Connect the "eyes" on a potato and you'll see its spiraling star!

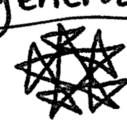
★ symbolism:

Human Life

Excellence

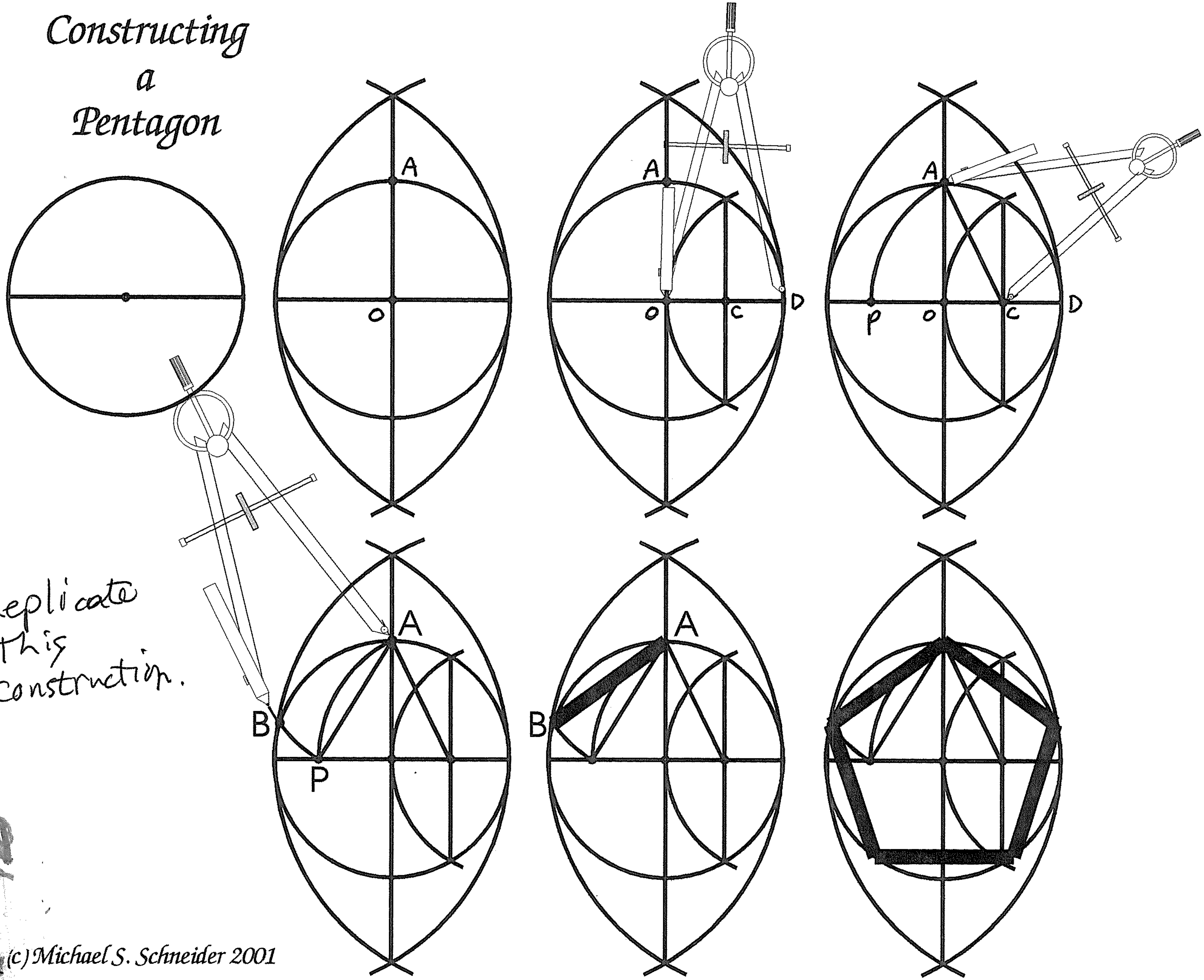


Regeneration



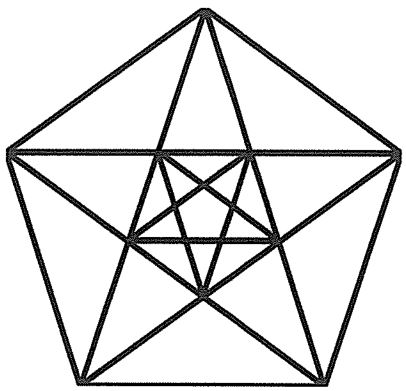
Righteous Authority

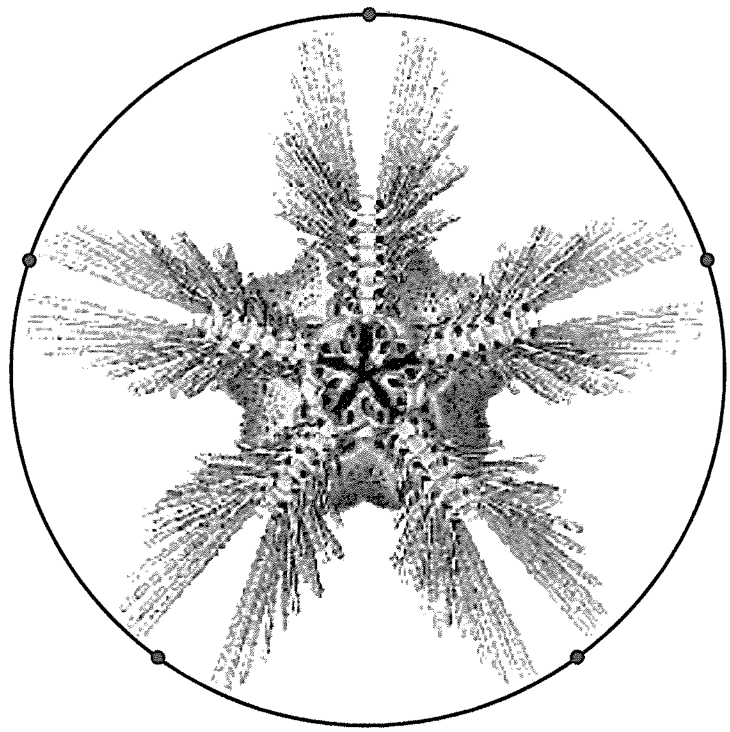
Constructing a Pentagon



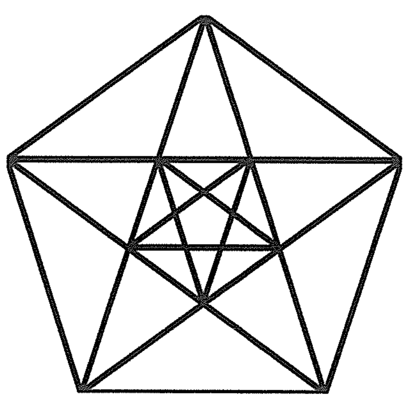
Replicate this construction.

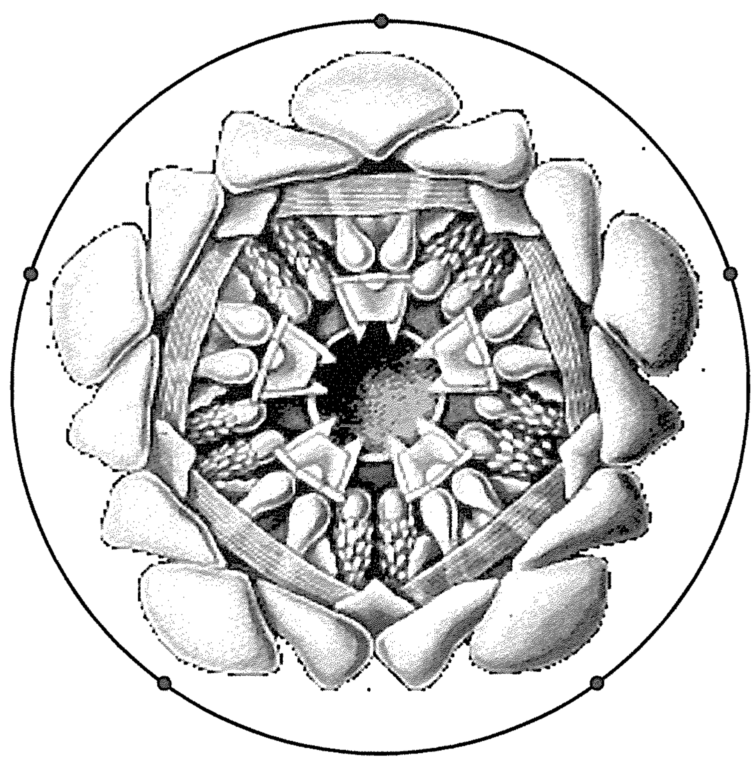
Starfish





Starfish Mouth
(close-up)





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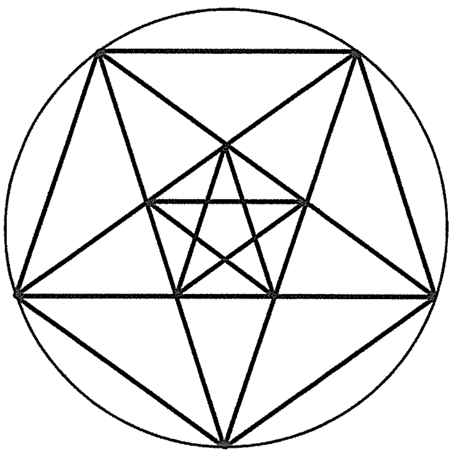
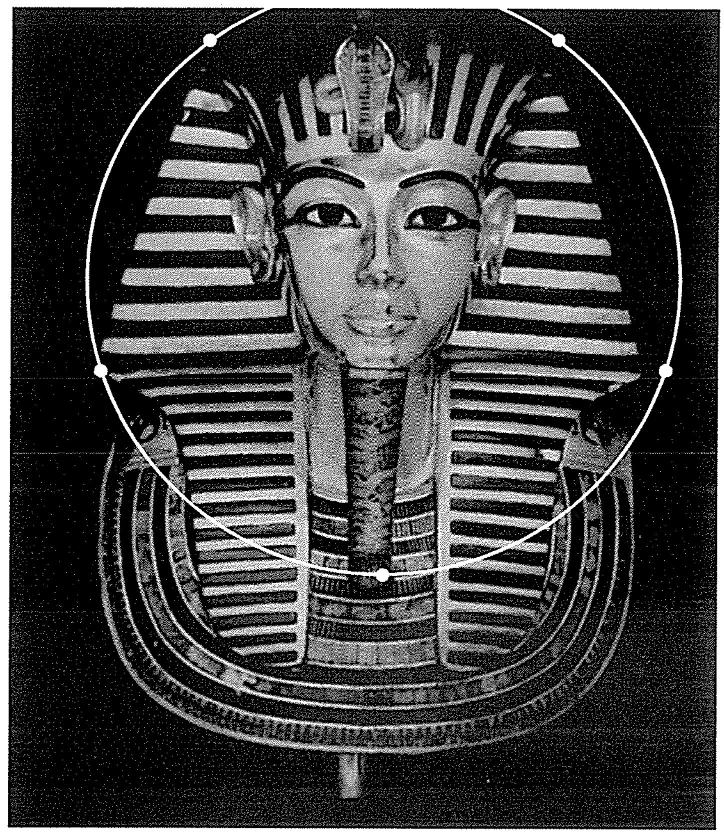
Pentagonal Design In Arts, Crafts And Architecture

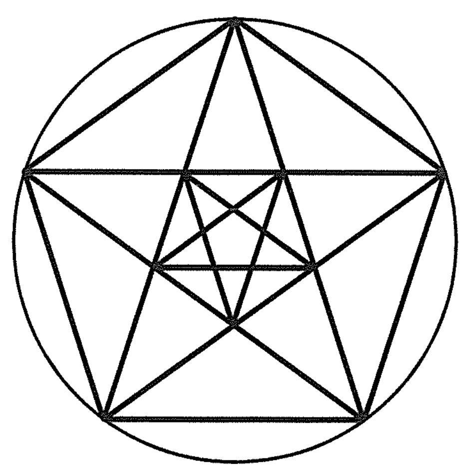
Many works of art worldwide seem to have been designed using Pentagonal geometry. Each of these pictures has a Circle with five equally spaced points around it for you to replicate the geometric scheme seen next to it. Look carefully to see how the geometry guides the parts of the object or scene.



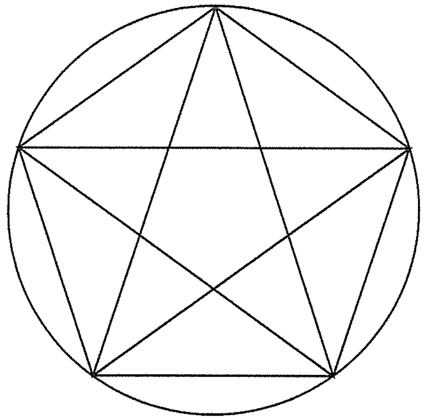


Gold mummy mask of Pharaoh Tut-Ankh-Amen

The Alba Madonna by Raphael, 1511
National Gallery of Art, Washington



Salvadore Dali:
Leda And The Swan

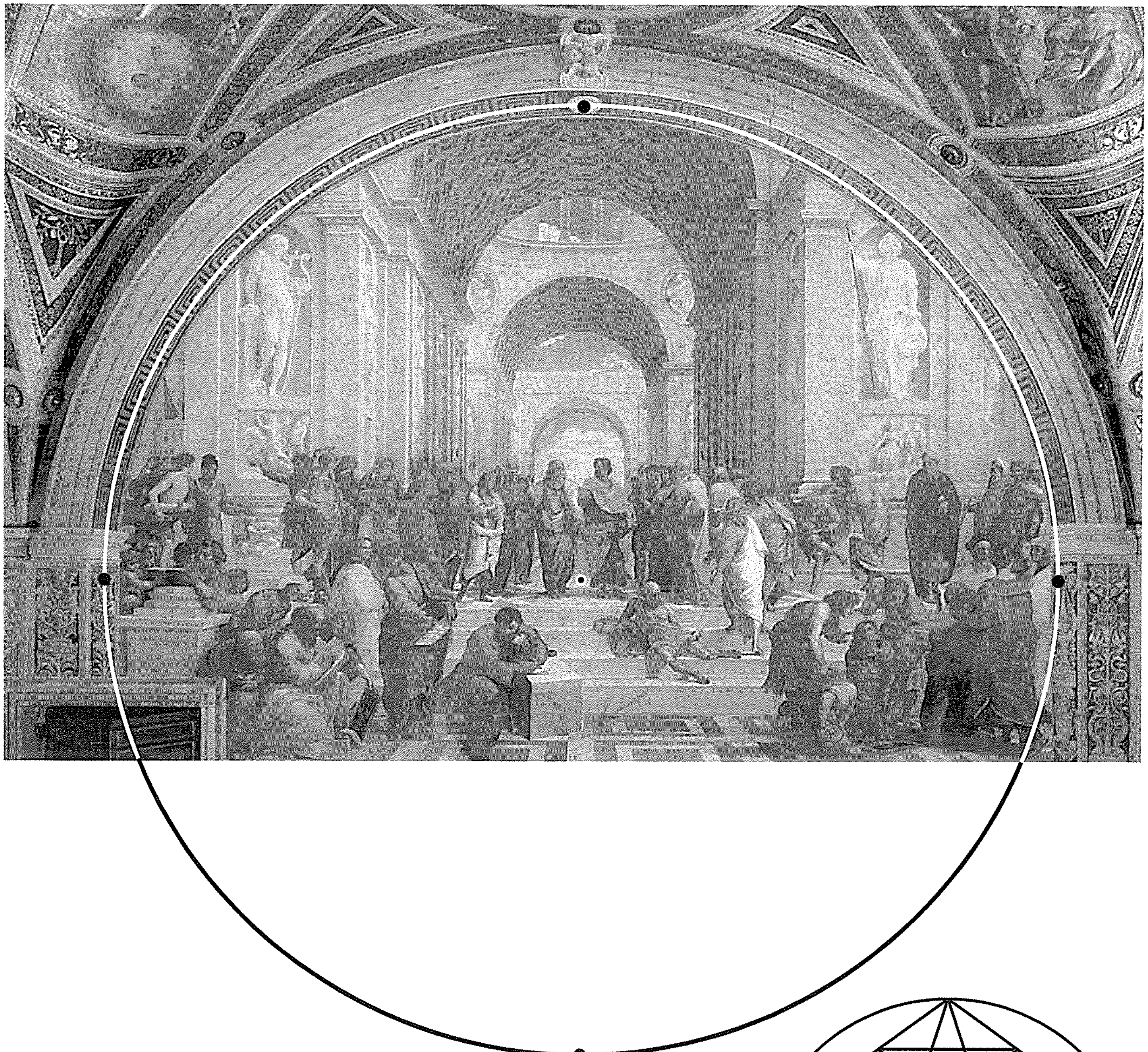


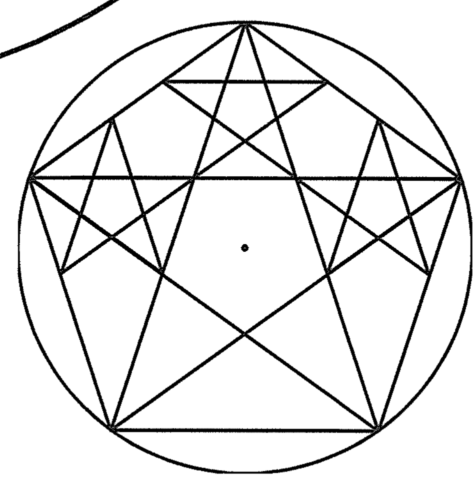
Subdivide parts of the geometry further to see more of the hidden structure.

Notice similarities to Raphael's Alba Madonna (Leg, etc)

***The School Of Athens* by Raphael**

Four points are given around a circle, with its center.
Use them to construct and subdivide a pentagram as seen below. Show how you did the construction.





