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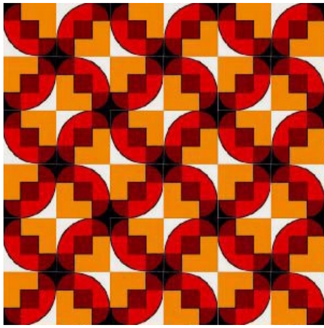
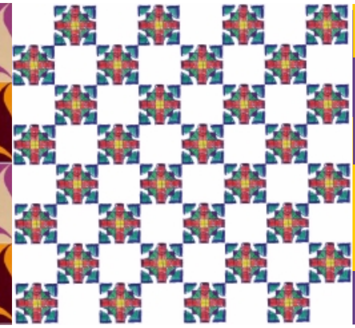
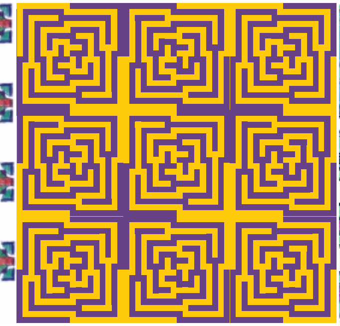
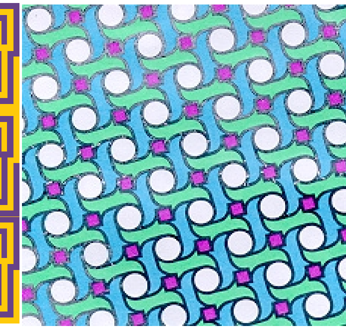
LEARNING ABOUT PERCEPTION THROUGH THE DESIGN PROCESS

How some of my ideas developed

In the following pages, some of my projects are shown together with the thought processes that were part of their development. For more up-to-date illustrations and some other published papers, please see also my Website at www.teknollogy.com. Enjoy!

June 2001, Eva Knoll



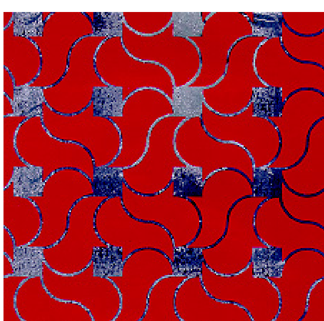
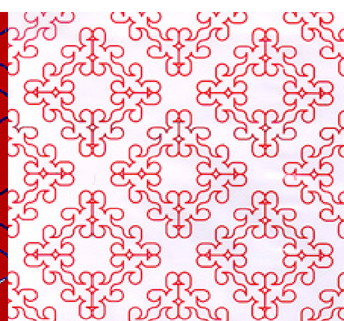
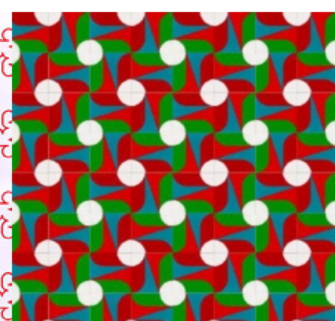
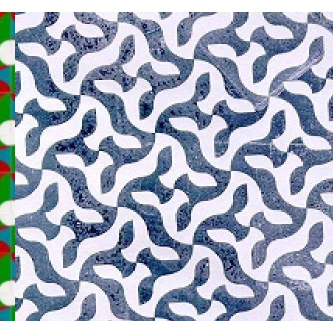
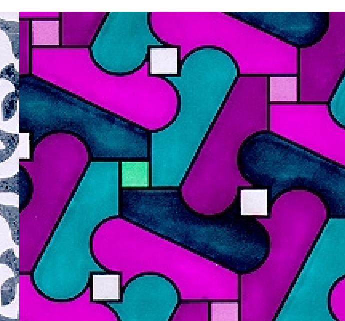
Early Work

Formally, my aesthetic endeavours began with two-dimensional abstract repeat patterns. Early on, the use of color became important because I could use internal relationships of the color wheel to emphasize relationships in the drawing. For example the second pattern from the left, above, is really made of two overlapping motifs, one a simple checker grid, and the other the floral design.

In the case of the central pattern in the bottom row, the combinations of orange with red and blue with green brings out the floral aspect of the design, masking the basic square tile.

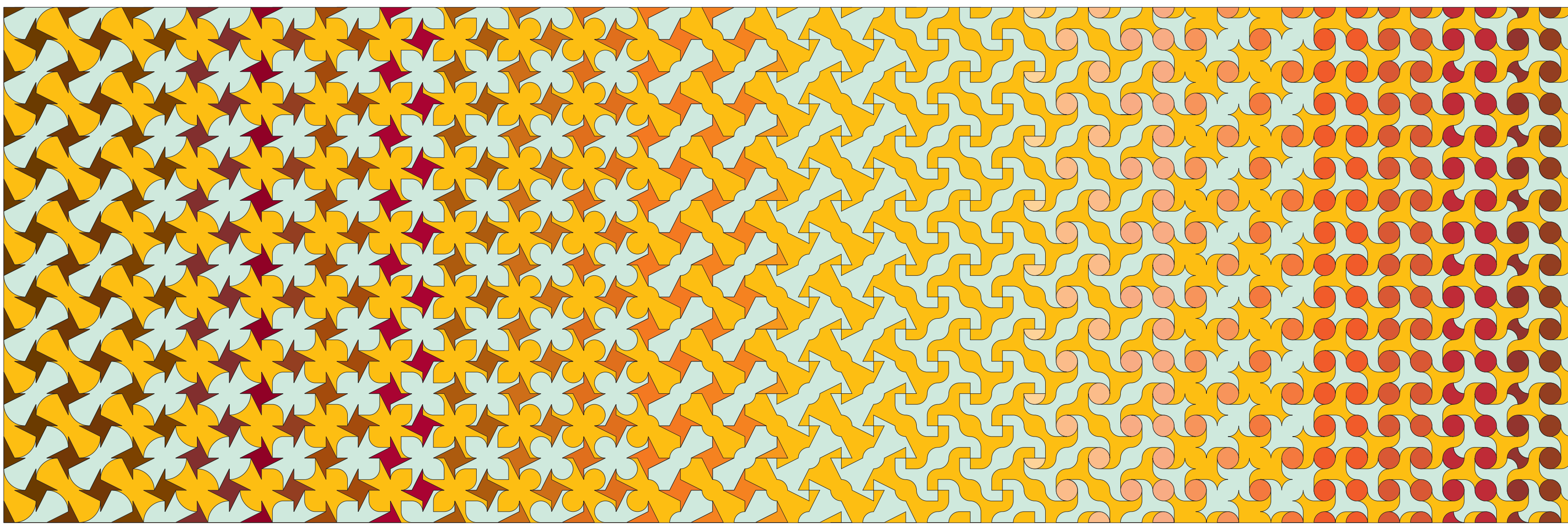
In the fourth pattern above, an optical deception gives the impression of another checker board. Meanwhile, the pattern is made up of a single two-colored square tile with a 2-fold symmetry that has been rotated by 90 degrees at each translation.