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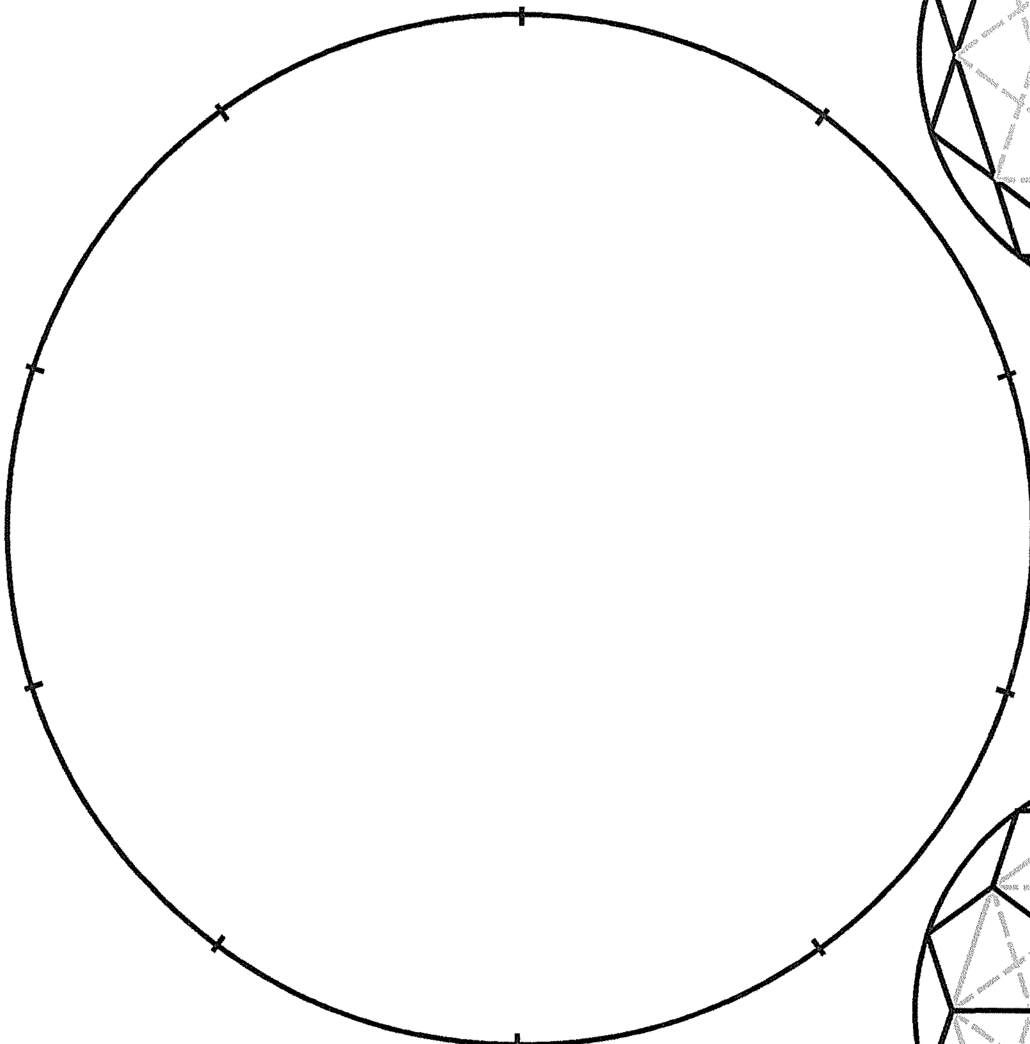
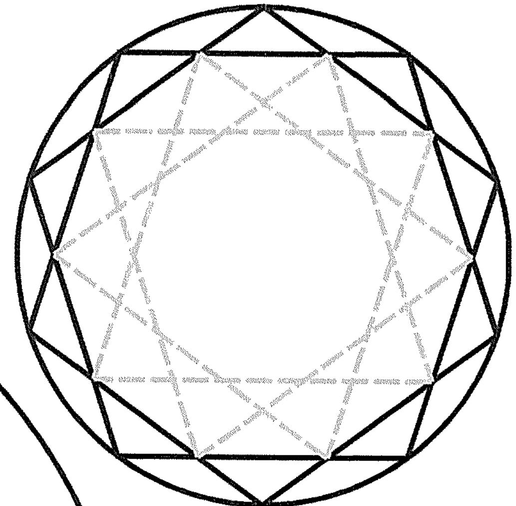
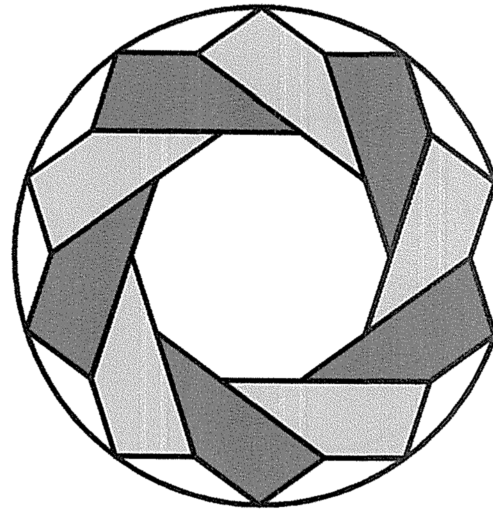
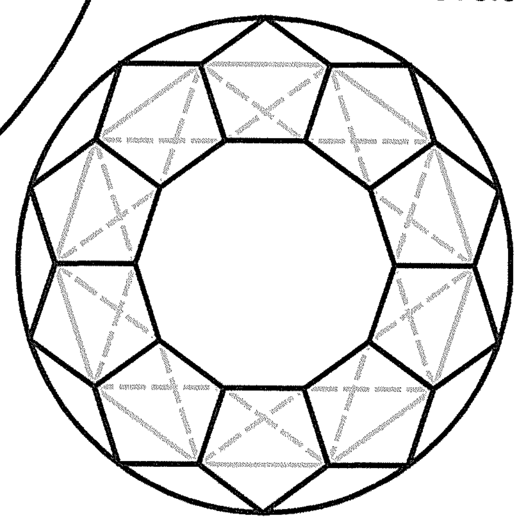


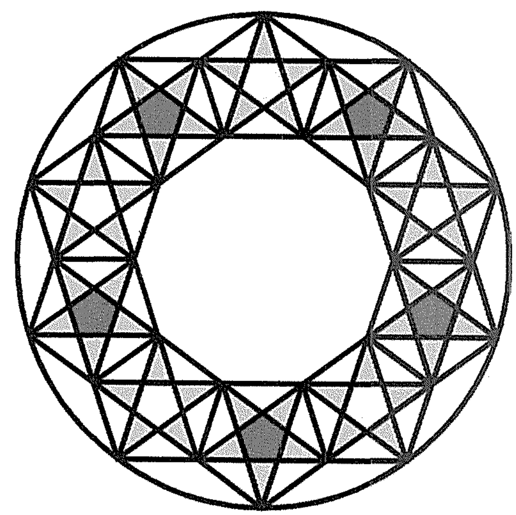




Woven Pentagons
and
Pentagram Acrobats

Start with 10 points around a circle.
Connect alternate points.
Identify and connect
crossing-points accurately,
then *color carefully*.
Develop them further...!

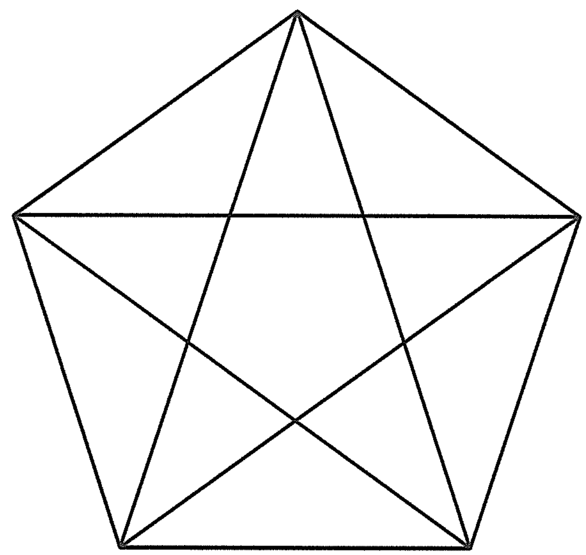


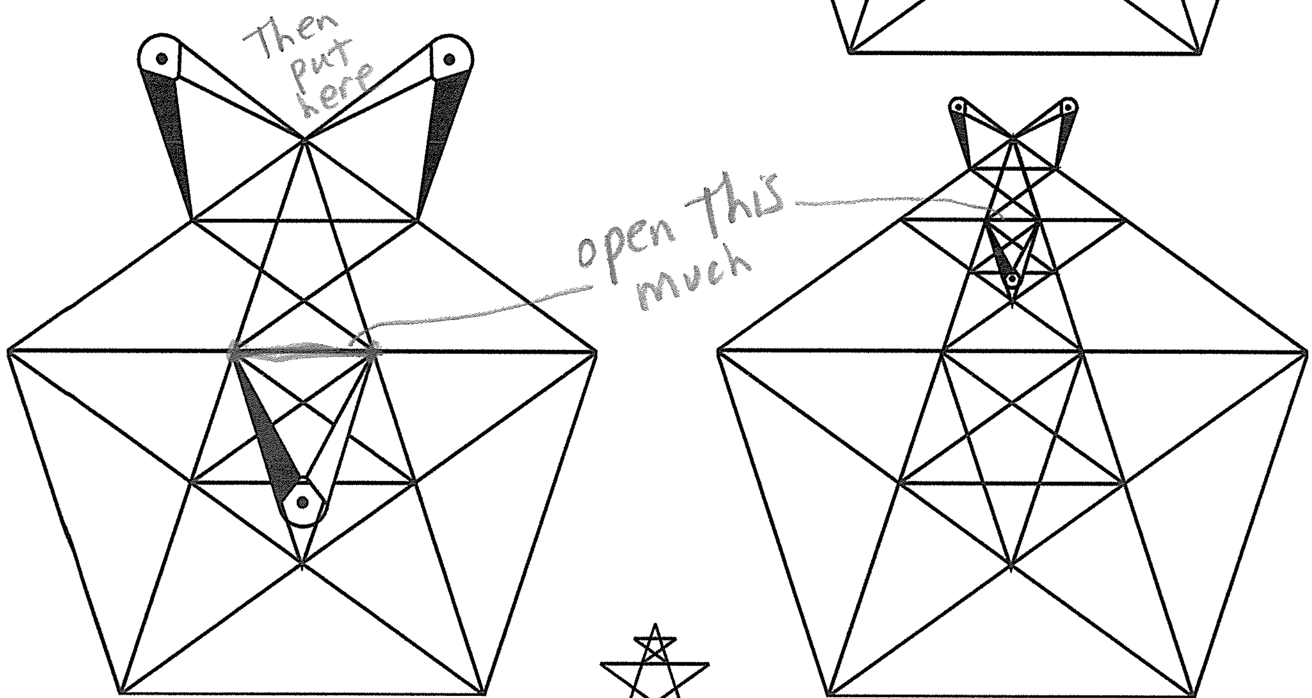


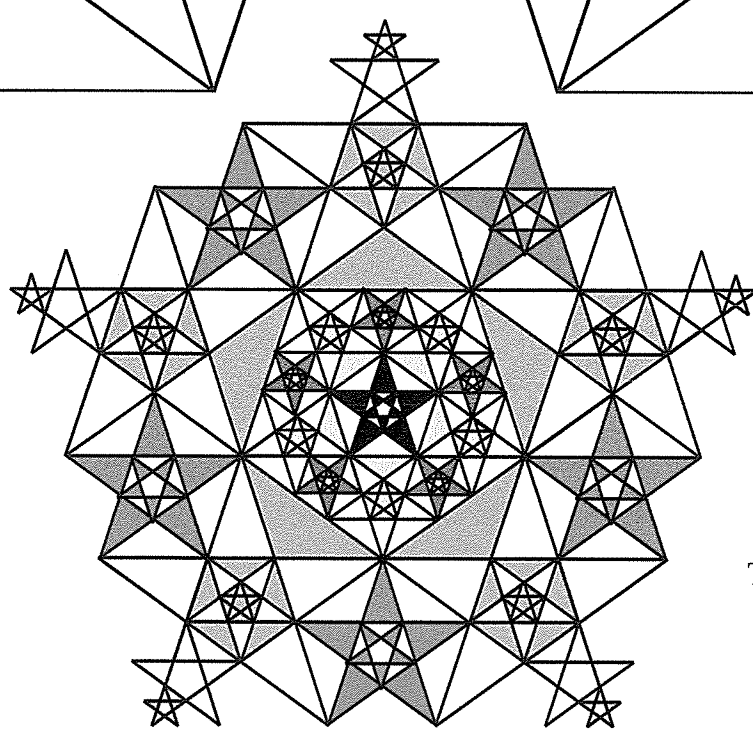
Learn this...

How to subdivide one arm of the Pentagram Star
into smaller Pentagram Stars.

Do it on this one --

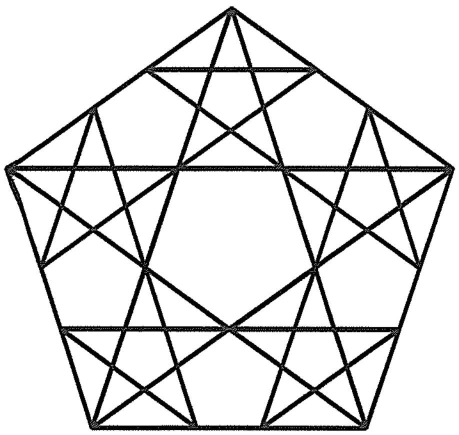


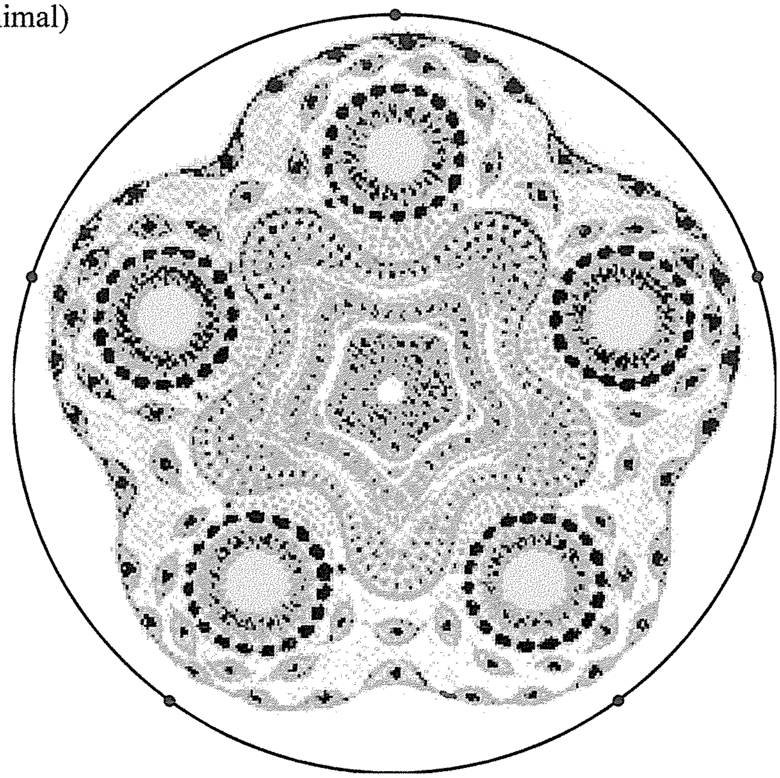




There's no end to the
subdivisions of a
Pentagram Star!

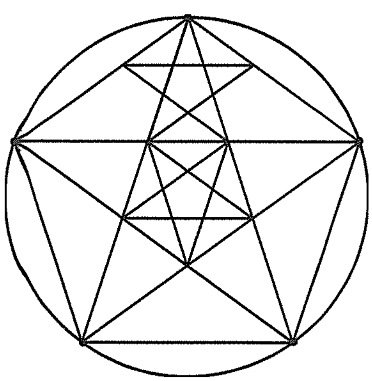
Cross section of a **Sea Cucumber** (an animal)

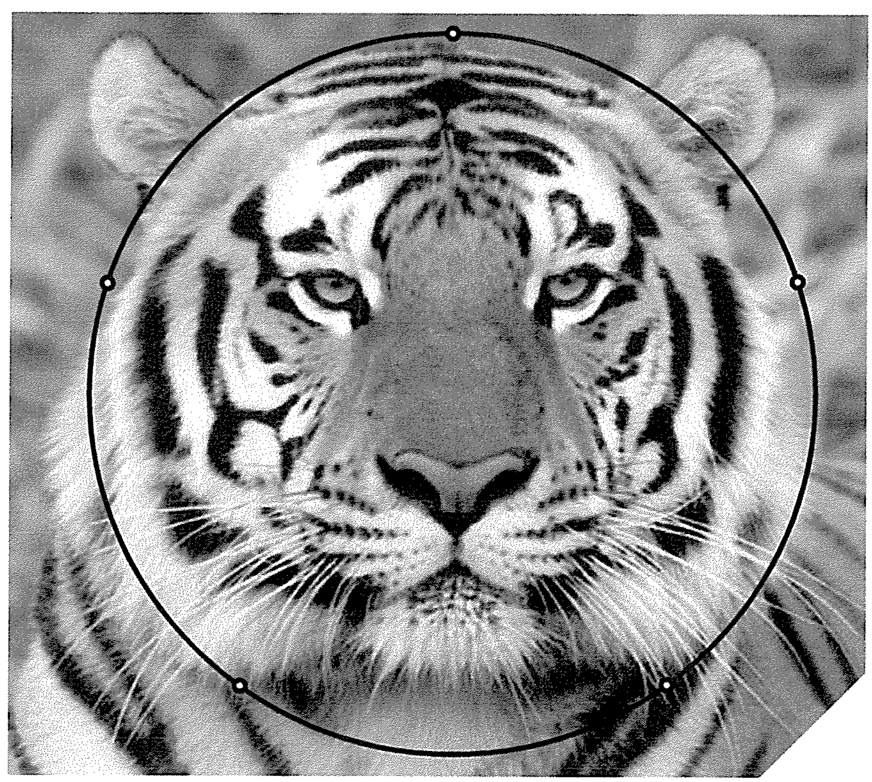


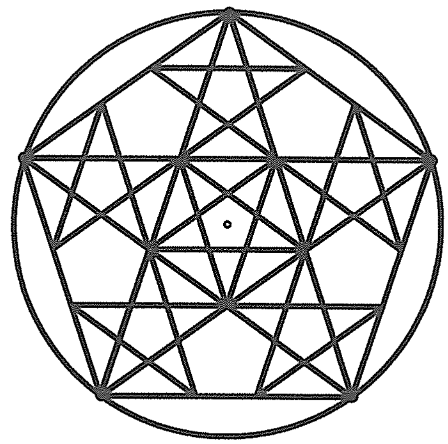


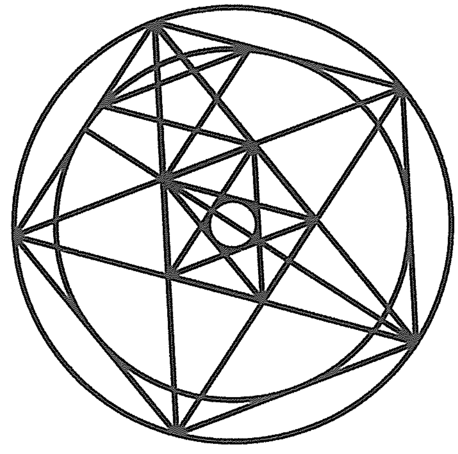
Faces

The faces of many animals can be understood through Pentagonal geometry.









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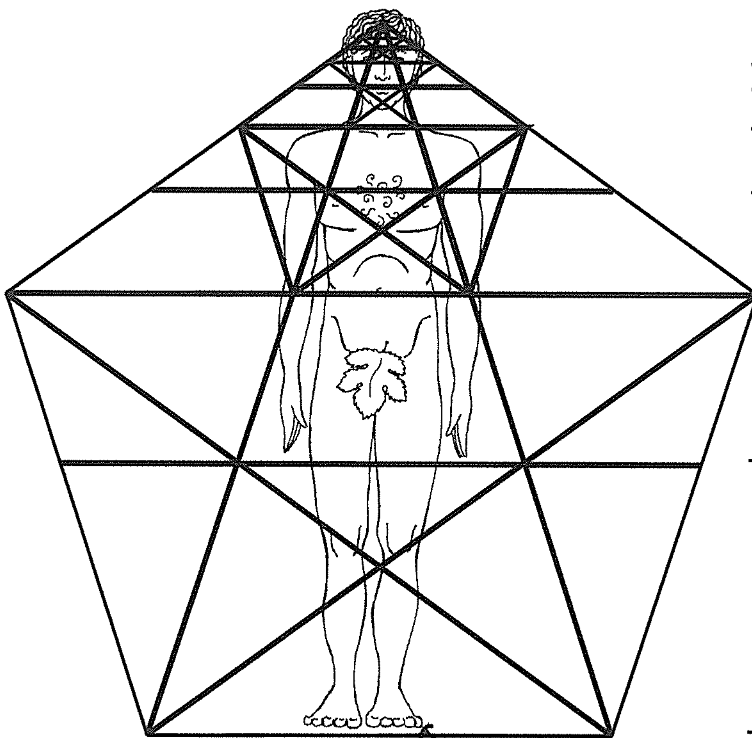
Find the Classic Greek Proportions of the Human Body in the Golden Ratios of the Pentagon.

Create smaller pentagons which show each horizantal level of the body.

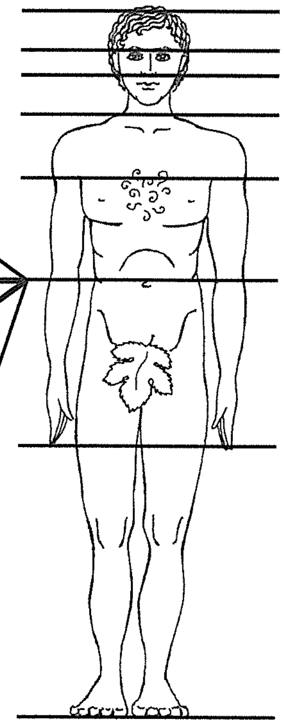
Notice that each two levels add vertically to equal the next larger one!

This is useful information when designing anything for the human body from fashion, sculpture and jewelry to machinery and dance.

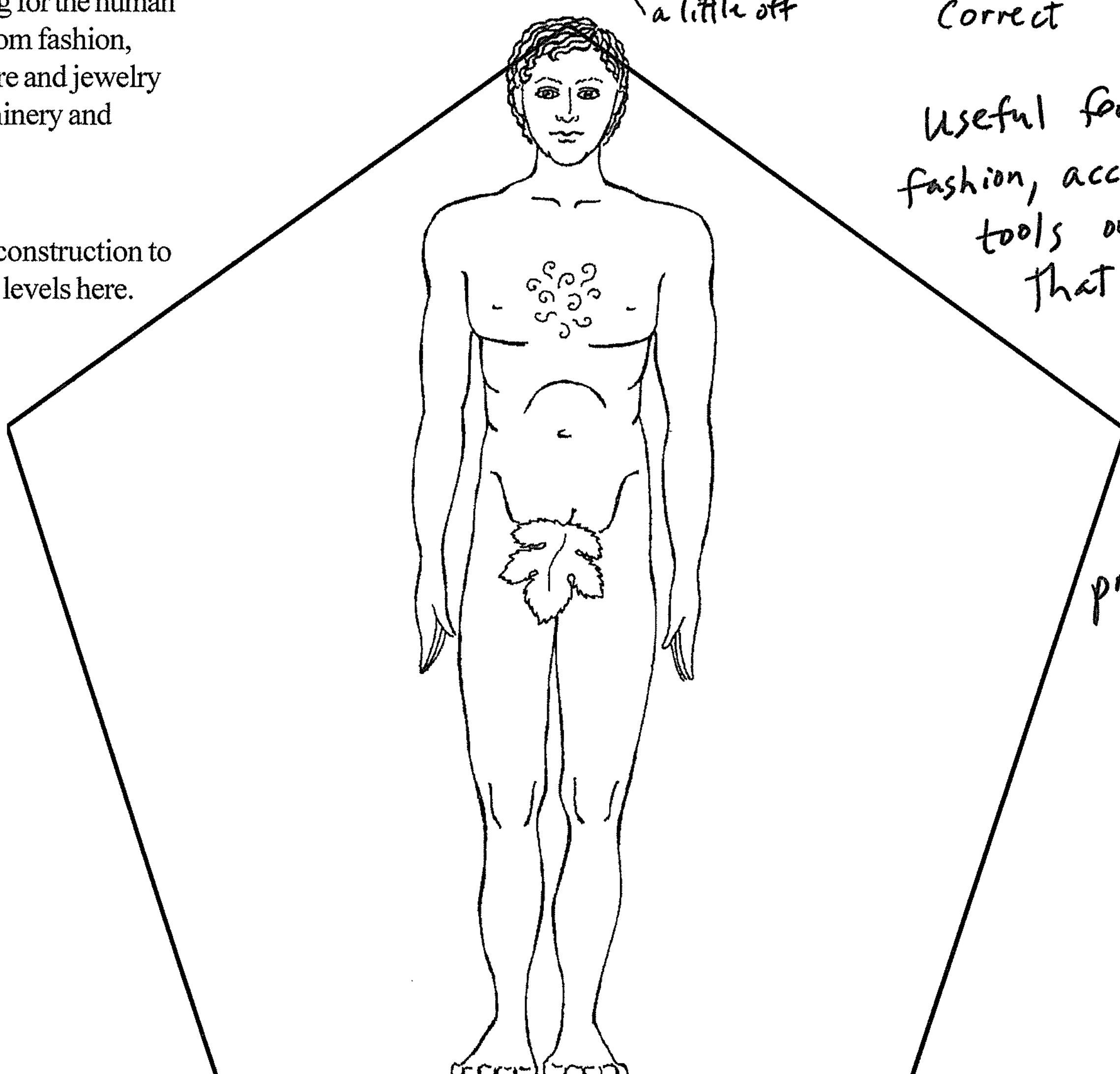
Do the construction to find the levels here.



a little off

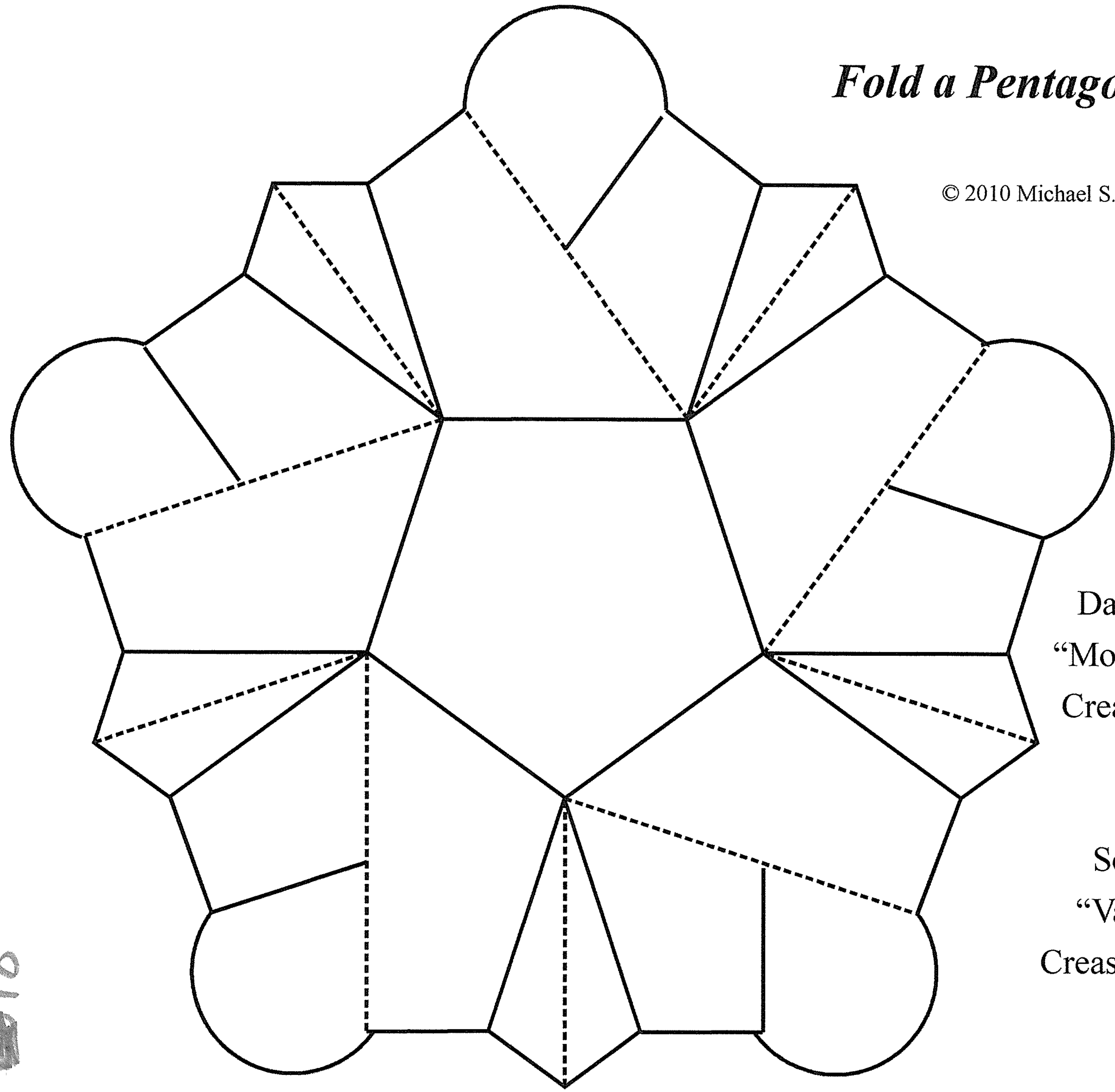


Correct



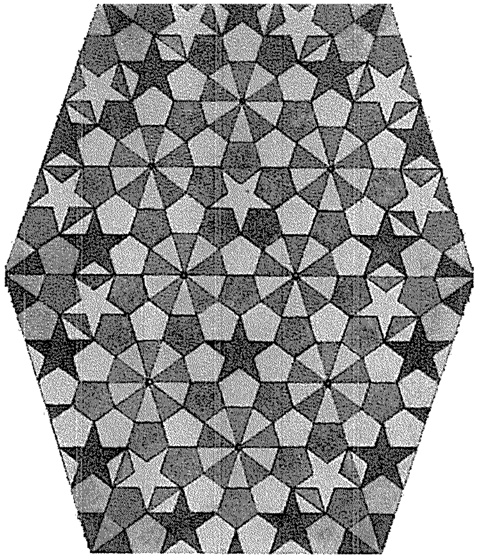
Useful for designing fashion, accessories, tools or anything that has to harmonize with the body's proportions!

Fold a Pentagonal Pocket

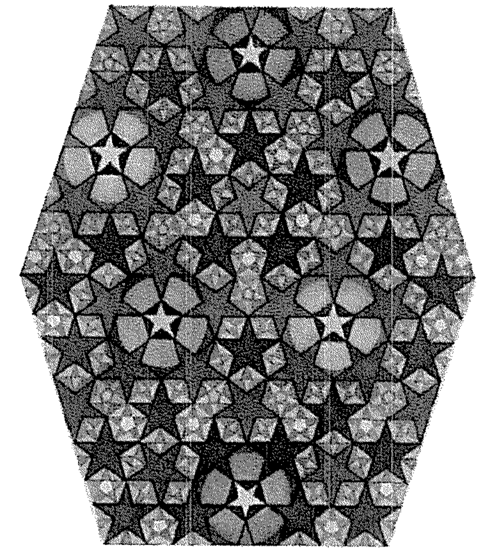


Dashed Lines
"Mountain Fold"
Crease edge up:

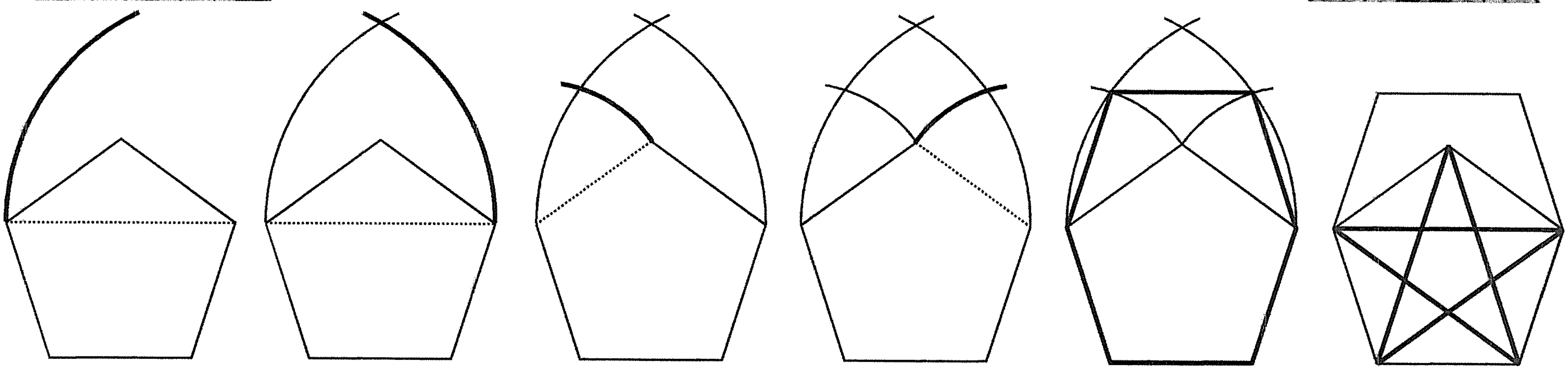
Solid Lines
"Valley Fold"
Crease edge down:

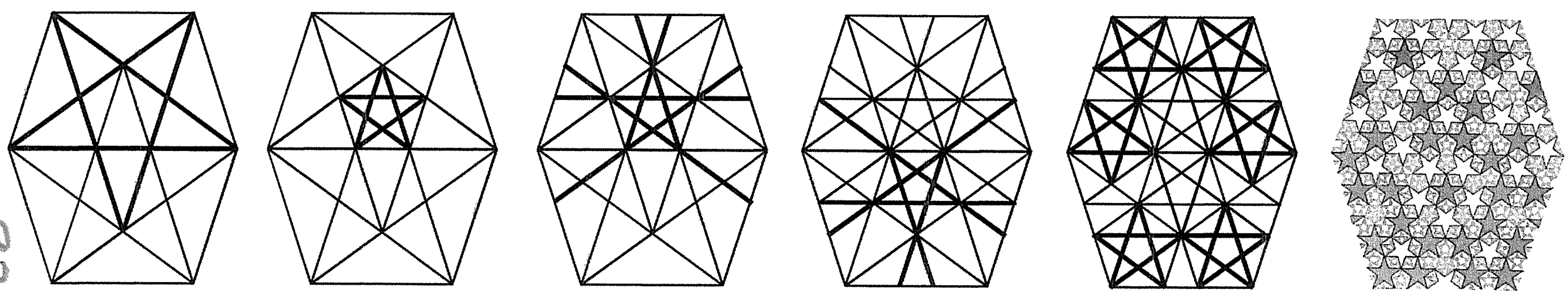


Construct and Develop
Married Pentagons



Start with a Pentagon.
Open your compass across the dotted lines and make arcs.
Connect the crossing to make a non-regular Hexagon.
Draw the two married Pentagons
and then find many more Pentagons and Pentagram stars!

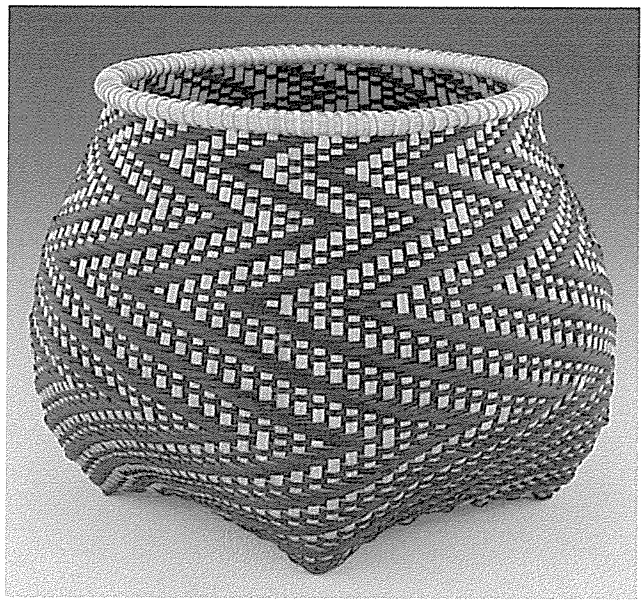




Find places to draw small pentagram stars then extend their sides in all directions.

This will show you more places to draw pentagons and pentagram stars. Then keep extending their sides...

Fibonacci Numbers



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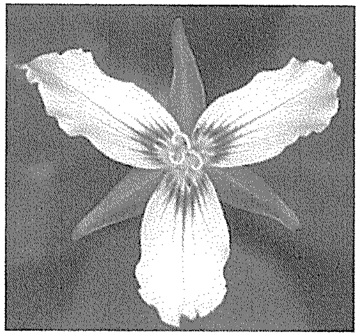
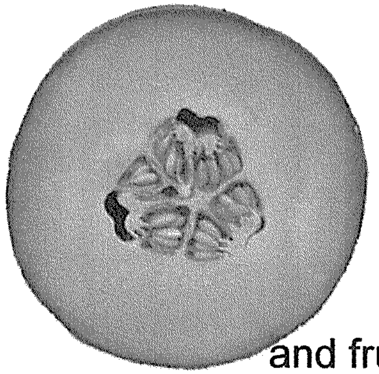
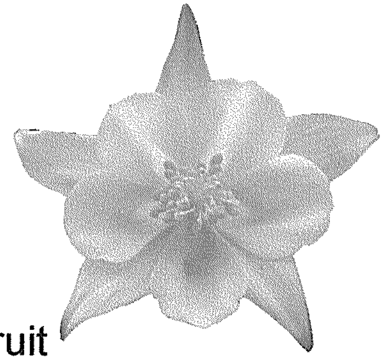
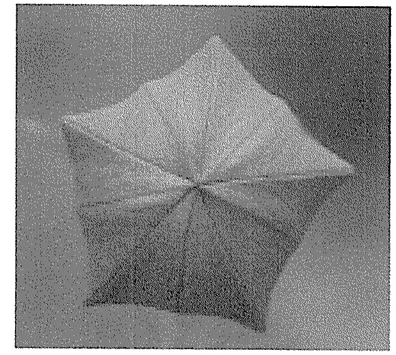
Fibonacci Numbers of Flower Petals

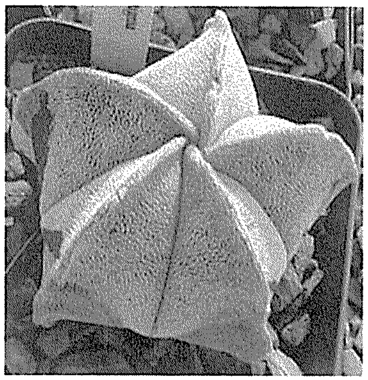
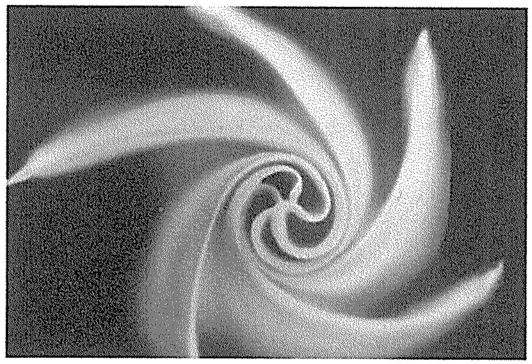
Write the number of petals by each picture.