Such tricks are common enough. The fourth pattern on the bottom is composed of a single shape in two corors, white and silver. Using metallic colors can add an interesting effect, first by making the patterns seem alive with the changing light, and second by changing the focus moment by moment.

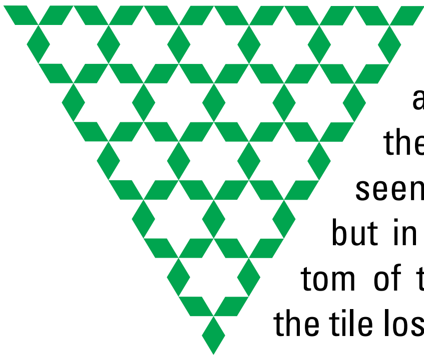
Changing Tiles (Metamorphosis)

Patterns are sometimes closely related, only differing by one line, making them useful for transformation designs such as this one. Although probably subconsciously inspired from Escher's metamorphosis, *Changing Tiles* simply was made to illustrate the link between the twelve different patterns in the series. All twelve patterns share a 4-fold rotational symmetry with a set of mirror symmetries around it, and each pattern is carried out across two rows of white shapes.

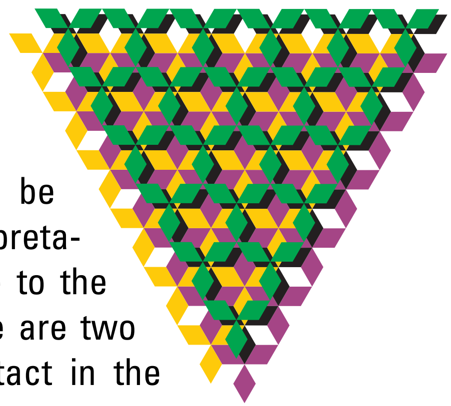


Triangular Patterns

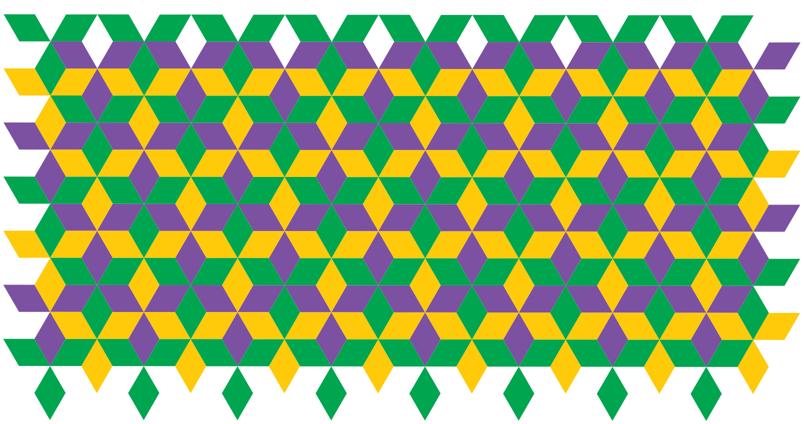
Tiling patterns in the triangular grid presents a different set of challenges.

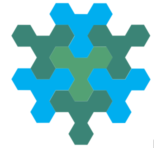


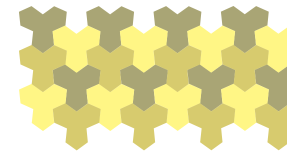
The present tiling illustrates a different problem. Yes, the tiling does fill space, as seen in the first four drawings but in the example at the bottom of this column, the unity of the tile loses its emphasis, and the pattern is a simple three-coloring of the rhombic grid.

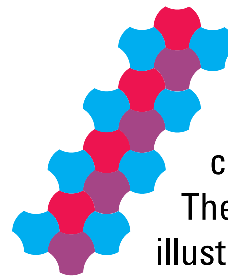


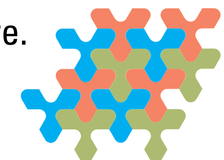
How can this situation be remedied? The misinterpretation in this case is due to the fact that although there are two kinds of points of contact in the tiles, they are interpreted in the same way in the finished pattern. There are the points of contact at the center of the tile itself, and there are the points of contact of same colored adjacent tiles. To take away this ambiguity, we need to modify the essencial shape of the unique tile. Of course, in order to conserve its tiling property, any local change in shape will have consequences elsewhere. The figures in this column illustrate a few solutions using this method. They range from the angular like the one at the top where each tile is made up of four hexagons, to the curved.

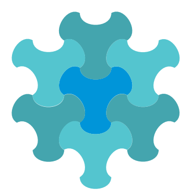


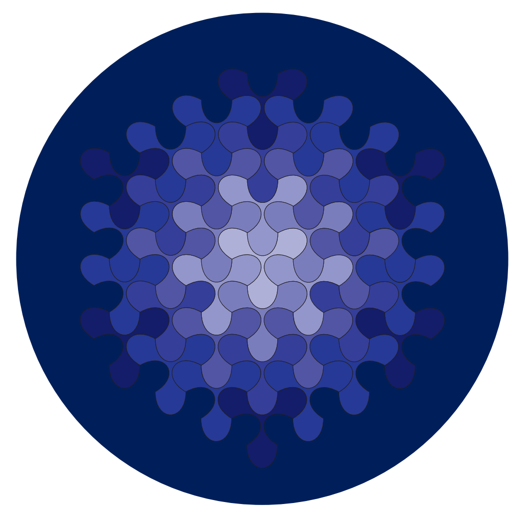


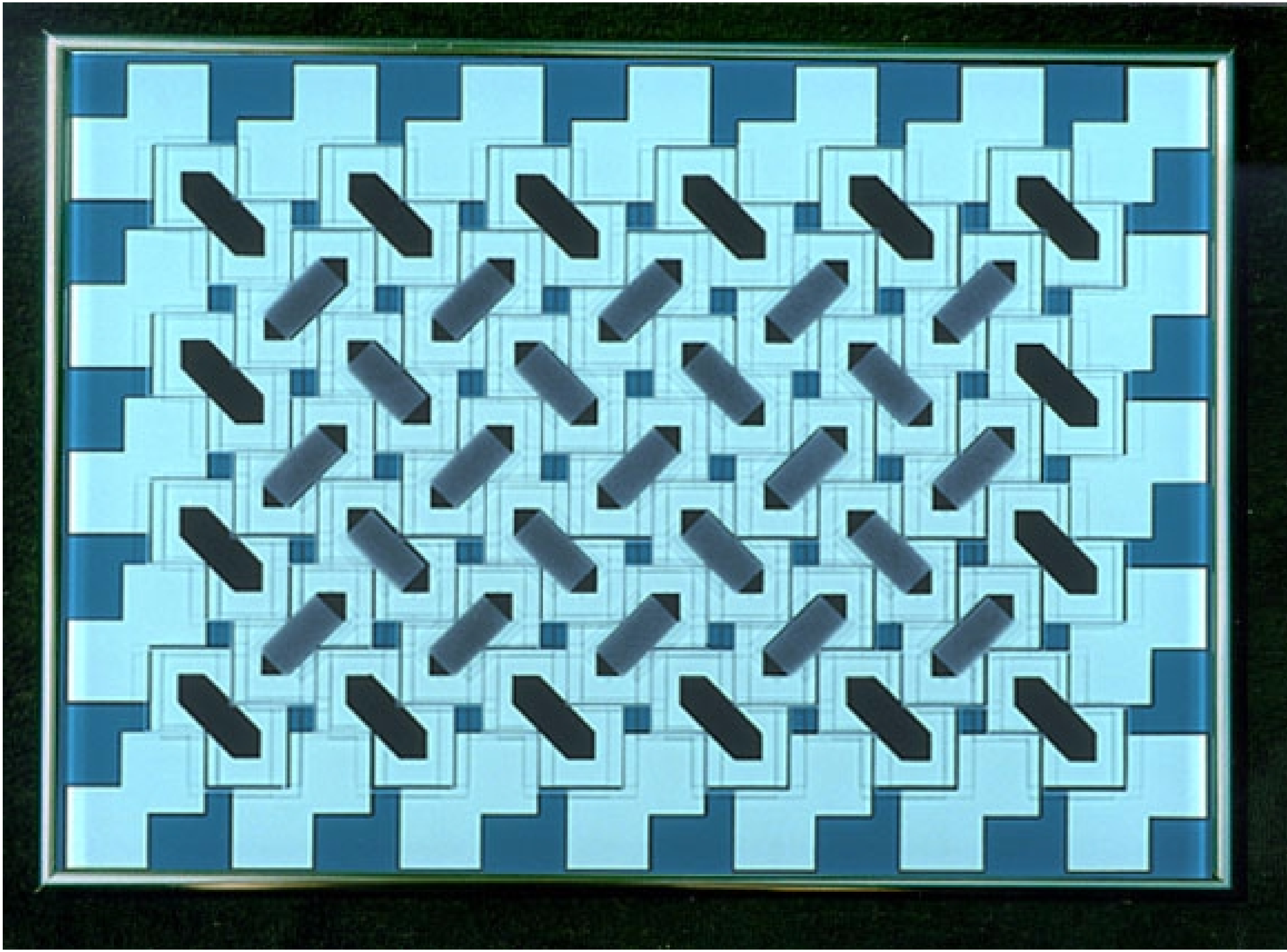






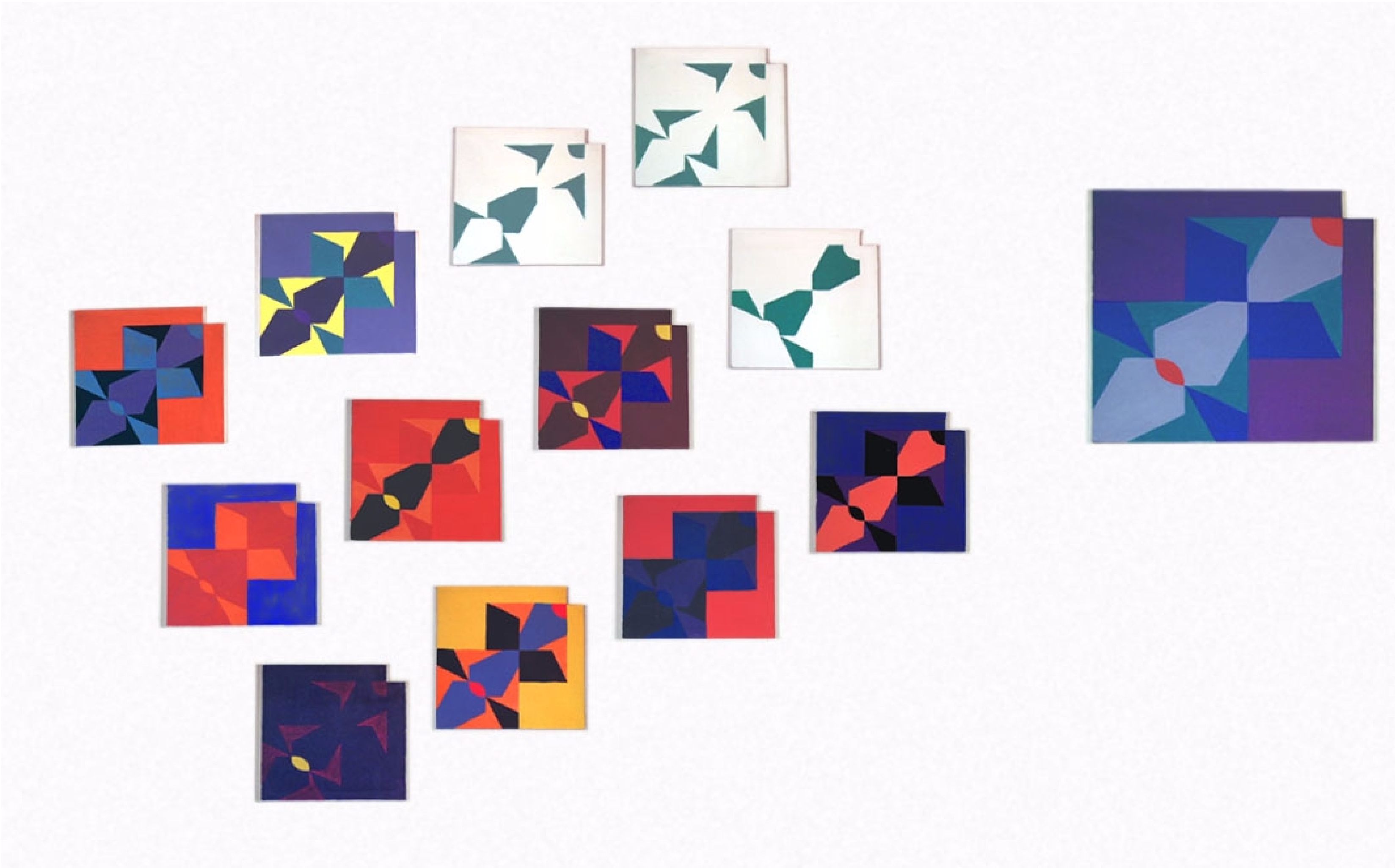






Depth Perception

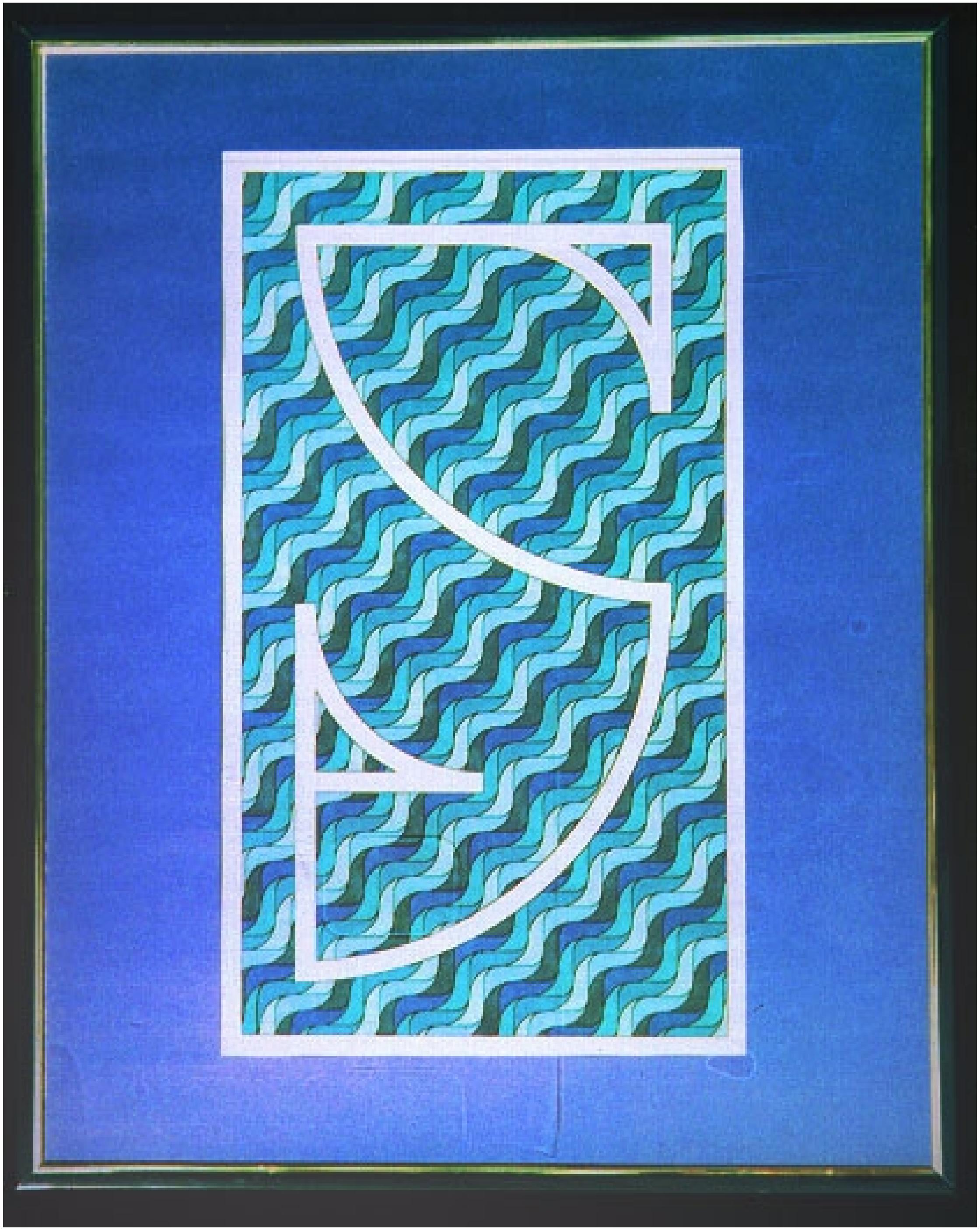
Sometimes a pattern has variations that are notable specifically through their relationship to each other. Here the patterns were layered in space using paralax and the thichness of the glass.



13 Variations on a Theme

Using color to emphasize shapes or their relatioships is only one side of the coin. Keeping the shapes constant, we can also compare how colors play off each other depending on their identity.

The 13 paintings were done in acrylic on custom-made canvases, each using the same basic pattern with a single mirror symmetry.