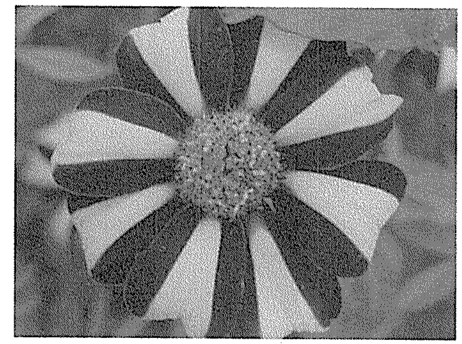



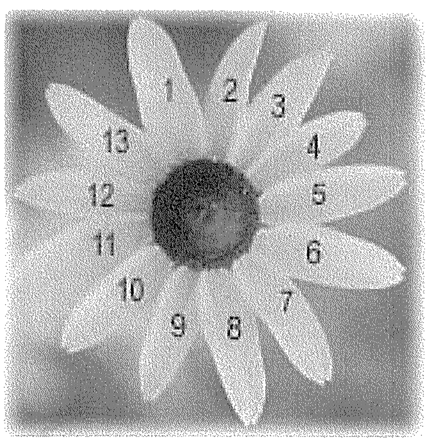
and fruit

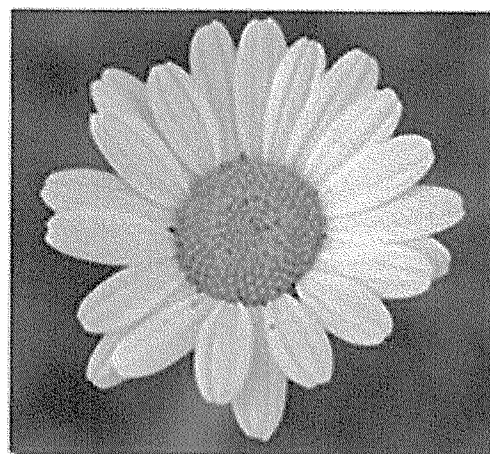


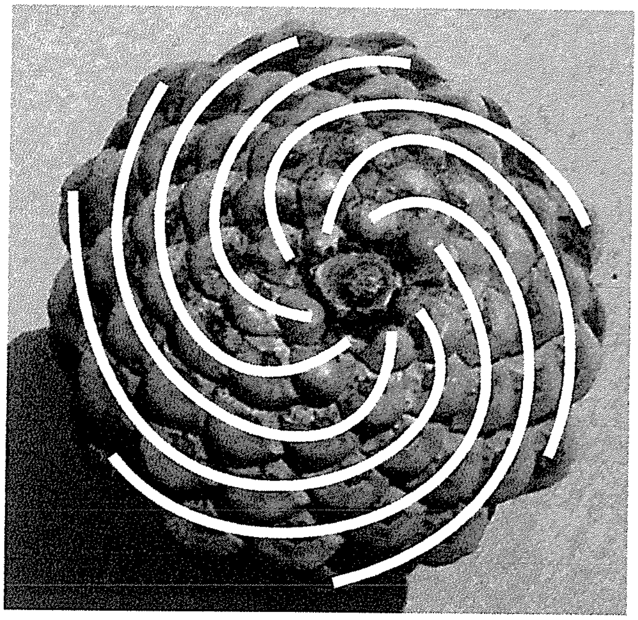



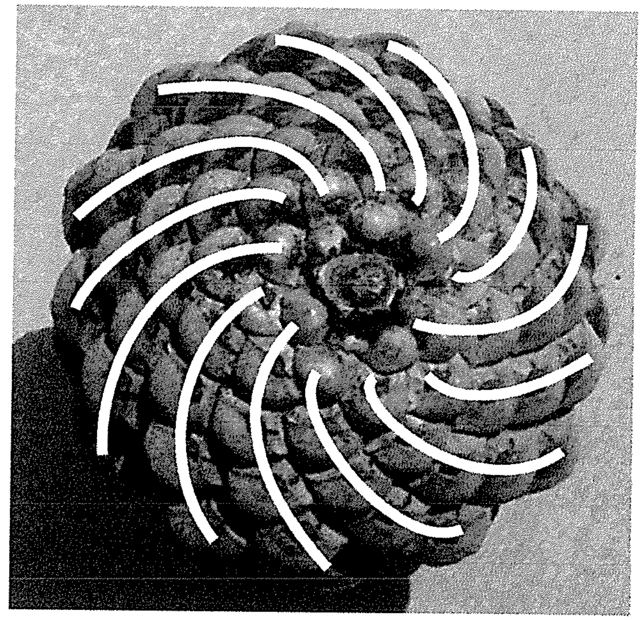







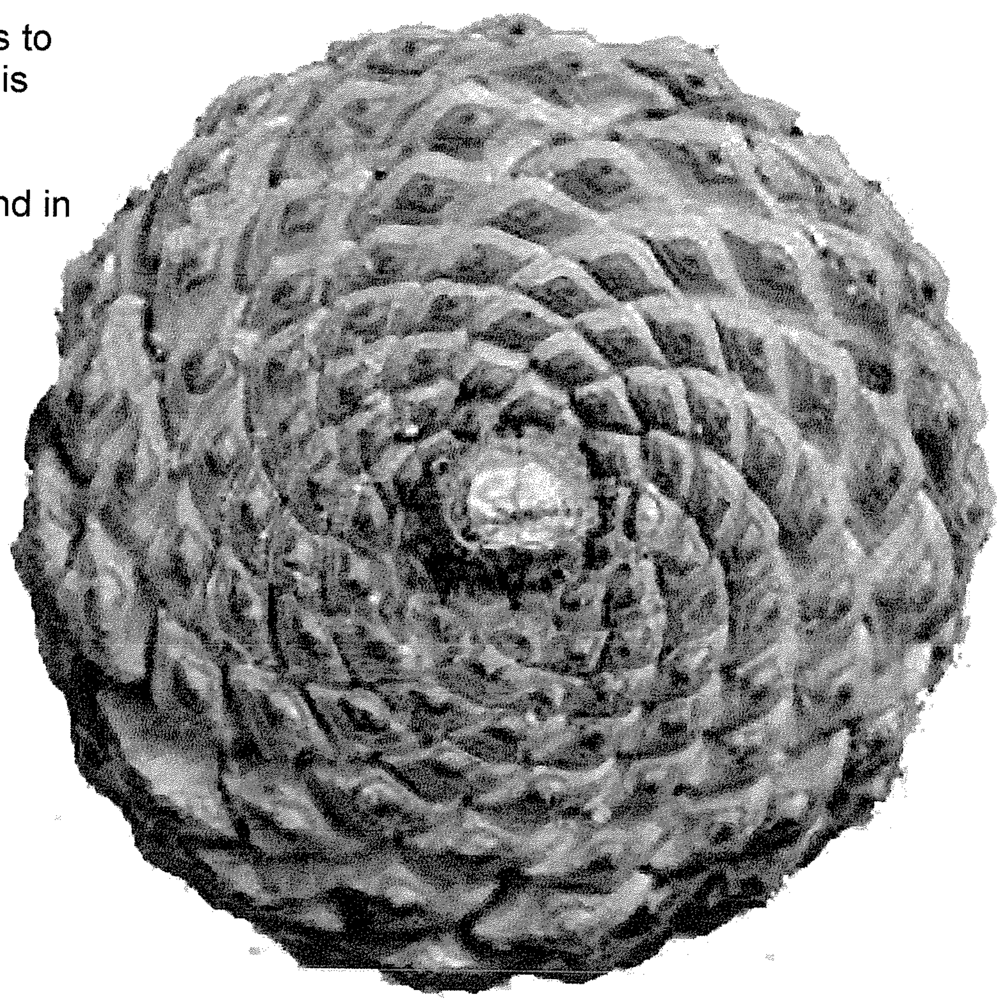

Counting Fibonacci numbers of spirals on a pinecone

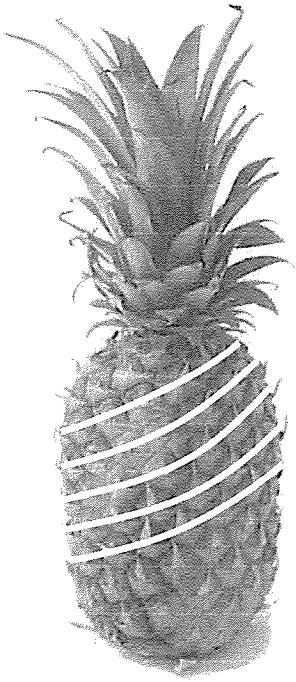


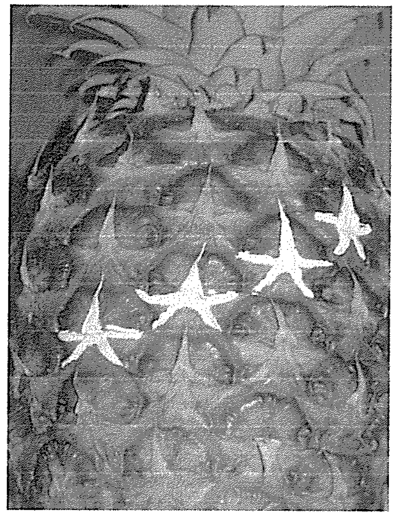


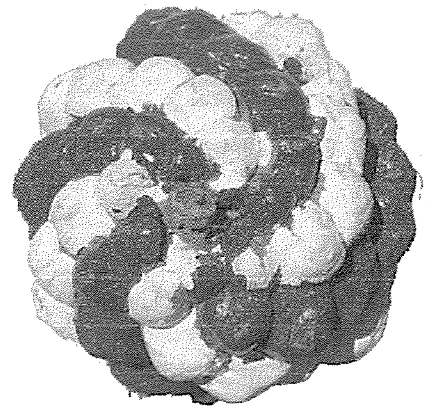
Use colored pencils to draw spirals on this pinecone.

How many do you find in each direction?

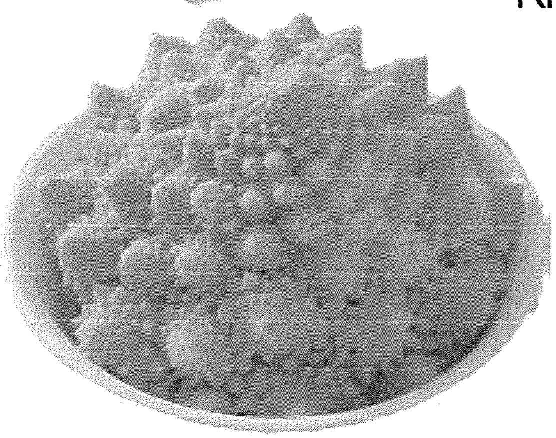


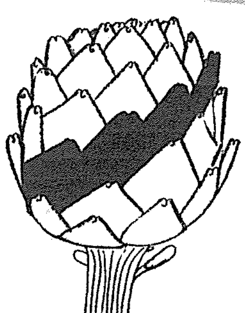


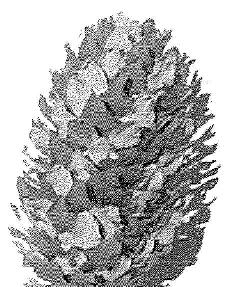


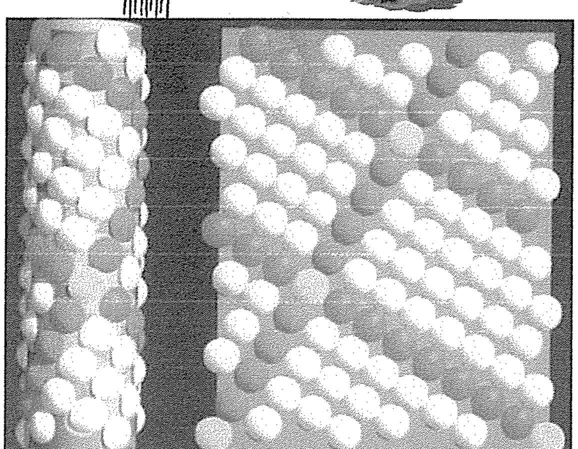


Fibonacci Numbers?







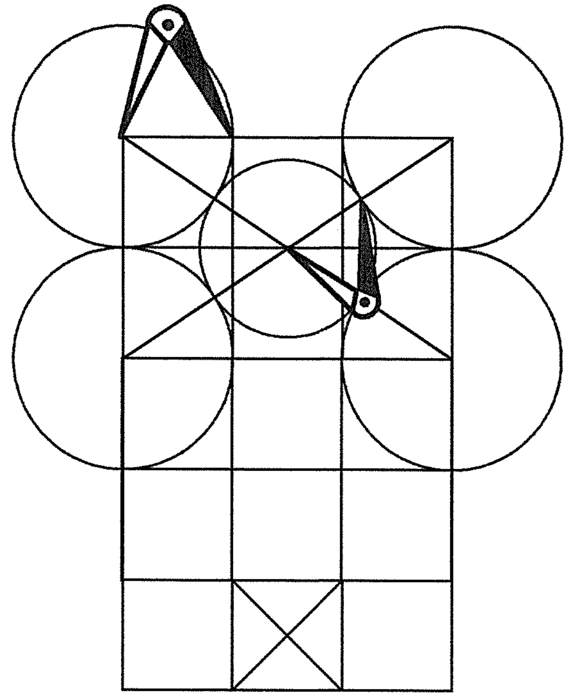


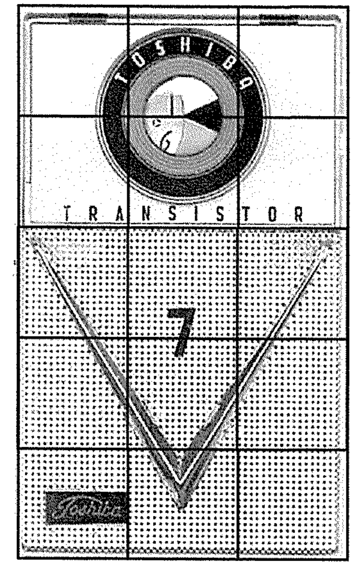
	Parallel Spiral Rows (Parastichies)	
	# Rows	# Rows
Pineapple		
Cauliflower		
Artichoke		
Asparagus		
Pinecone 1 (smallest)		
Pinecone 2		
Pinecone 3		
Potato		

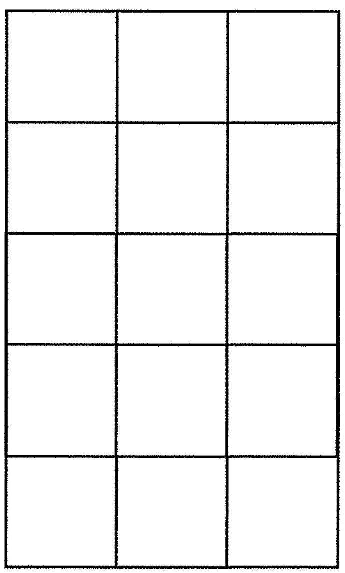
Both this early transistor radio and early model iPod were based on a 3x5 scheme.

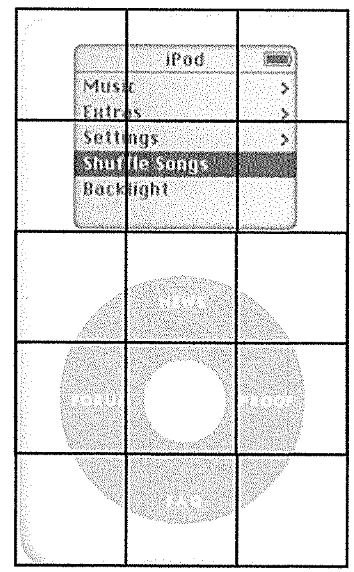
Use your compass to draw the four outer circles on them, and then the inner circle of each to see how they were designed.

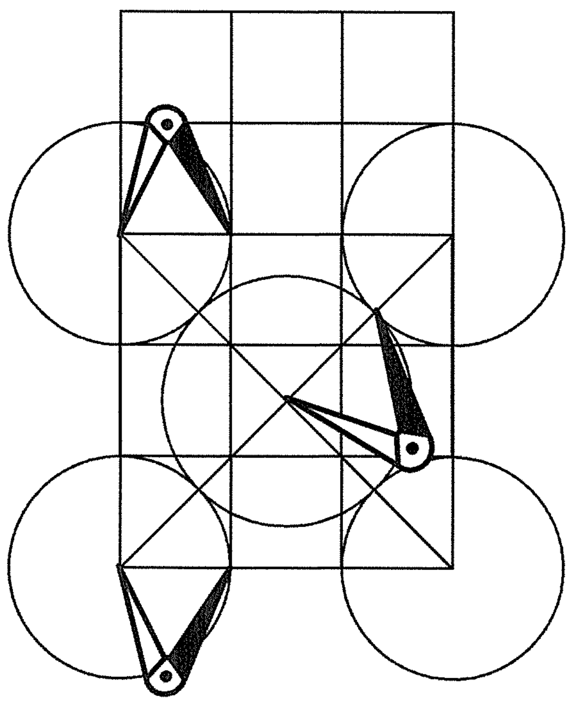
Then design your own device similarly using the blank 3x5 grid below. If you want to, design something using larger Fibonacci Numbers.