Monogram

Patterns can sometimes speak for themselves, suggesting a stylized reality. In this case, the similarity to waves in the sea prompts the use of shades of blue. We can almost see a flock of dolphins jumping in and out of the waves. Using the pattern as a background for a monogram adds a tension and complexity that the drawing would otherwise lack.

Moiré

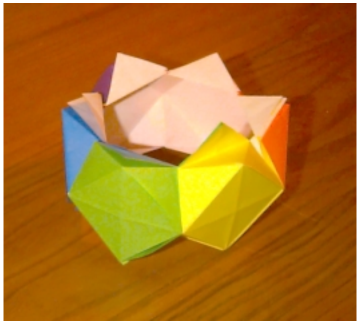
From the French for mohair, *moiré* refers to a visual phenomenon occuring when more than one layer of translucent material containing a grid or pattern are superimposed. The pattern is the consequence of the interference between the layers and occurs as a result of the visual misinterpretation we make of the result.

Moiré can easily be generated in a controlled environment, once it is understood as a phenomenon. Therein lies the challenge. This particular project shows an instance where the complexity of the elements has a strong impact on the final product. If the basic elements are complex enough to begin with, the final visual effect will lose its impact by becoming so complex that the patterns disappears in the image and the picture is reduced to simple noise. If the basic elements are too simple, the moiré effect will not occur and the image will remain flat.

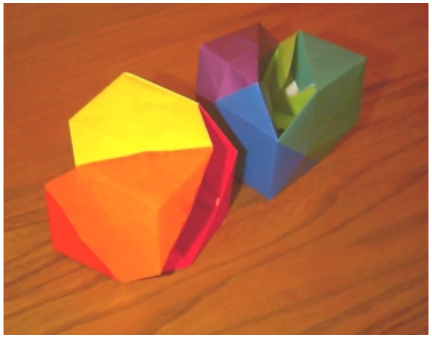
The image below shows an example of a moiré pattern produced by the layering of a stripe pattern and a deformation of the same pattern. Click on the image to see the animation.

Modular Origami using Squares or Bands

Repeating patterns occur in three dimensions as well as in two, even if they take a different form. This page shows a few examples of origami using modular folding techniques.

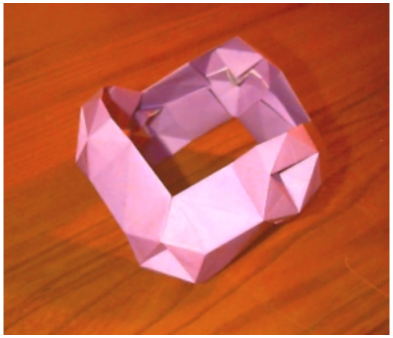


Except for the last figure, all the designs use simple square paper, folded according to basic lines. In the three figures on the left and the middle one on the right, the colors show the individual pieces of paper used. The middle figure on this side shows the path of a tennis ball curve moving diagonally around all the faces of a cube.



The top figure on the right also describes a tennis ball curve but this time following the edges of a cube.

The challenge in this type of exercise is to find a way for the pieces to 'hook' or link together without the use of glue or scissors. This is often done with tabs inserted into pockets, making use of the natural friction of the paper.



In the case of the last design, the folding was done using a band of paper, from cashier rolls or similar, and the folds are the symmetry lines of the regular triangular grid. When reconnected at the ends, the shape becomes what could be called a flexahedron. Analogous to a flexagon, a flat shape that can be twisted inside out forever, the shape in the last figure is flexible, toroidal and can be twisted, turned inside out and inverted forever.

Origami Lotus Blossom

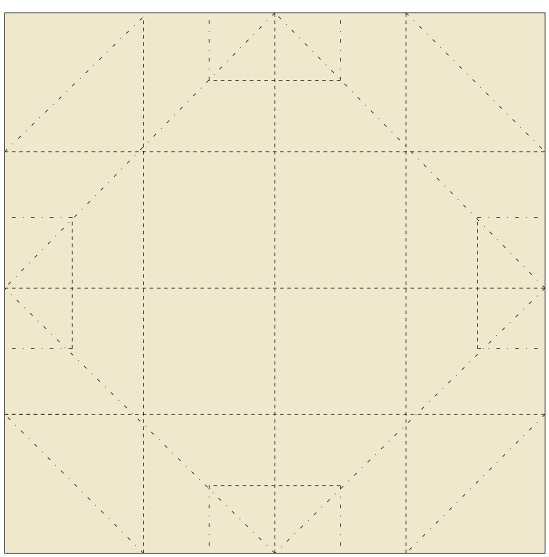
An origami project can go through many stages, before it can be considered to be finished.

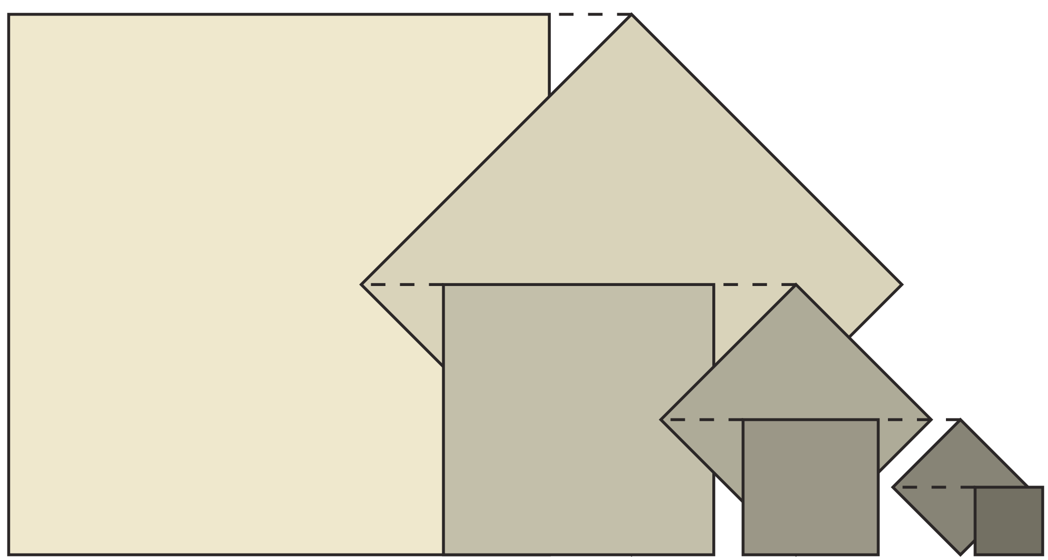
In the case of the *Lotus Blossom*, I started with a known fold of a simple flower I had learned many years ago from a book. The fold had never quite satisfied me and I had often felt that something was missing so that I periodically went through it to see if I could make a departure from it that would improve it.