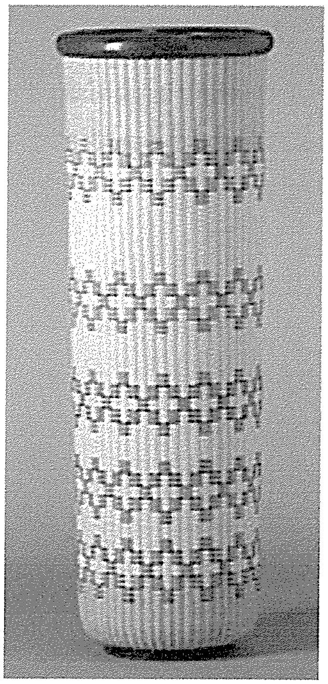




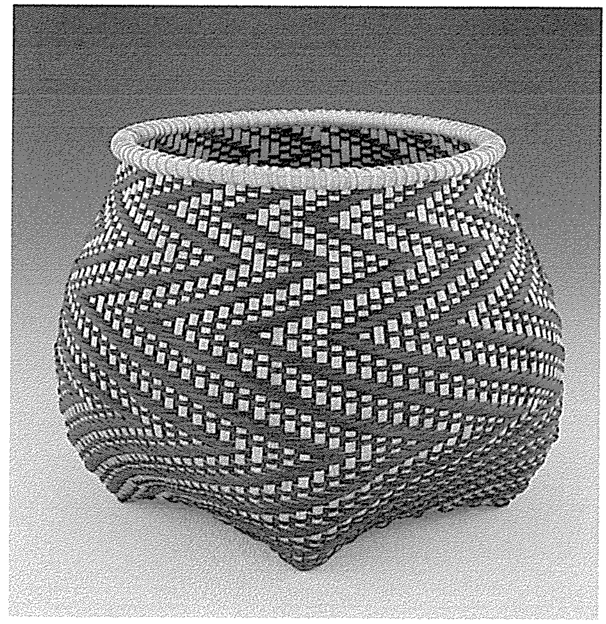


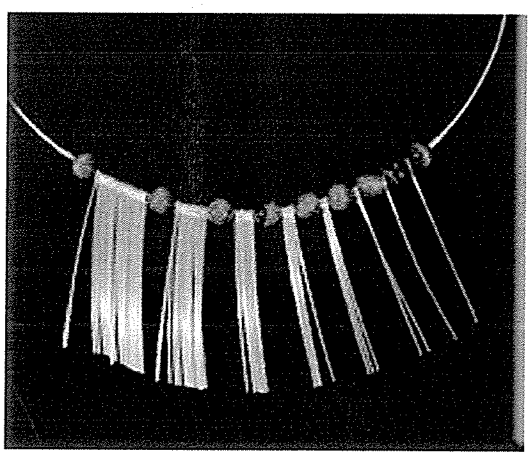
#87

Basket
Joan Brink



Basket
Billie Ruth Sudduth

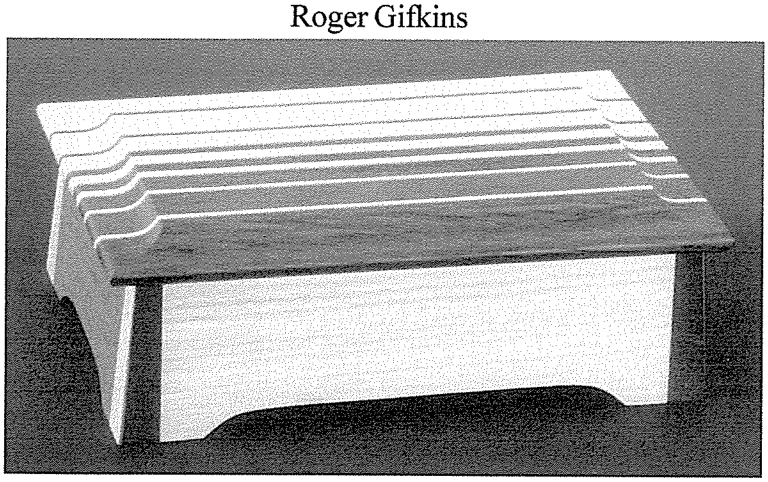




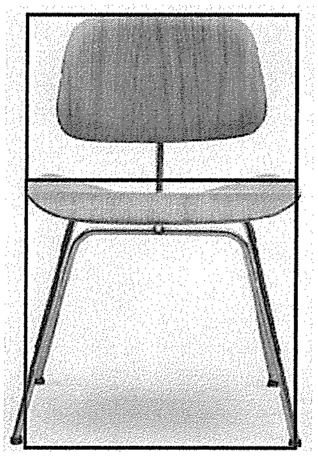
Neck Ring
Gretchen McPherson

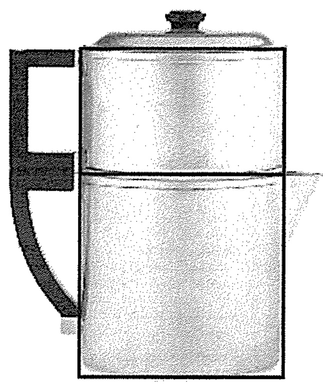
Chest
Stephen Mildenhall

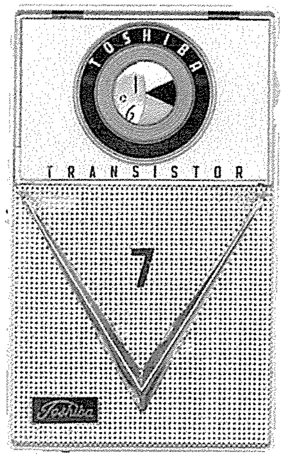
Box
Roger Gifkins



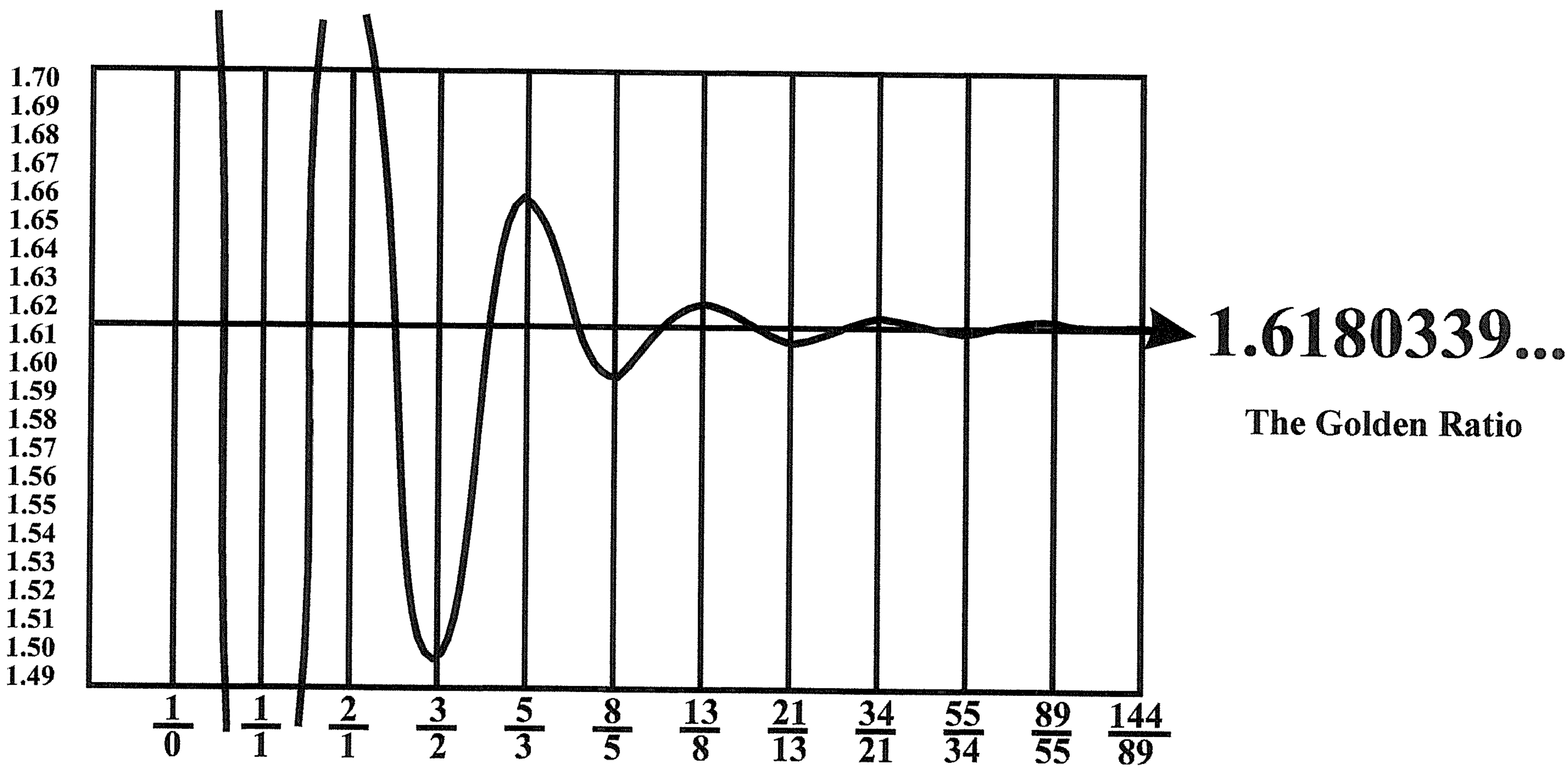
Golden Rectangle Symmetry







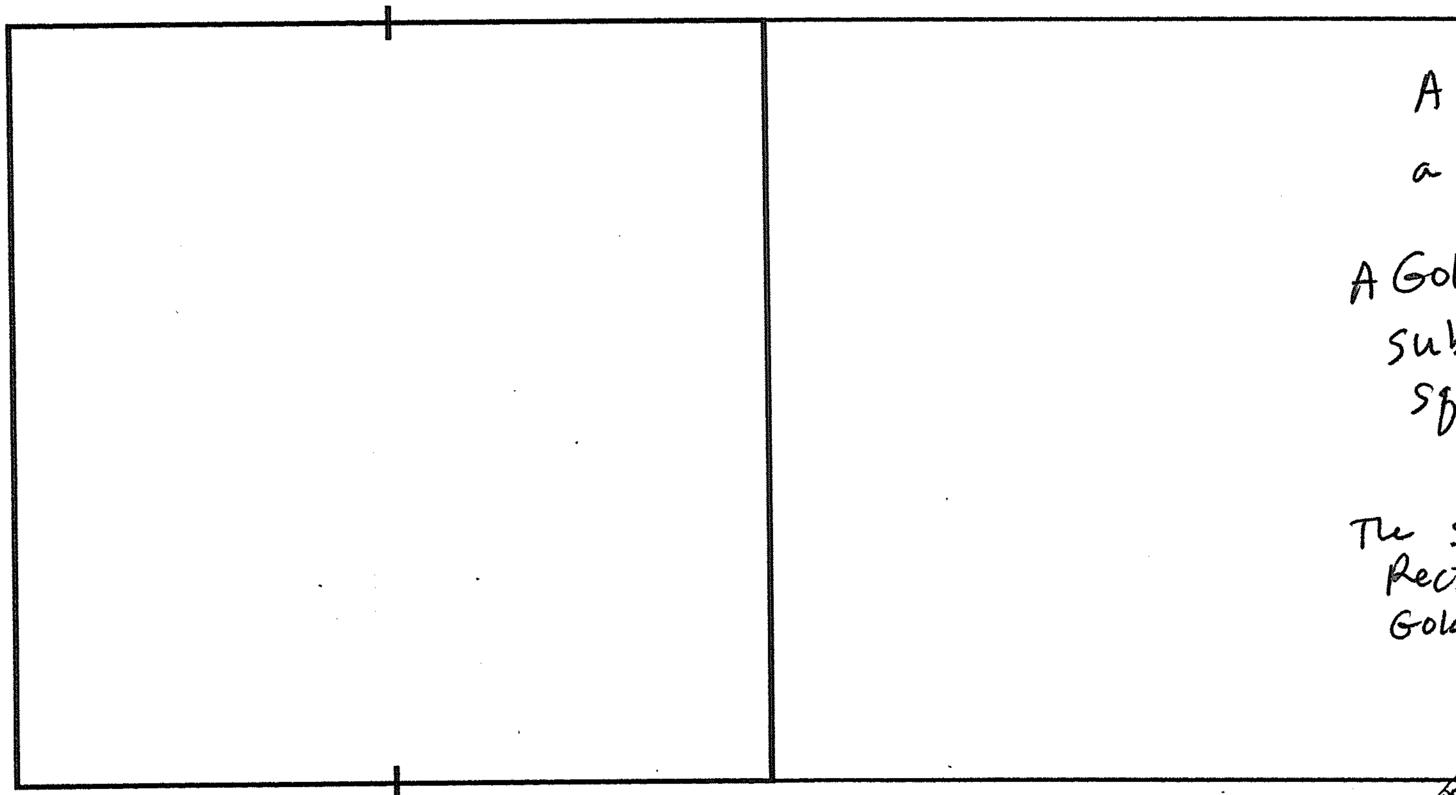
When consecutive Fibonacci Numbers are made into a series of fractions, they get closer and closer to the Golden Ratio.



90

Constructing a *Golden Rectangle* and *Spiral*

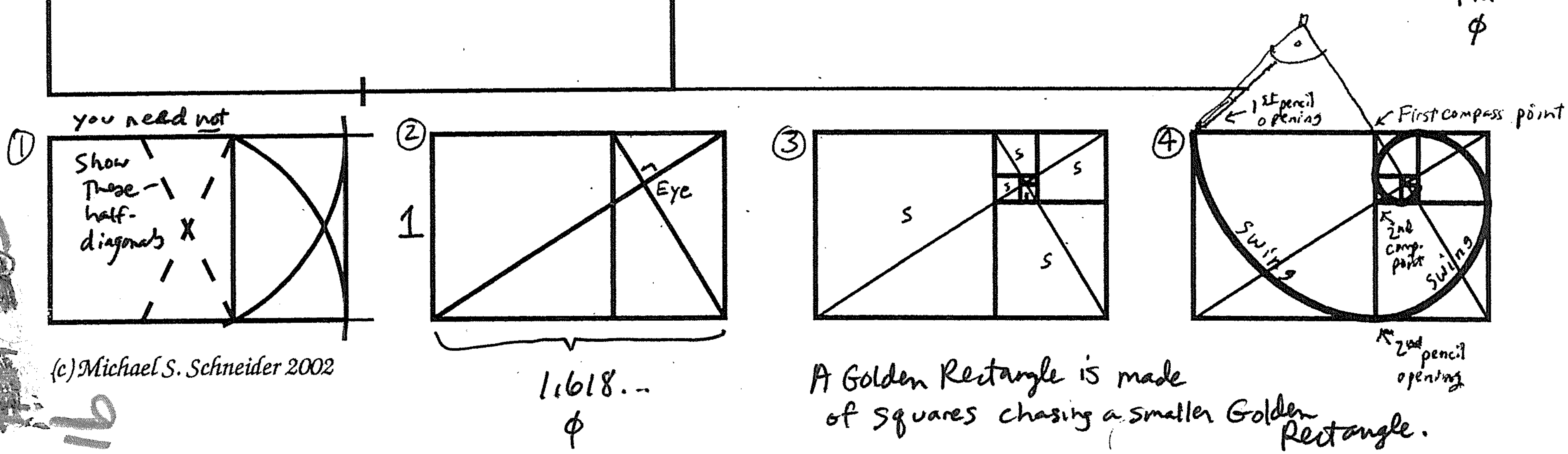
1) Place the compass point at the middle of the bottom side of this square, open it to the upper right corner, swing down to cross the line. Repeat at top and construct a Golden Rectangle.
2) Predict where the "eye" will be (show where the diagonal of the whole Golden Rectangle crosses the diagonal of the smaller GR).
3) With your compass, mark off a square in the smaller GR, and in each successively smaller GR.
4) Use your compass (from each square's corner) to construct a Spiral (actually a "pseudo-spiral").



A square Generates a Golden Rectangle.

A Golden Rectangle may be subdivided into a square + smaller Golden Rectangle.

The sides of a Golden Rectangle are in The Golden Ratio of 1.618... to 1 "Phi" ϕ



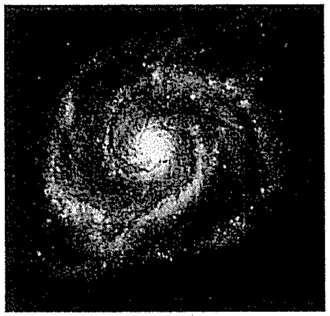
A Golden Rectangle is made of squares chasing a smaller Golden Rectangle.

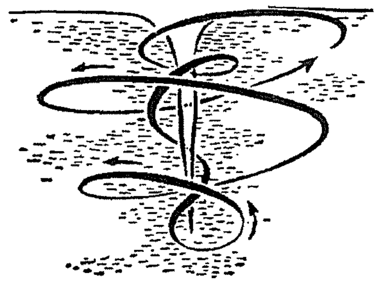
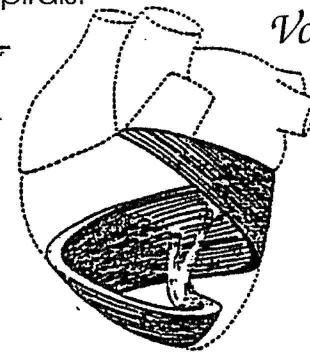
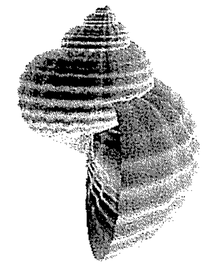
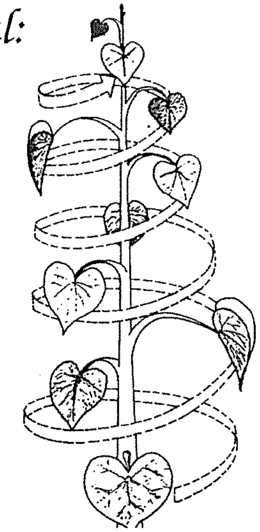
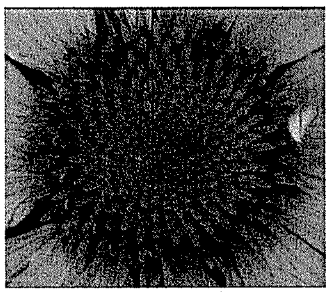
91

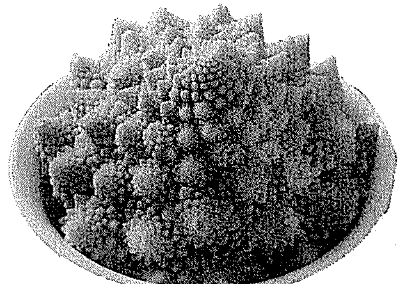
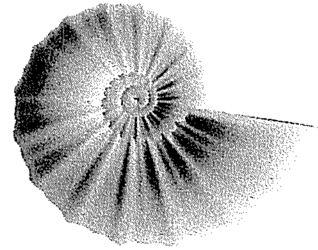
The Spiral Path shows us the harmonious resolution of conflict. Spiral growth occurs when opposites (complements) clash, meet resistamce and harmoniously balance by building self-similar parts into a whole.

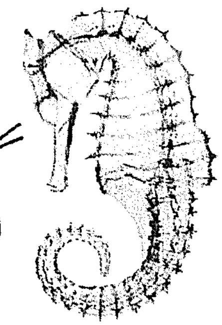
We *think* we live in a world of 'things' but we actually *function* in a world of dynamic energy.
When left alone, energy moves in spirals.

4 ways to see the Spiral:
Whirlpool
Wave
Mushroom rings
Vortex Street

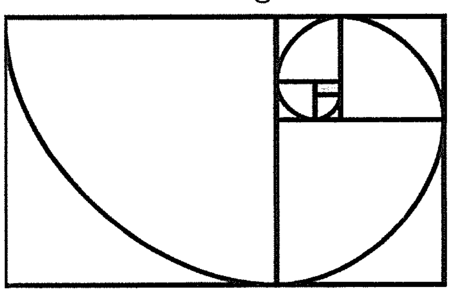
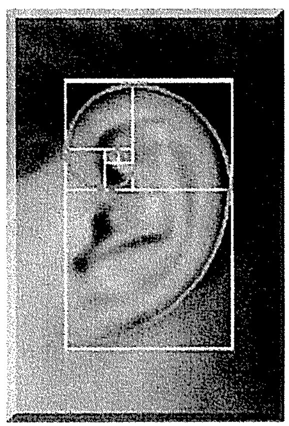
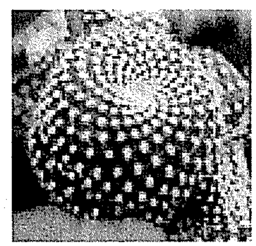


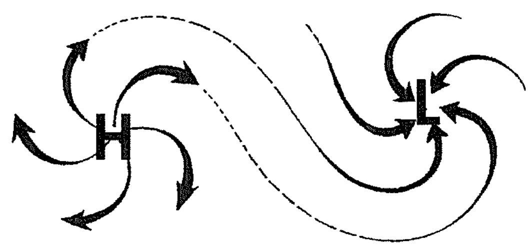








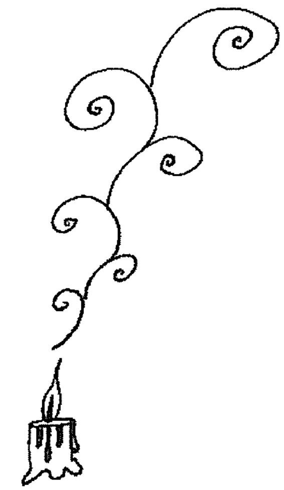
Rational squares endlessly chase irrational Golden Rectangles

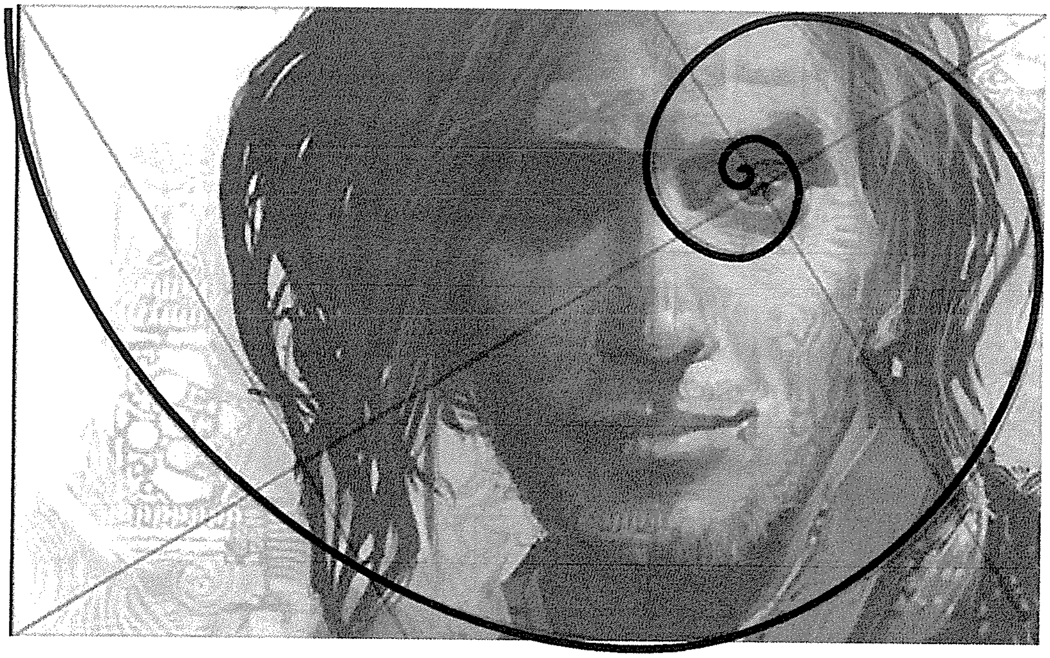




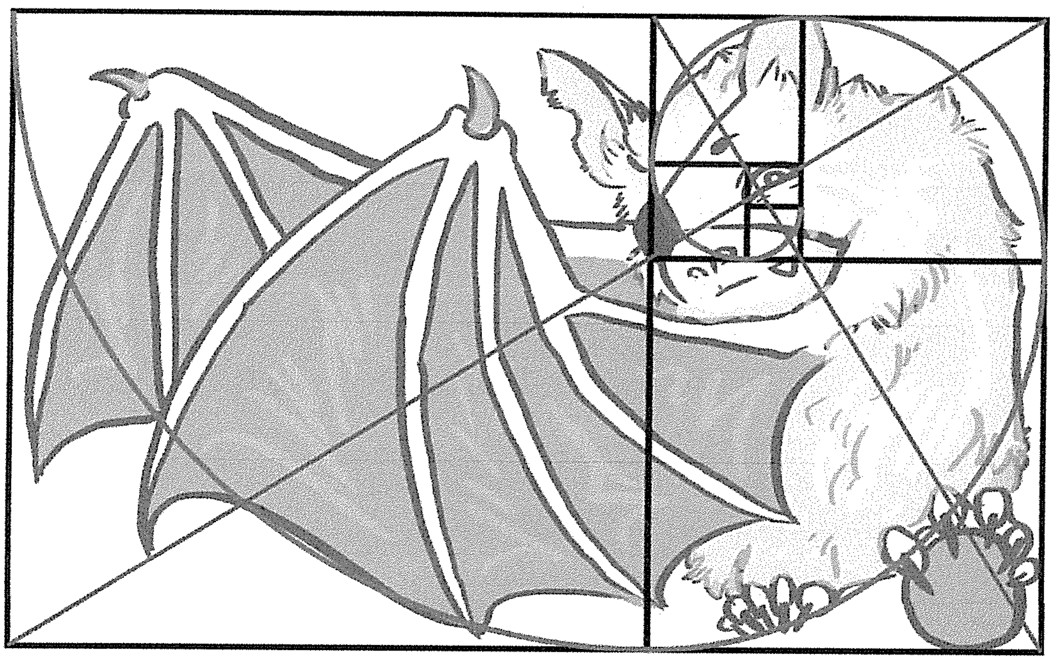


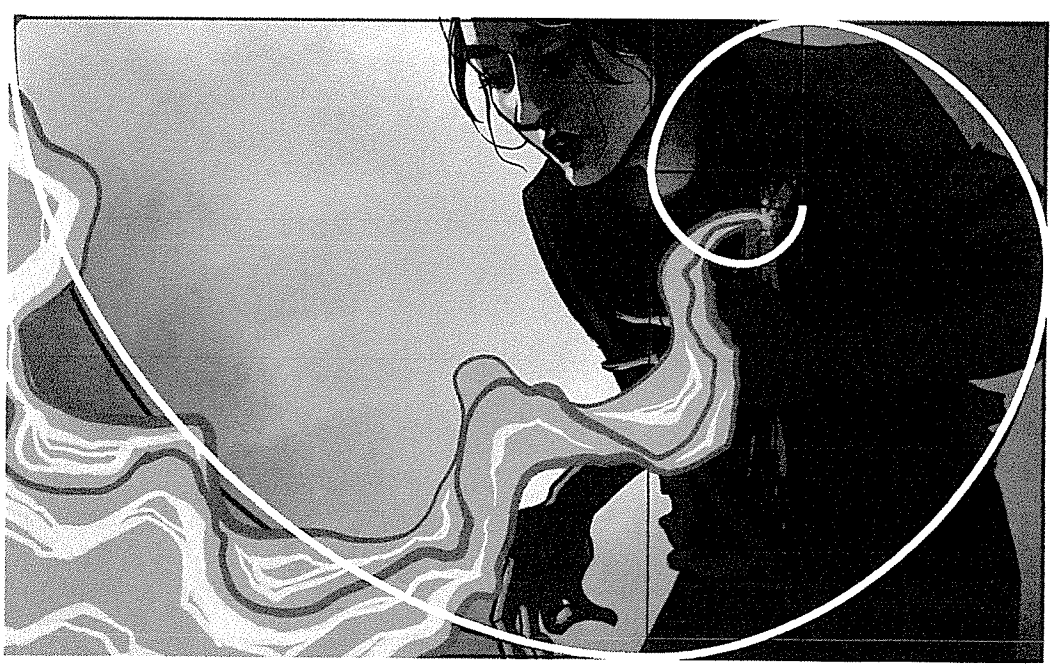
Weather pressure systems

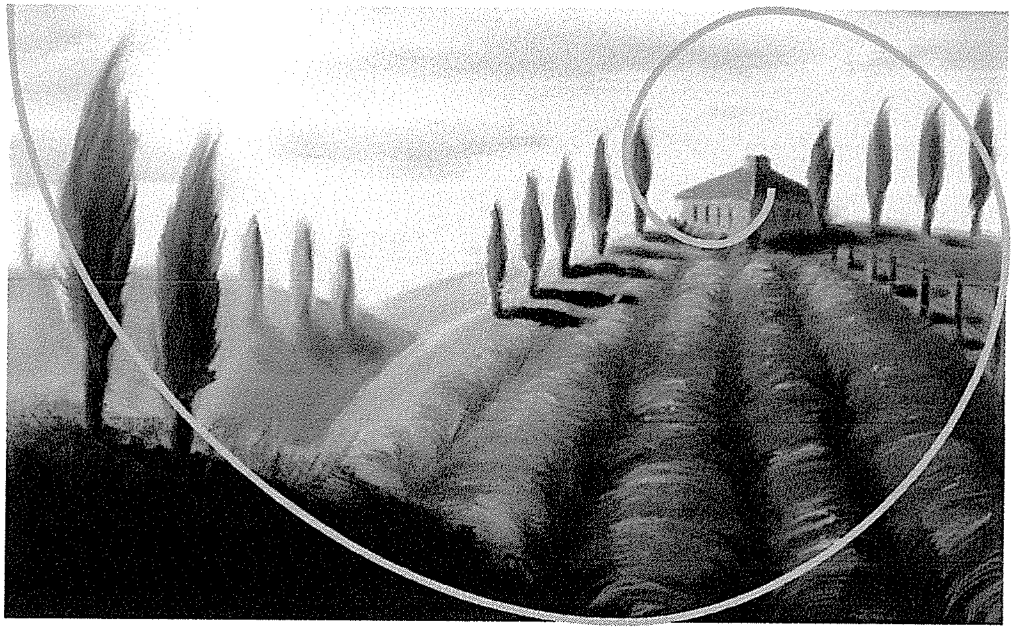
Plants: Oldest at bottom
Smoke: Oldest at top