After coming up with several variations, learning some important tricks along the way, I put it asside again.

The epiphany occured when I realized that if I took a square of paper the diagonal length of which was the side length of the first piece, I could then insert one folded piece into the other to create a concentric effect. The rest of the folding process then fell into place due to the conditions of the insertion. Because of the scalar symmetry, the number of iterations is limited only by the quality of the paper and the whim of the folder.

The Lotus Blossom remains one of my favorite creations in square origami. The various stages of its development show clearly how ideas can develop over time and really only emerge in a strangely timely fashion.





Circular Origami

Origami can be done using all kinds of shapes of paper, and in most cases, the shape of the paper will determine the possibilities.

For a while now I have been using circular as well as square paper. Though in the beginning I treated the circles as if they were squares, folding only perpendiculars and bissectors, it soon became clear that there were advantages in using the circle beyond the curved edges obtained in addition to the straight ones from the folds.

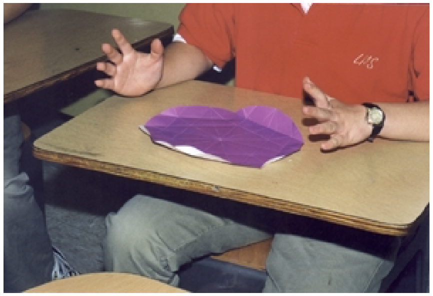
Because the circle subdivides exactly into 6 radii, it will give you easy access to angles of 30 and 60 degrees. In folding, this translates to taking the intersection of the circle with the line subdividing a radius in two perpendicularly. An arc of 60 degrees is defined by that point and the end of the original radius. From there on, all the 30 angles can be defined through symmetry lines and perpendicular folds. The figure below shows some of the results obtained after this realisation. Notice the red metallic piece near the center. This particular piece is significant as one of the first where I used the tucking method that lead to experiments with circular paper to make polyhedra based on equilateral triangles.

"Project Geraldine"

Project Geraldine was the first project I worked on in collaboration with Simon Morgan who was then a mathematics graduate student at Rice University in Houston, Texas. Inspired by some of my findings in circular origami (see previous page), and after having tried a medium sized model (approximately 1 meter in diameter), we decided to develop a modular system allowing us to build large shapes made of equilateral triangles.

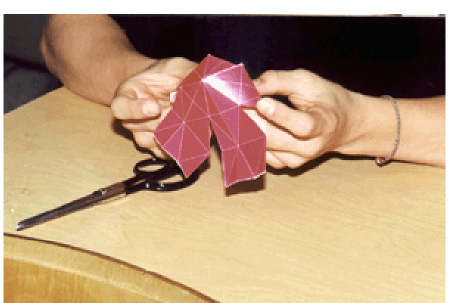
As an educational tool, the deltahedra (polyhedra made of equilateral triangles) were an immediate success in the progressive schools linked with the university. The main attraction, however, consisted of the barn-raising of Geraldine, the shape that started the whole project. Her true mathematical name (according to Kepler and John H. Conway) is *Endo-pentakis-icosi-dodecahedron*, and she is made of eighty equilateral triangles distributed among twelve five-sided inverted pyramids (the dimples) and twenty other faces.

"Project Geraldine" (continued)

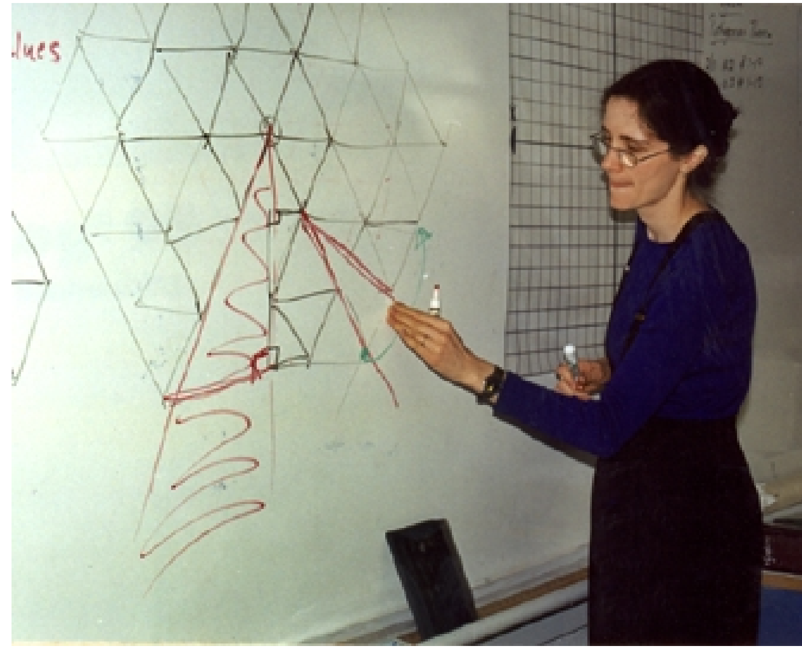


The first part of the event consisted of an Origami exercise for which the children followed instructions to fold an icosahedron (a shape bound by 20 equilateral triangles) starting with an unmarked circle.

Besides the real manipulation and application of concepts they had just learned, the exercise was aim at familiarizing the children with the visual experience of seeing the shape unfold in a rational way from the start. The children were in fact deliberately lead down the same path I had followed the first time I made the shape. Each step had a purpose that related it to the entire exercise. This part of the event brought home to them the real applicability as well as the aesthetic componant of mathematical notions.



Using the same principles, the children were then given all the pieces to build the large shape. Under the direction of Simon Morgan, their teacher Mrs. Sack and myself, they then built Geraldine.