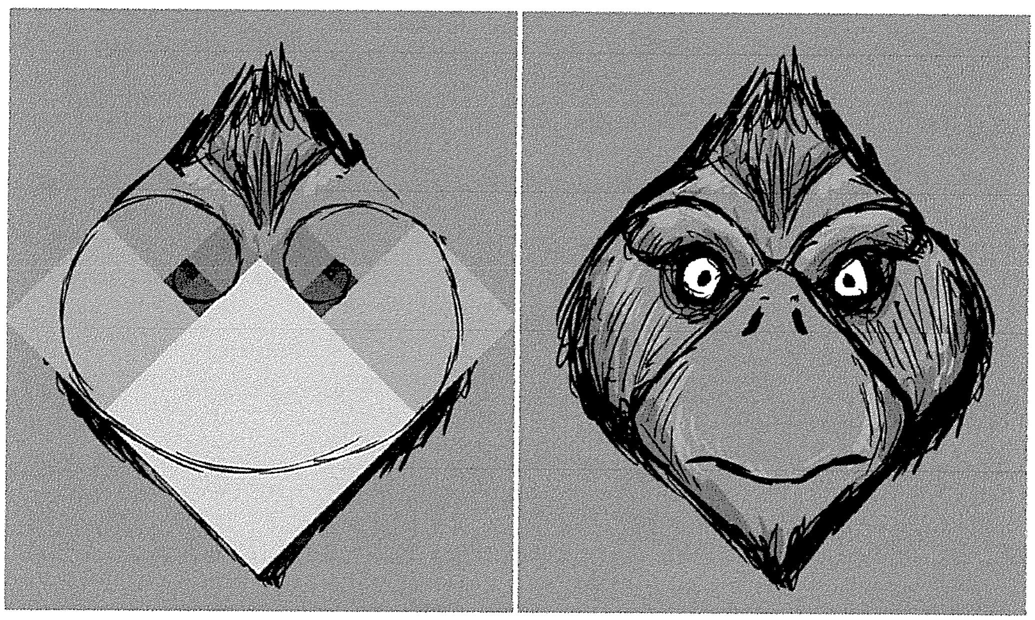



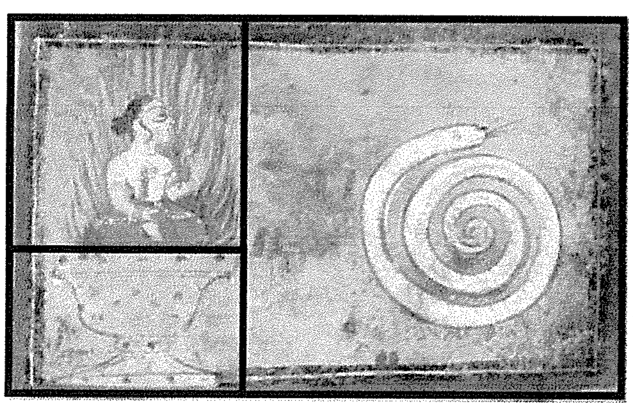


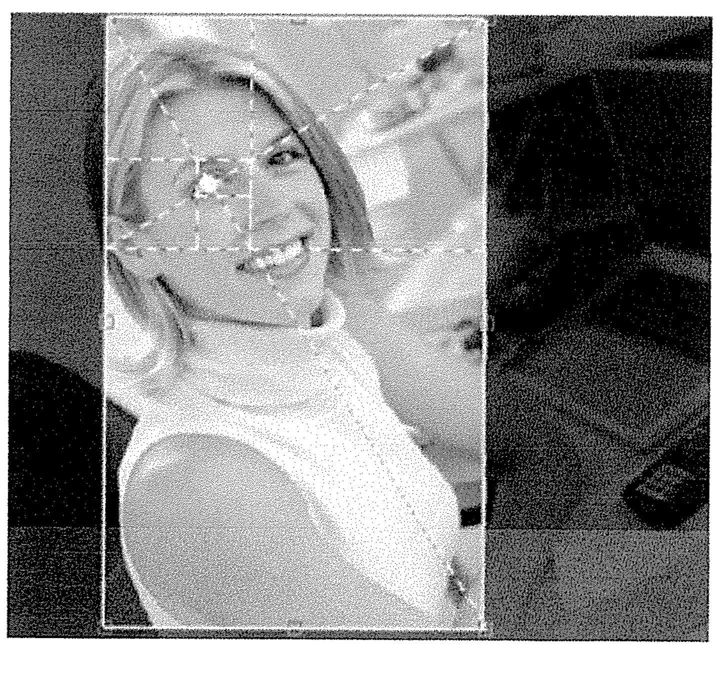










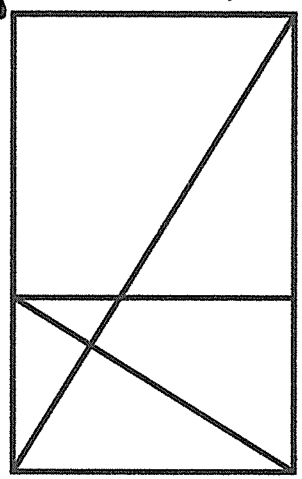


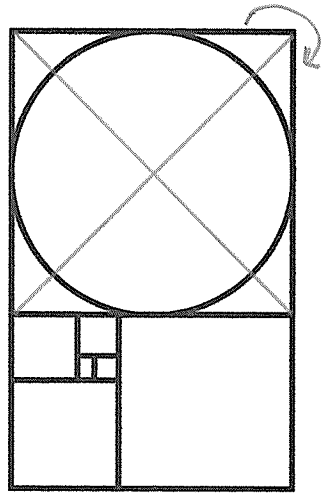
November

The Book of Hours
of the Duke du Berry

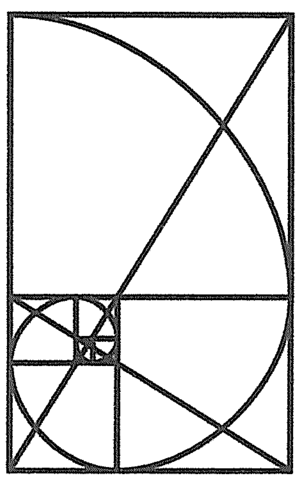
Designed & painted
by Limbourg Brothers

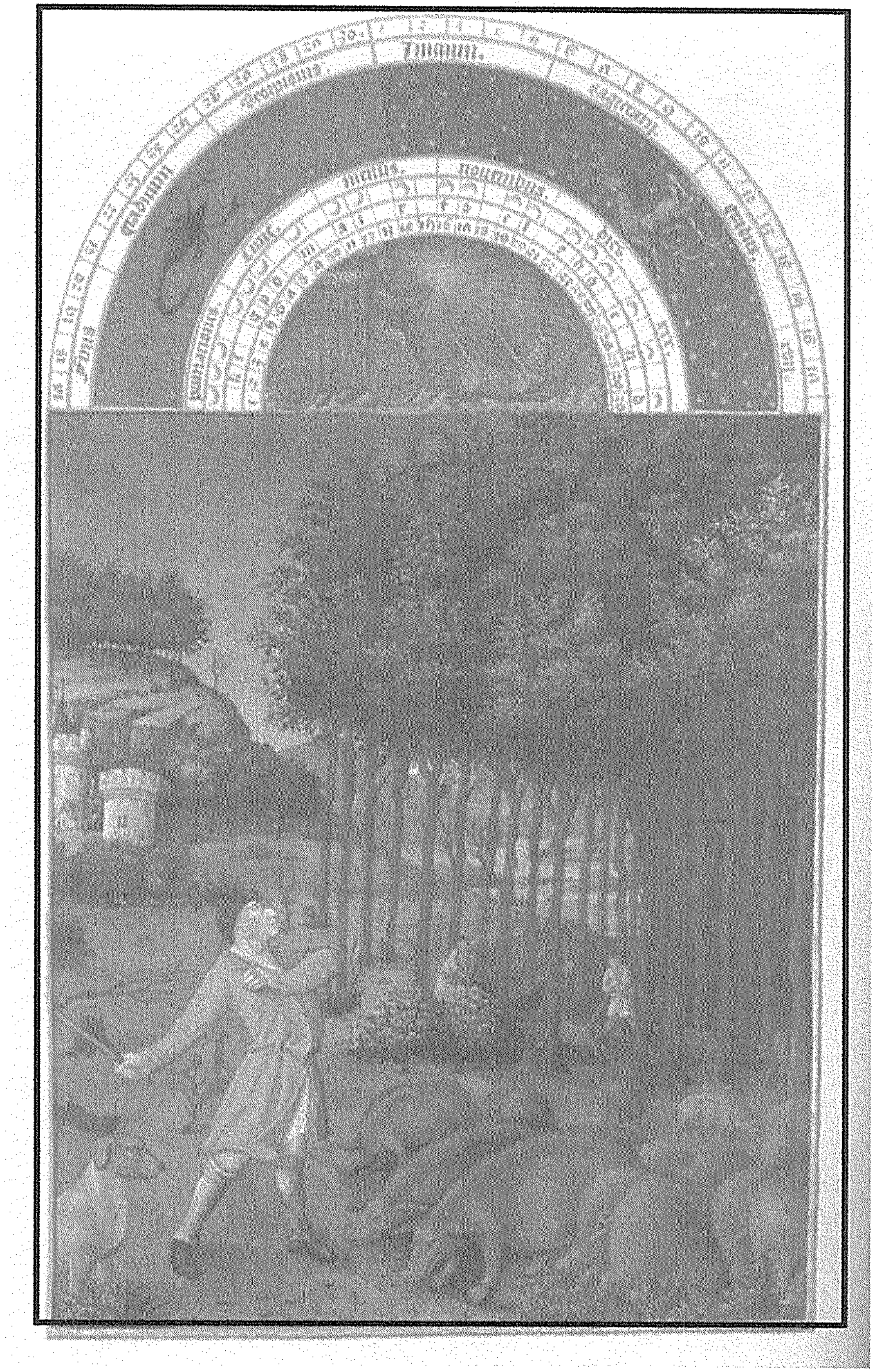
Start by constructing This square
from The short side





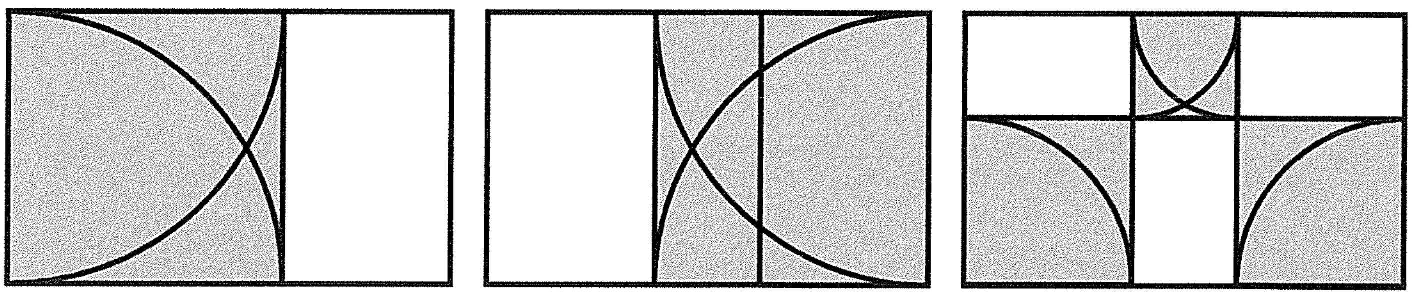
What did The
artist want
to call our
attention to
at The
spiral's
eye?

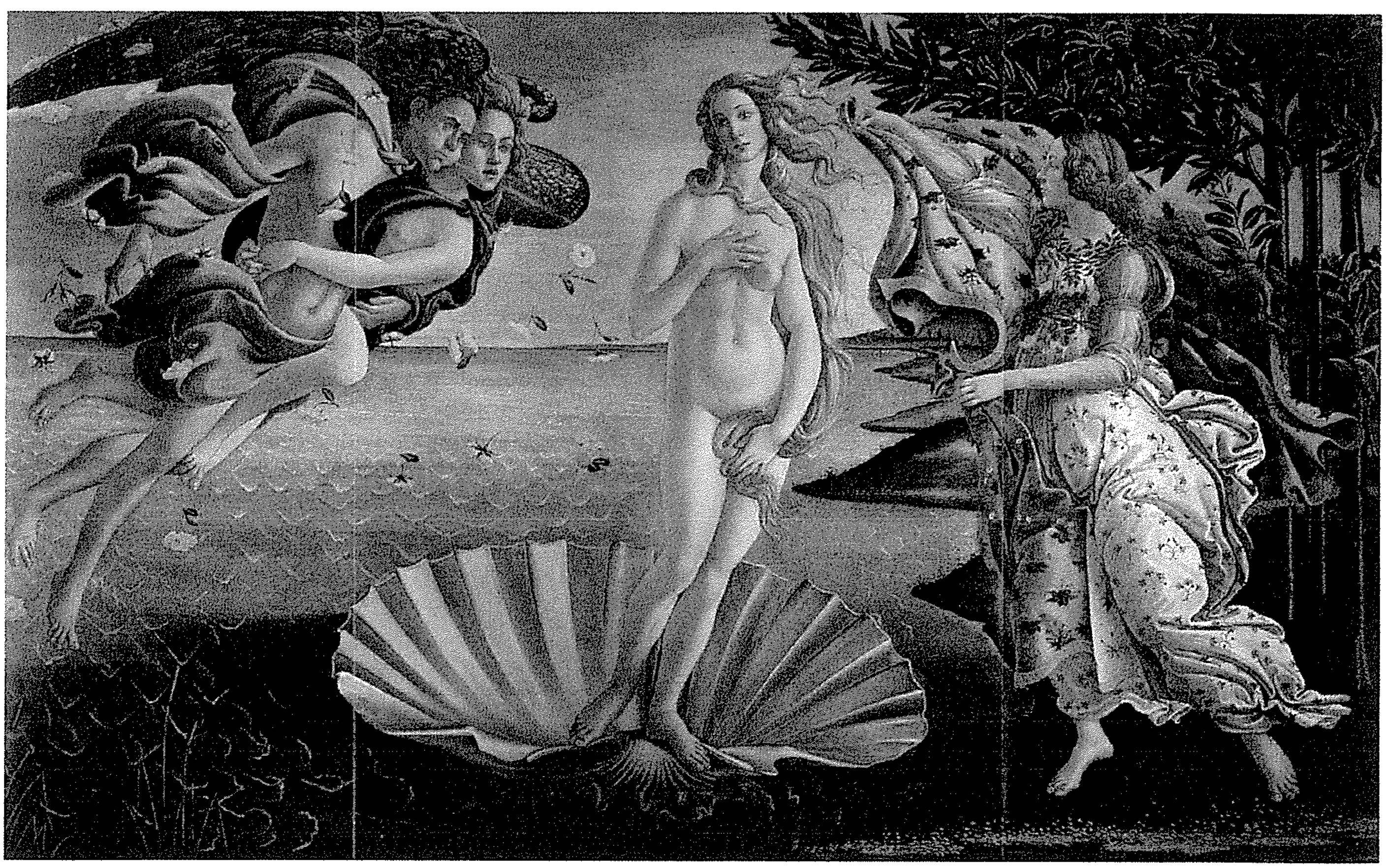




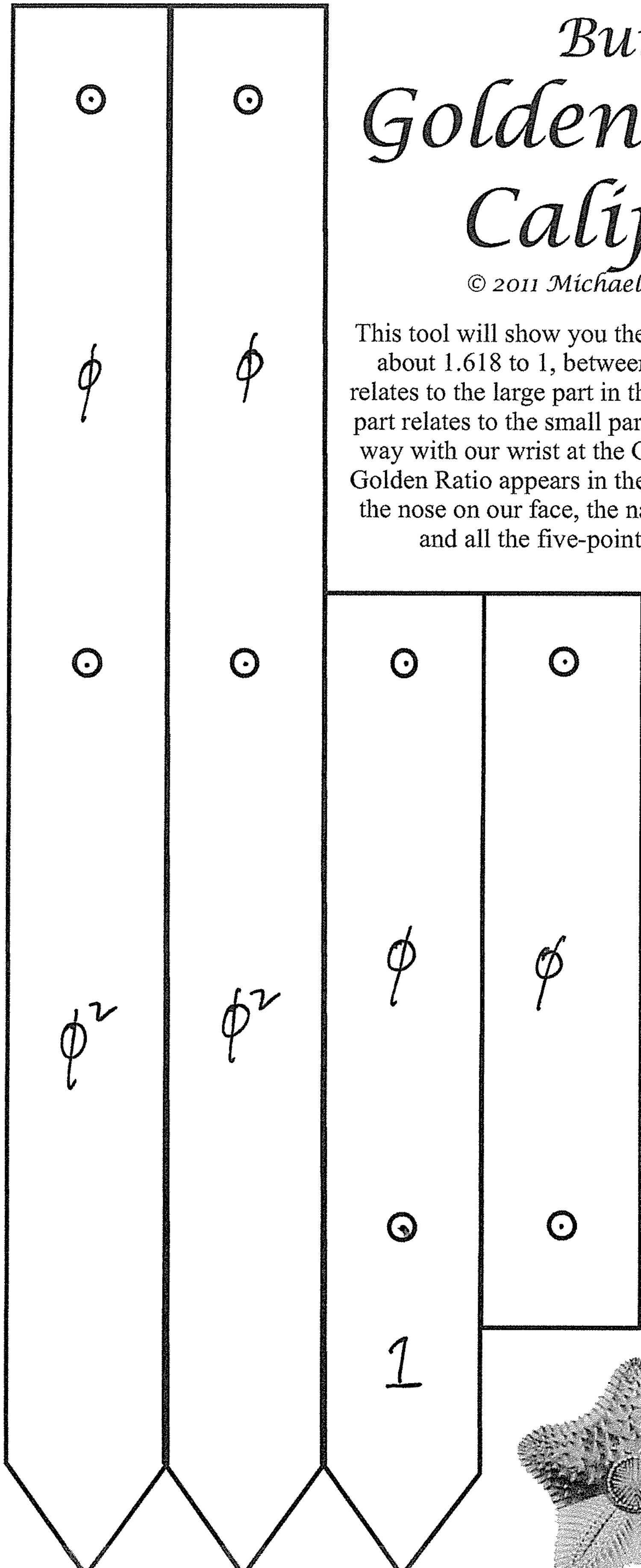
The Birth of Venus
Botticelli

It was designed as a Golden Rectangle.
To see how it was used, construct a square inside each end.
Construct smaller squares in the rectangles as shown
to reveal the horizon and her navel.
Drawing diagonals and squares, can you find more?



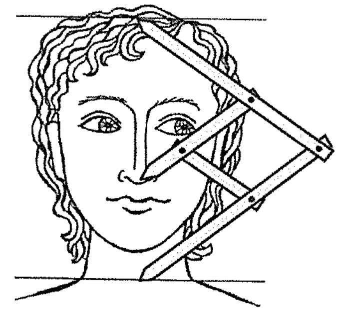


Golden Rectangle typeface

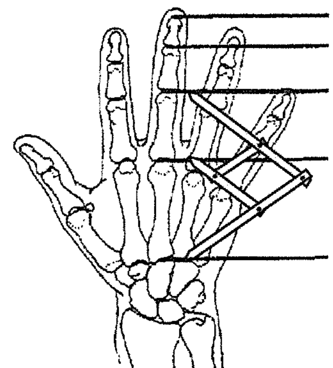


Build Golden Ratio Calipers

© 2011 *Michael S. Schneider*



This tool will show you the famous **Golden Ratio,** about 1.618 to 1, between its points: the whole relates to the large part in this ratio, just as the large part relates to the small part. Your arm is made this way with our wrist at the Golden Ratio point. The Golden Ratio appears in the bones of our fingers, at the nose on our face, the navel of our whole body, and all the five-pointed stars in nature.