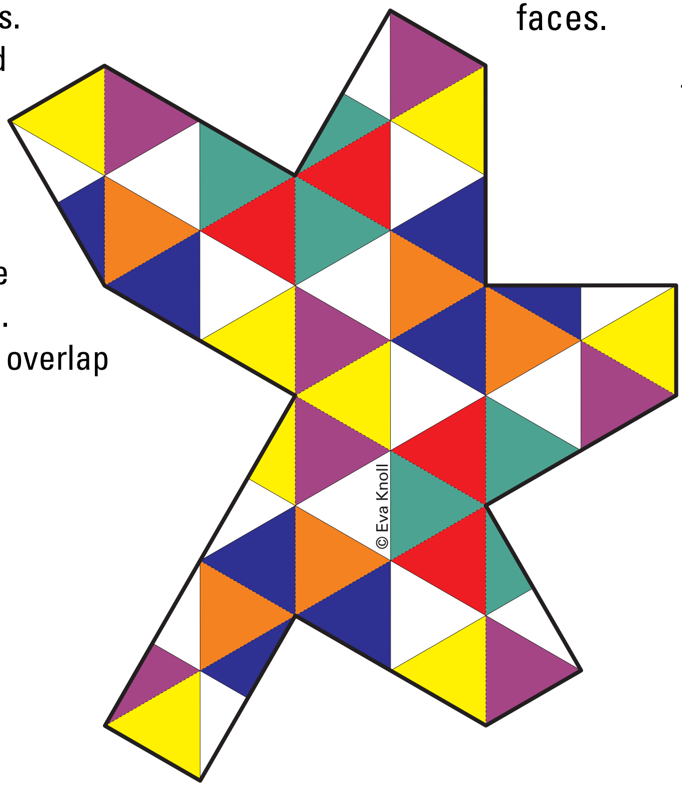
The deltahedron was raised again the following summer at the Bridges Conference in Winfield, Ks and the modules have been used ever since in schools and teacher training at K-12 levels as well as in geometry up to graduate level classes.

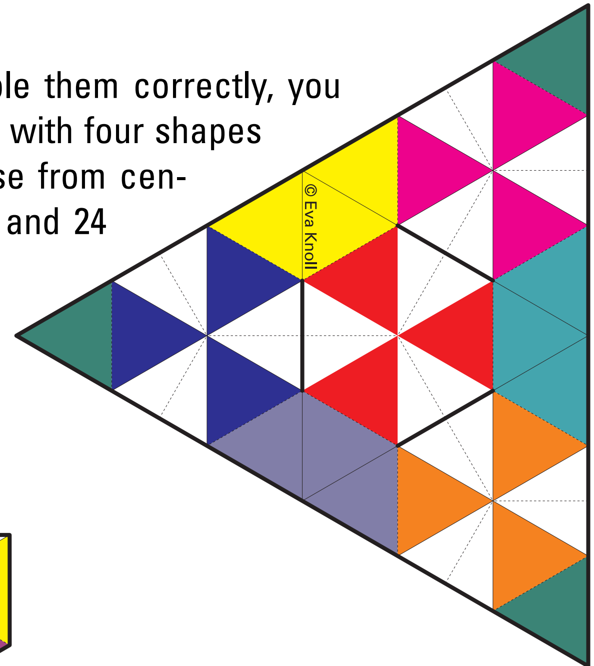
Other Deltahedra

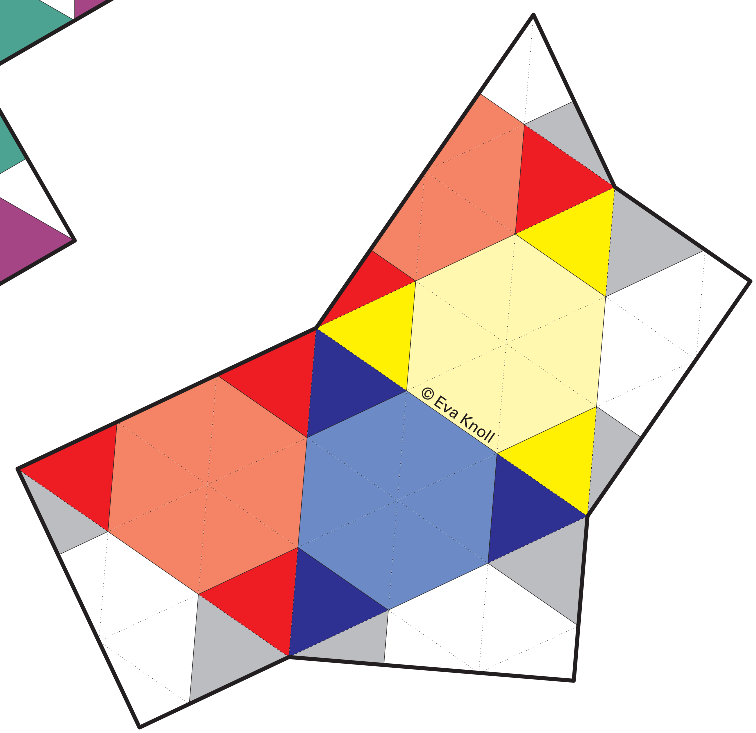
After Geraldine, I became interested in creating other deltahedra using the same tucking system. This page illustrates some of the results. The four shapes can be printed out and assembled using the following rules:

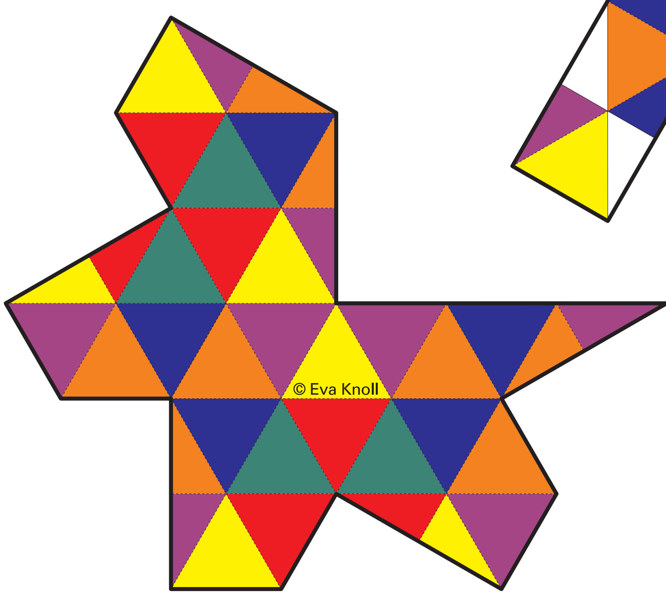
- Cut following the bold lines.
- Fold along all the thin solid lines for mountain folds.
- Fold along dashed lines for valley folds.
- The dotted lines do not require folding. They serve only to emphasize the grid.
- When assembling, always overlap parts with the same color.