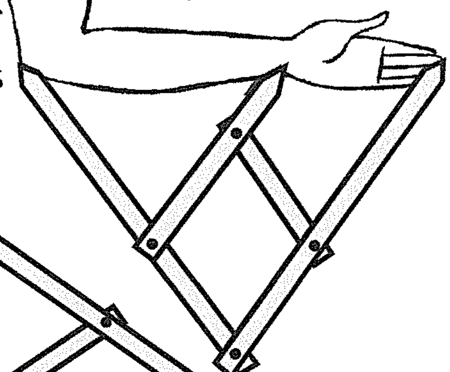
$\phi \approx 1.618...$

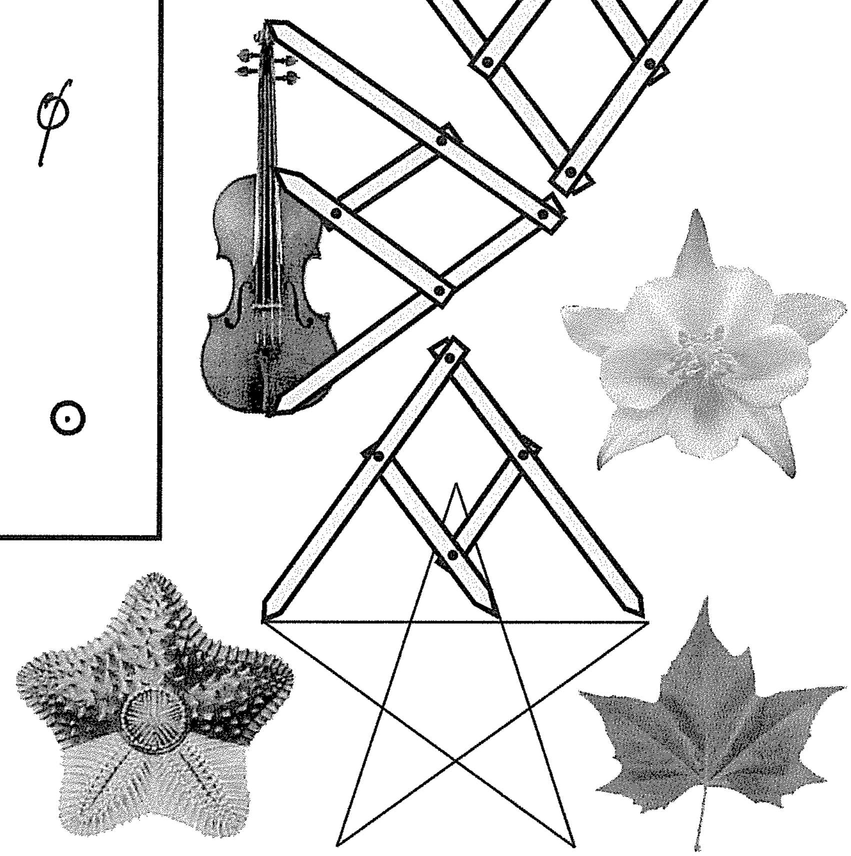
$\phi^2 \approx 2.618...$

measured between centers of holes

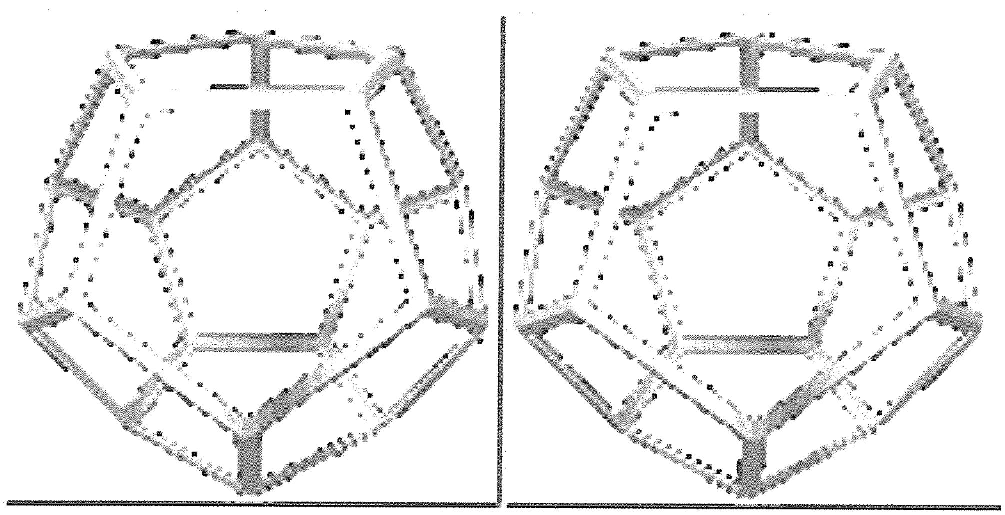
Cut out the four strips.

Punch holes to put fasteners through so it looks like this.



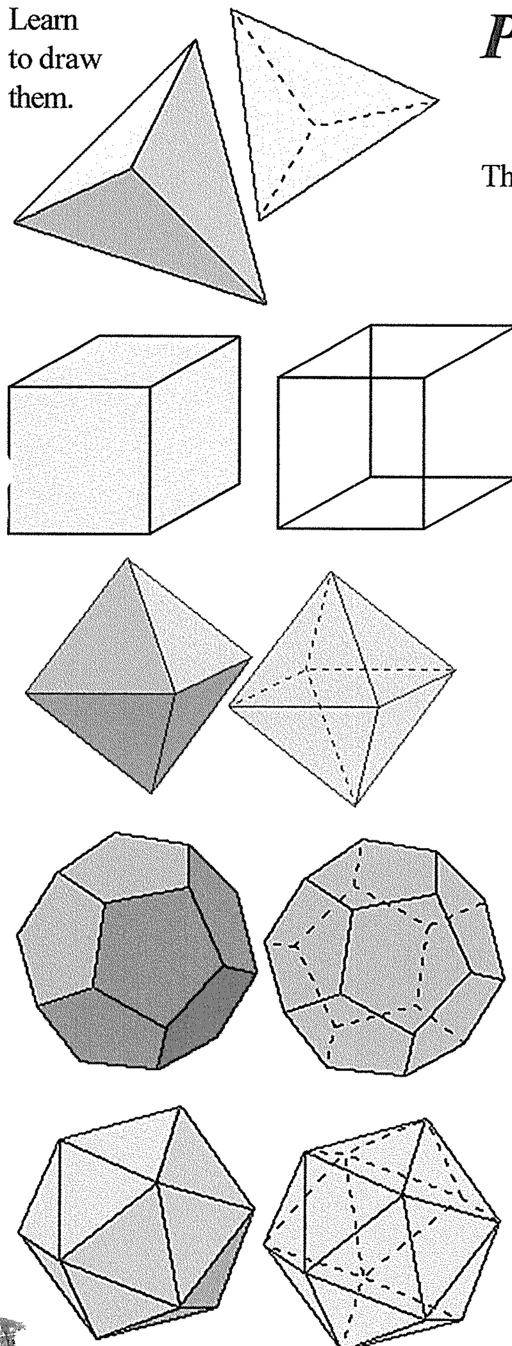


The Platonic Solids



Stare at these two images until a third appears between them
which will seem to be 3-dimensional.

Learn
to draw
them.



Platonic Solids

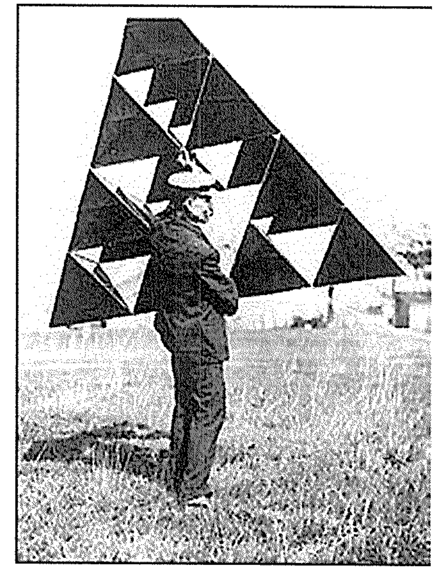
also called:

Regular Polyhedra ("many faces" or "many seats")

They show the only five ways to divide 3-D space equally in all directions.

In three dimensions there are just **five** regular polyhedra:

Tetrahedron -	made of 4 equilateral triangles
Hexahedron (Cube) -	made of 6 squares
Octahedron -	made of 8 equilateral triangles
Dodecahedron -	made of 12 regular pentagons
Icosahedron -	made of 20 equilateral triangles



A.G. Bell
TetraKite

They are "Regular" polyhedra, so everything's *equal*:

- All vertices are equal distance from the center.
- All edges are equal length.
- All faces are identical regular polygons, having identical shape and same area.
- A Platonic Solid looks the same when viewed from any vertex, edge or face.
- All together create a convex solid enclosing three-dimensional space.

Euler's Formula:
 # Faces + # Vertices = # Edges + 2

not necessary to memorize

Animal Virus Structure

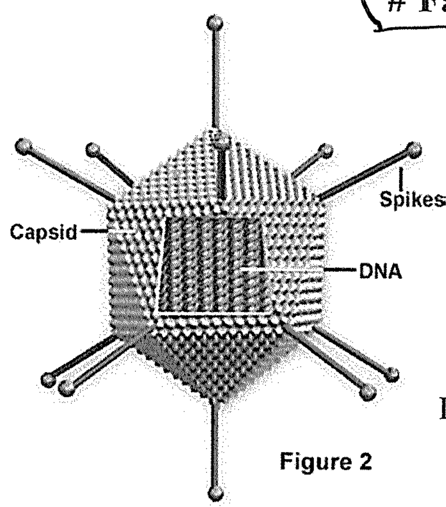
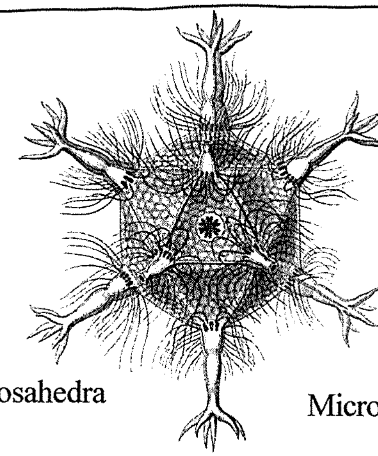
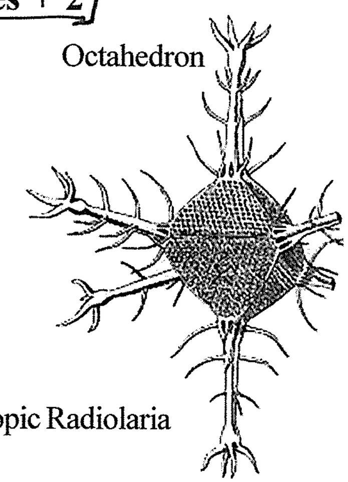


Figure 2



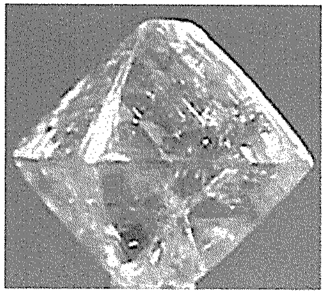
Icosahedra

Octahedron

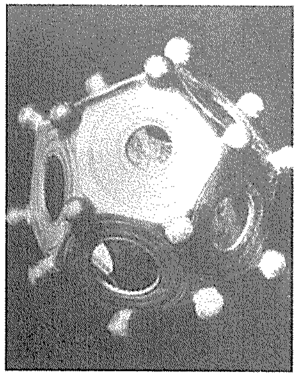


Microscopic Radiolaria

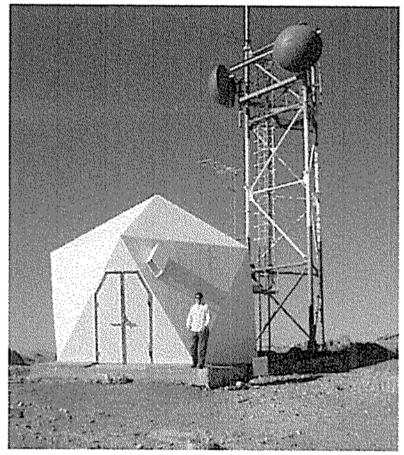
Match these natural and invented objects with the type of Platonic Solid it is based upon:
(Write the name of the Platonic Solid under each)



Diamond crystal

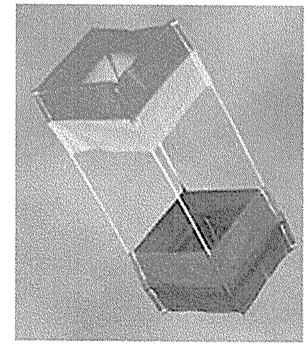


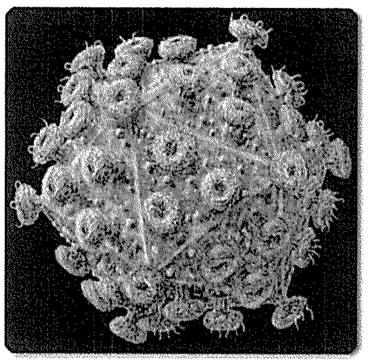
Etruscan (Roman) dice



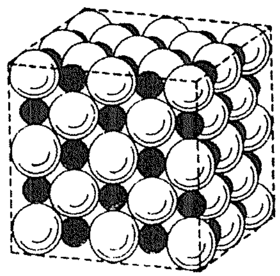
Microwave station

Kites

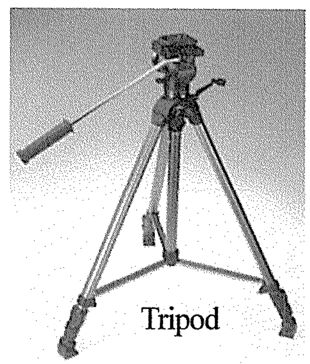




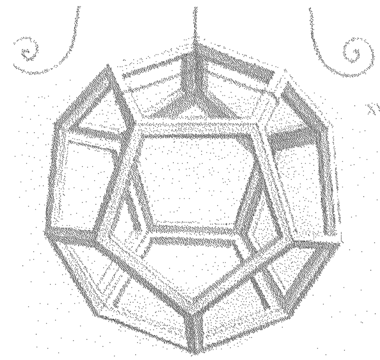
Virus



Salt (Sodium Chloride
NaCl)

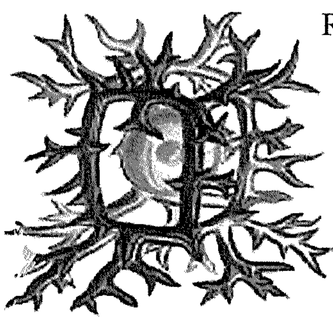


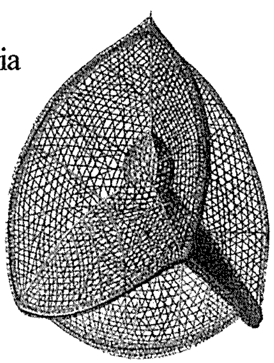
Tripod

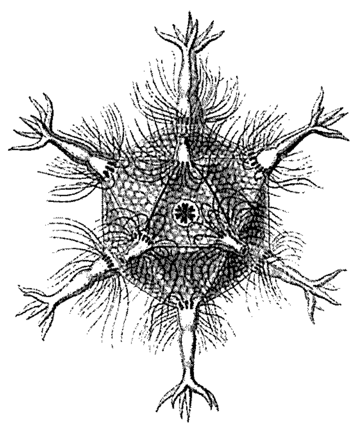


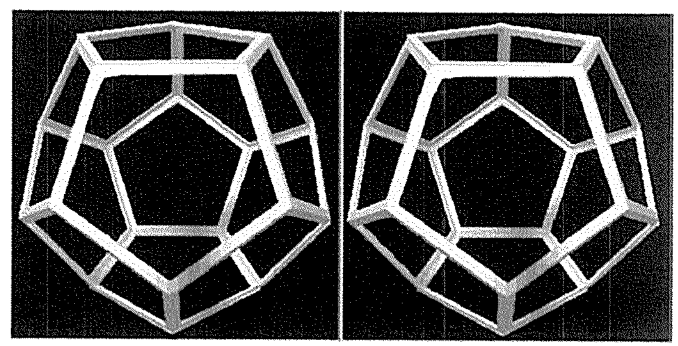
Leonardo da Vinci
drawing

Radiolaria









Stare at these until a 3-D image forms inbetween them

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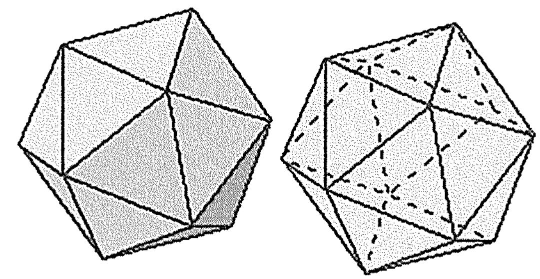
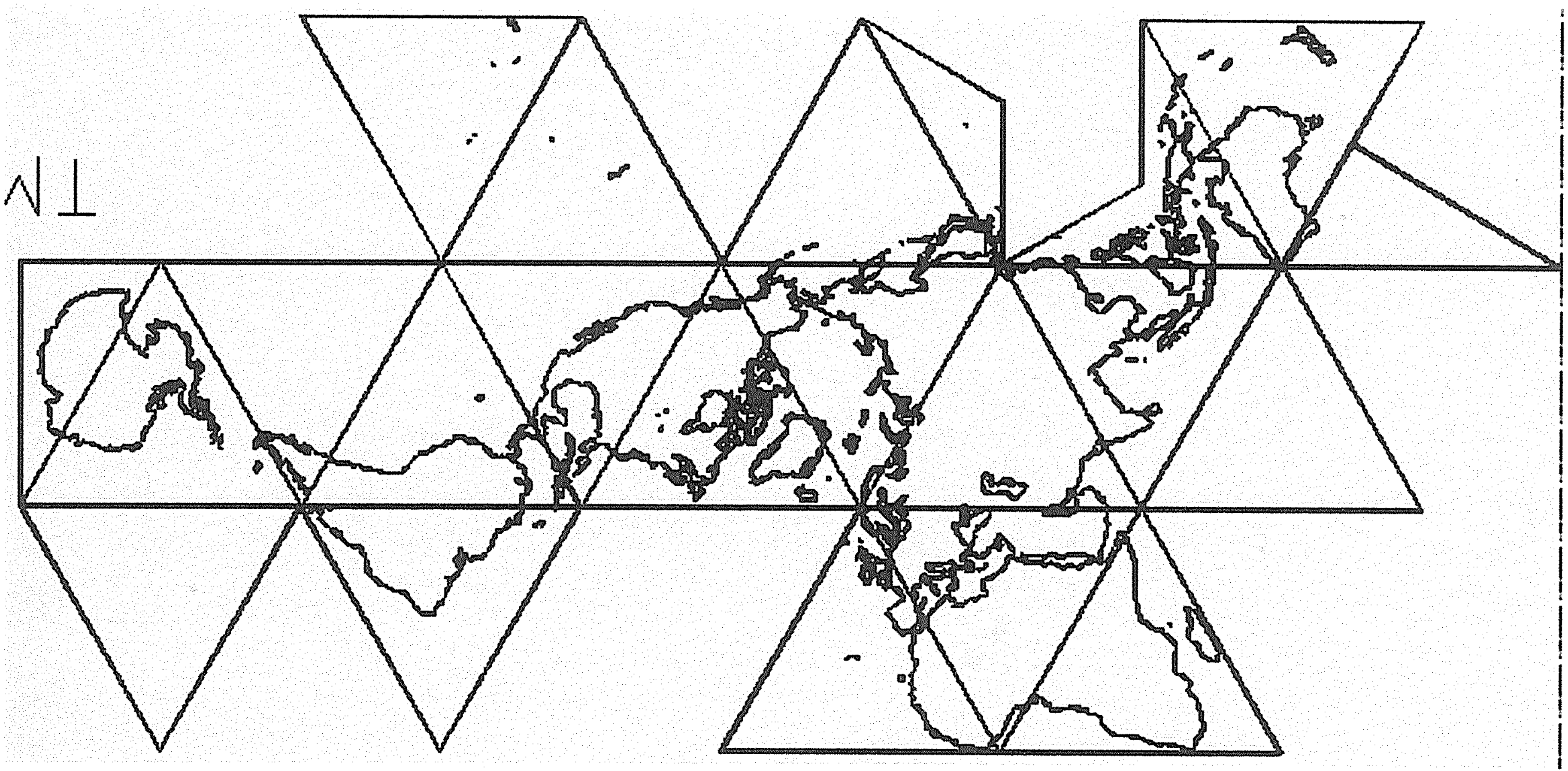
The Dymaxion Projection Map
by Buckminster Fuller



It is the only flat map showing the entire Earth at once, with its land masses in their true contour and proportion.

It can be folded to become the 20 equilateral triangles of an Icosahedron.



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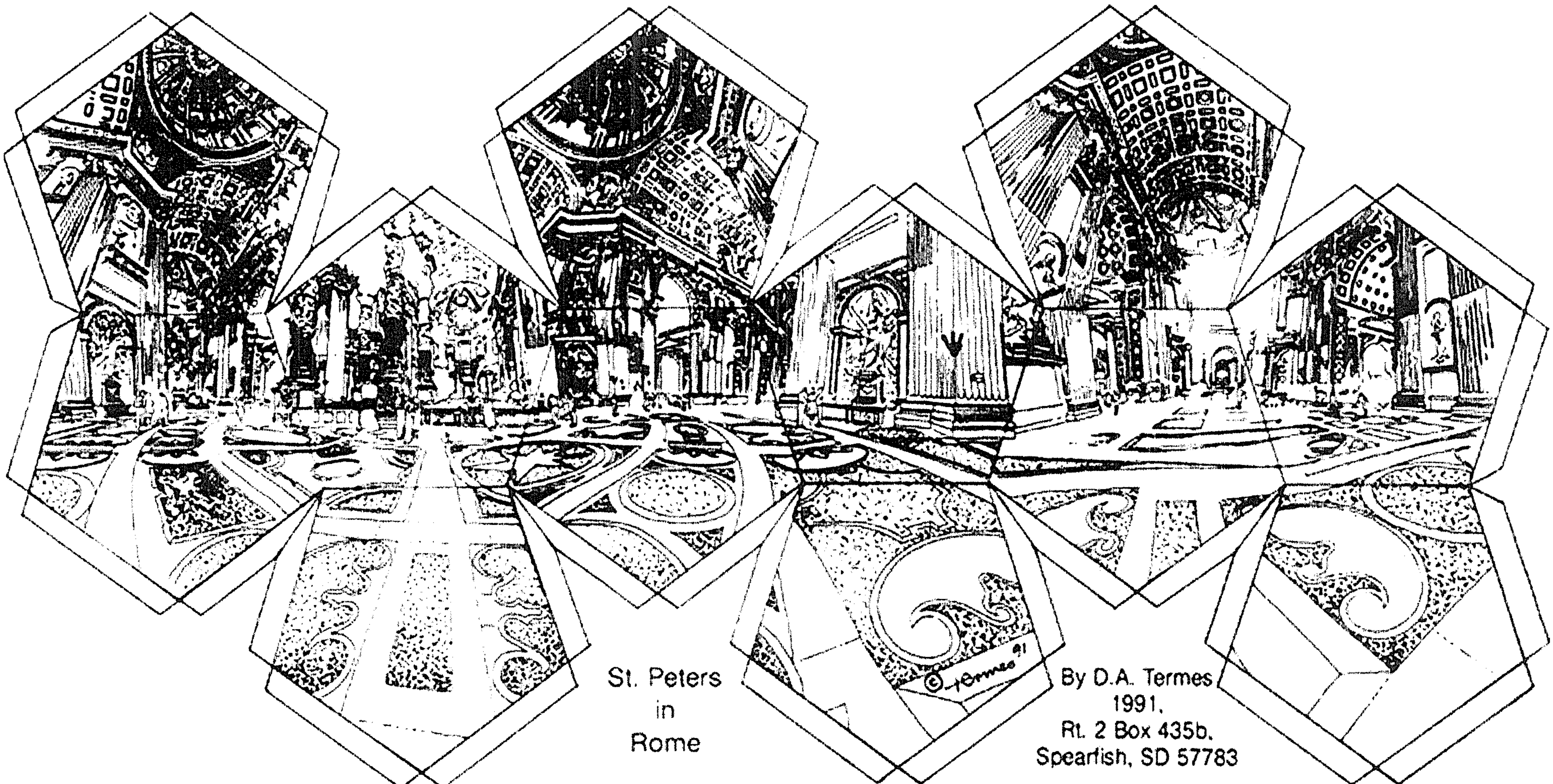

St. Peters
in
Rome

By D.A. Termes
1991,
Rt. 2 Box 435b.
Spearfish, SD 57783

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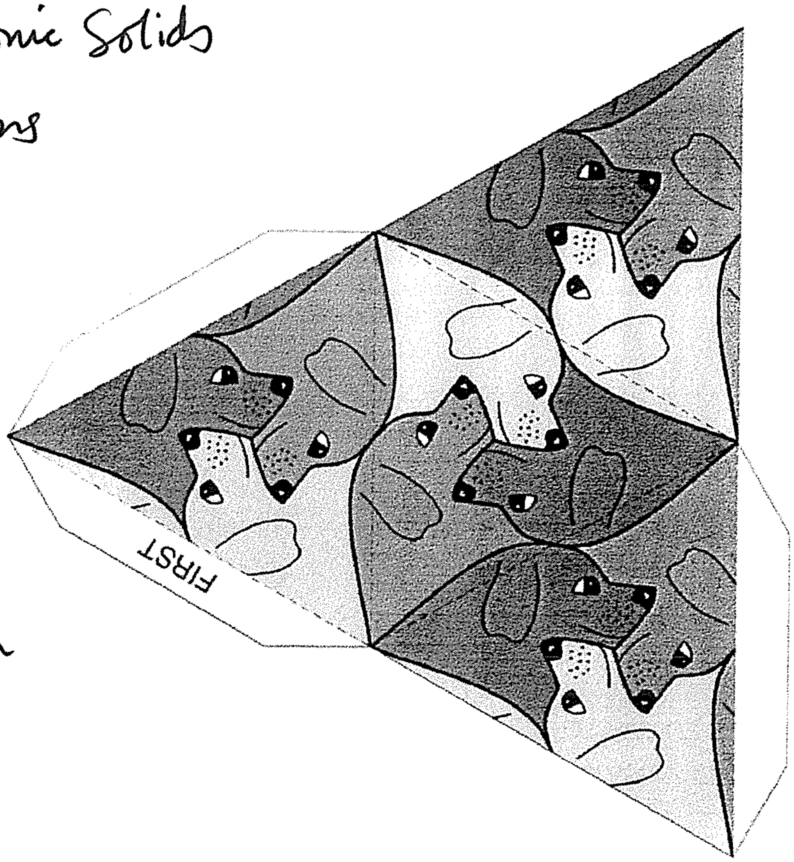
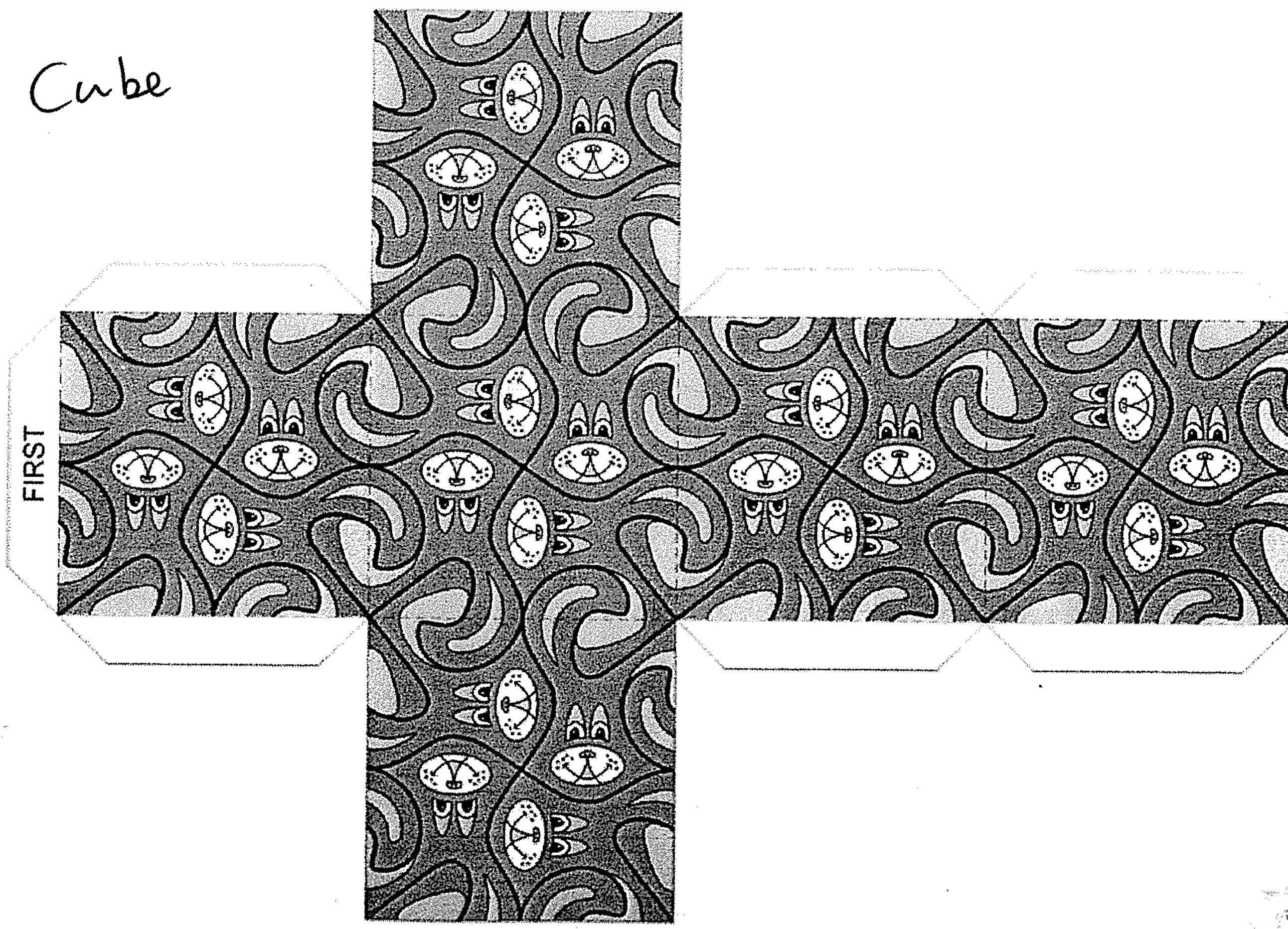
Extra Credit

Cut, Fold & Connect These Platonic Solids Tessellations



Tetrahedron

Cube



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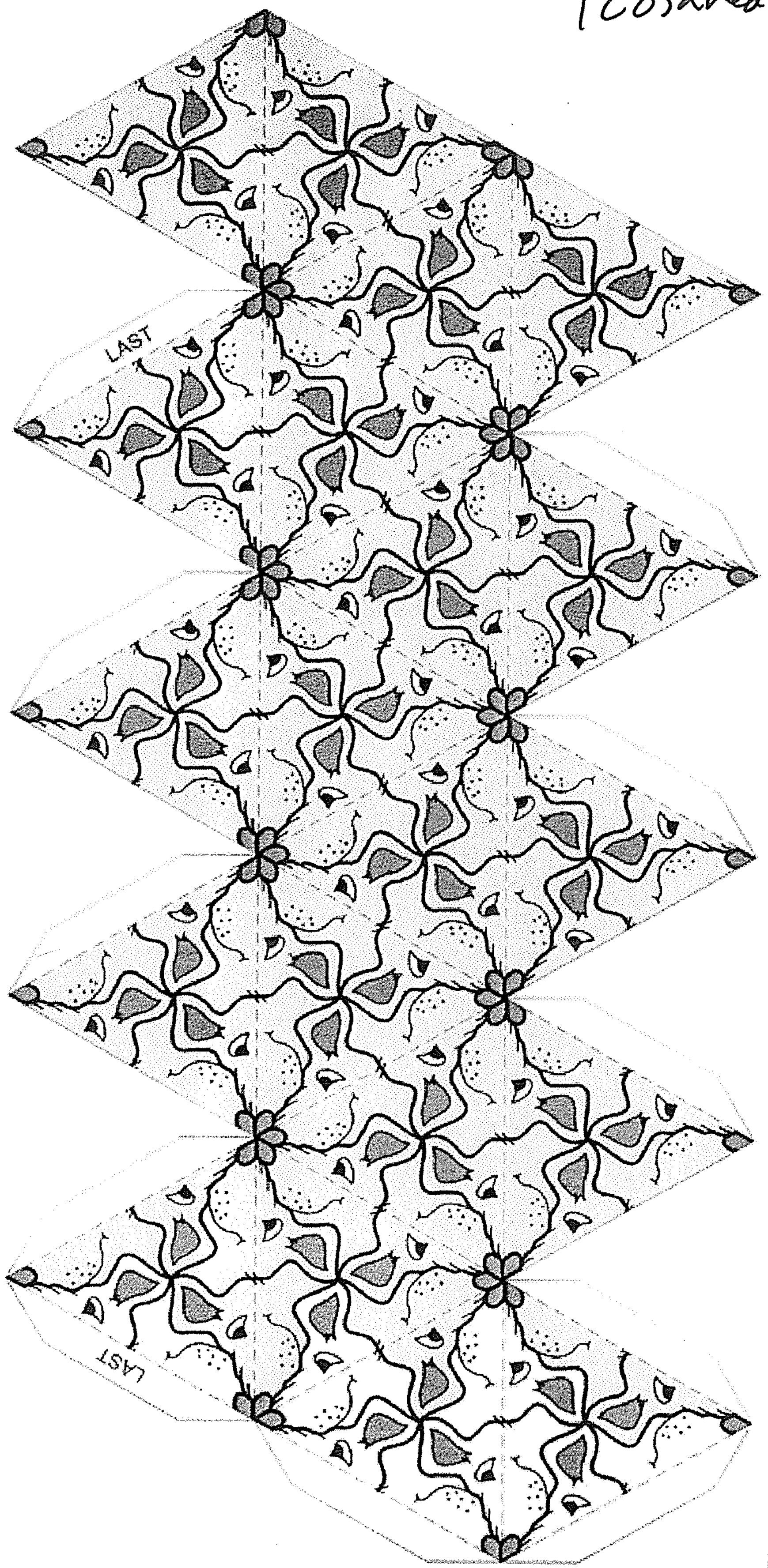
Icosahedron



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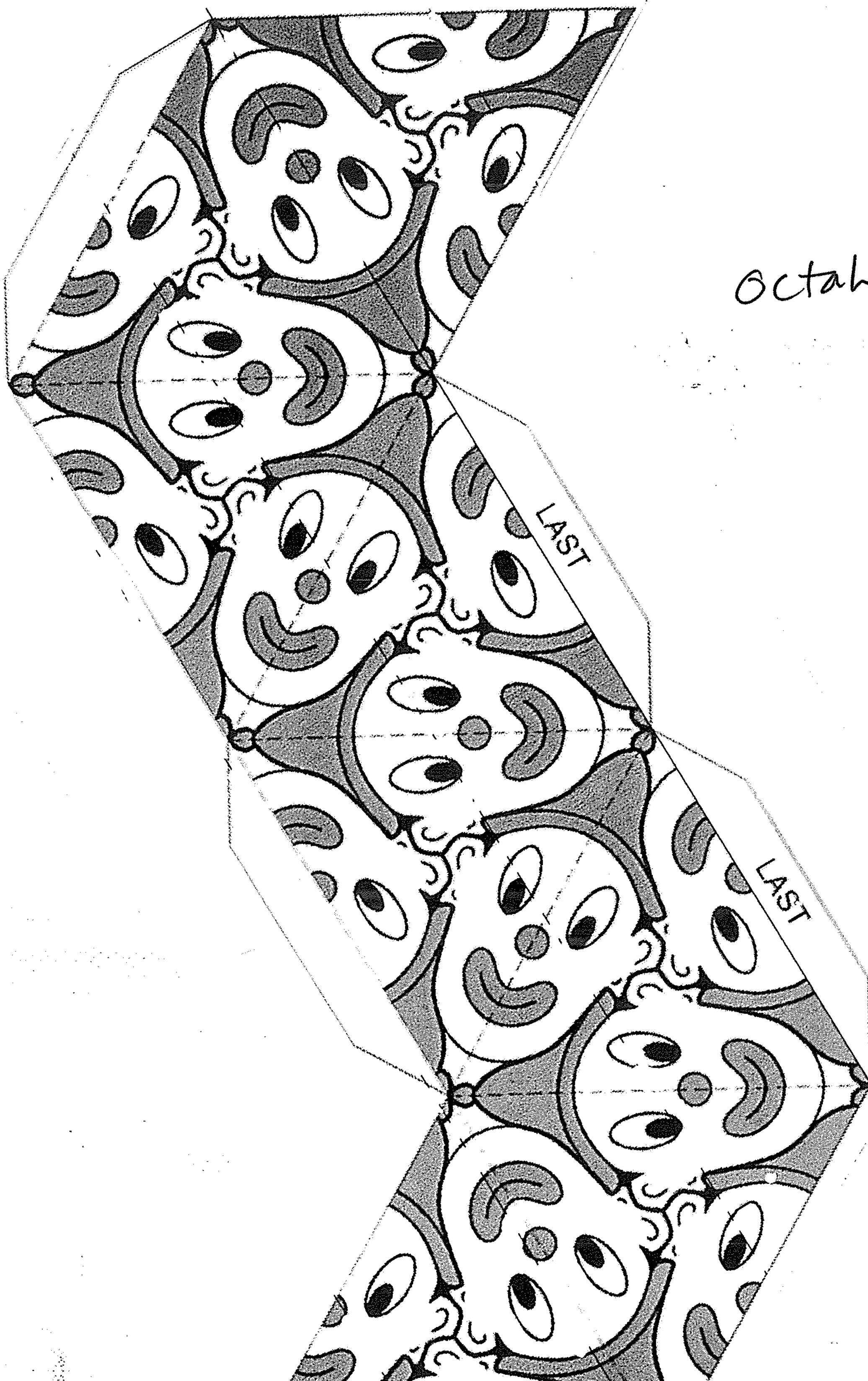
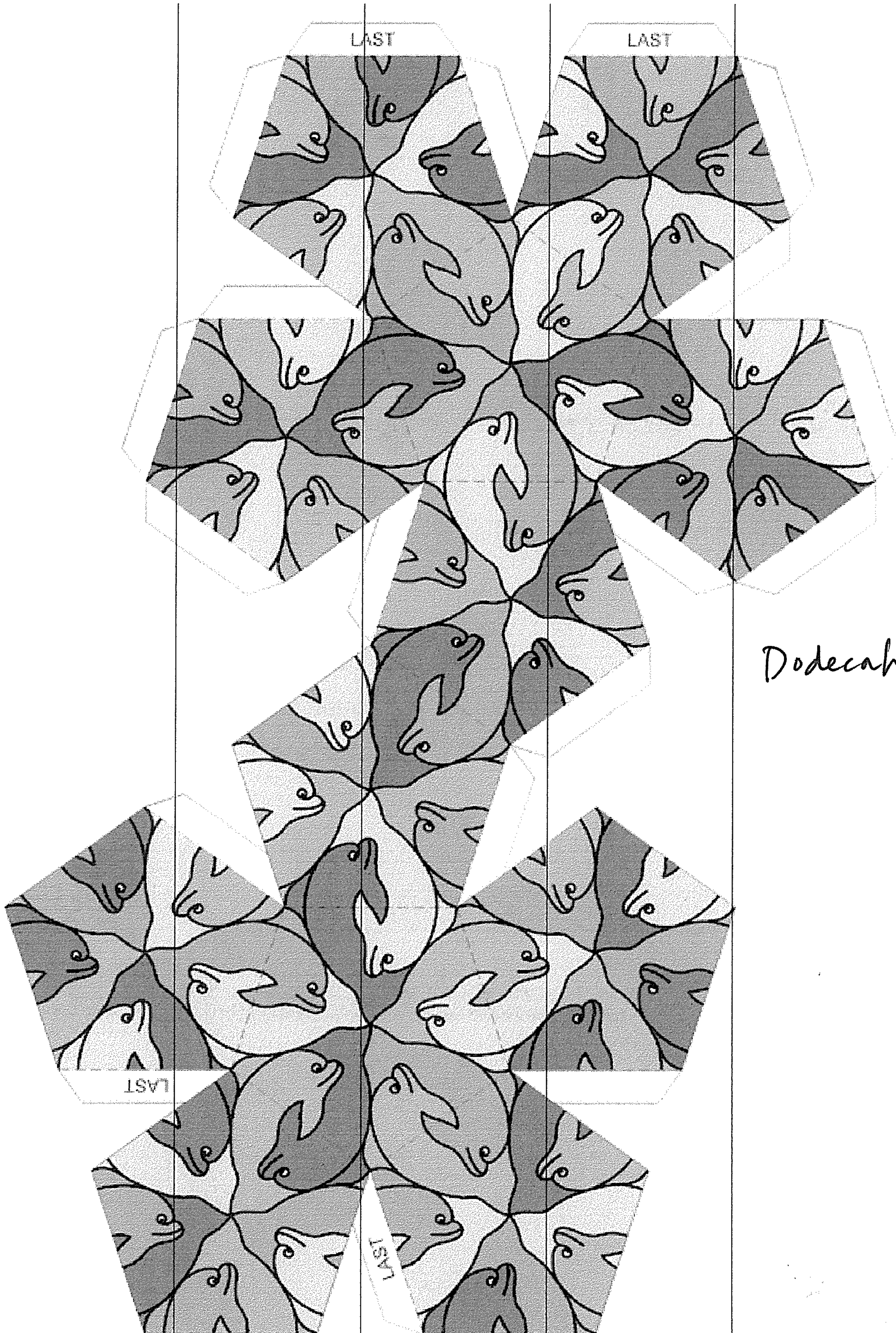
Octahedron





Dodecahedron

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