If you assemble them correctly, you should end up with four shapes with (clockwise from center) 32, 24, 16 and 24 faces.







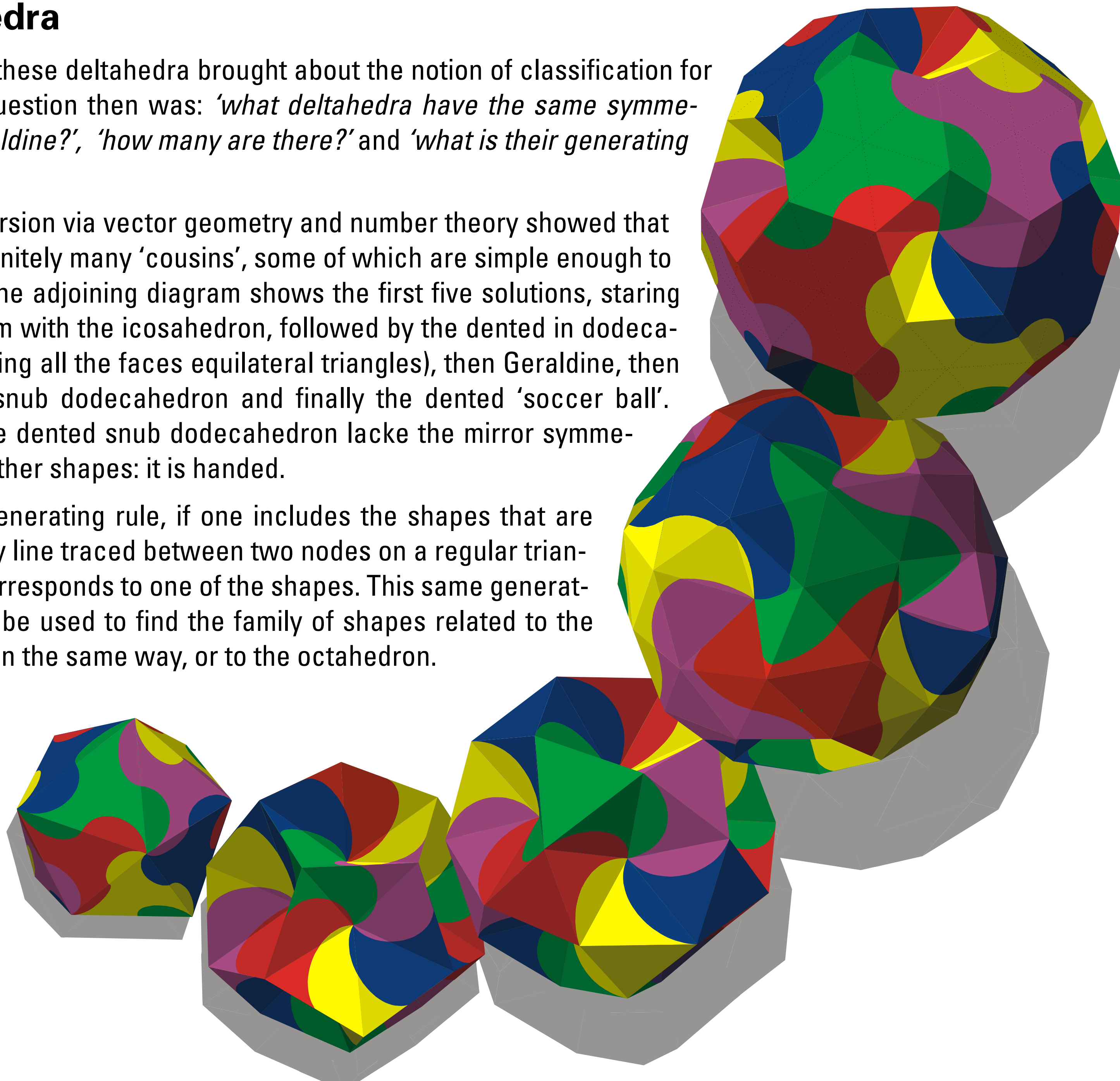


Twirlahedra

Studying all these deltahedra brought about the notion of classification for them. The question then was: *'what deltahedra have the same symmetries as Geraldine?', 'how many are there?'* and *'what is their generating rule?'*

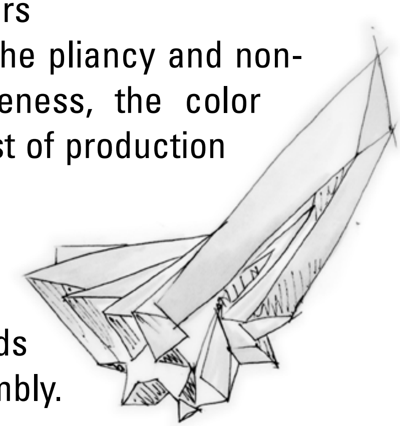
A short excursion via vector geometry and number theory showed that there are infinitely many 'cousins', some of which are simple enough to be known. The adjoining diagram shows the first five solutions, staring on the bottom with the icosahedron, followed by the dented in dodecahedron (making all the faces equilateral triangles), then Geraldine, then the dented snub dodecahedron and finally the dented 'soccer ball'. Note that the dented snub dodecahedron lacke the mirror symmetries of the other shapes: it is handed.

As for the generating rule, if one includes the shapes that are 'handed', any line traced between two nodes on a regular triangular grid corresponds to one of the shapes. This same generating rule can be used to find the family of shapes related to the tetrahedron in the same way, or to the octahedron.

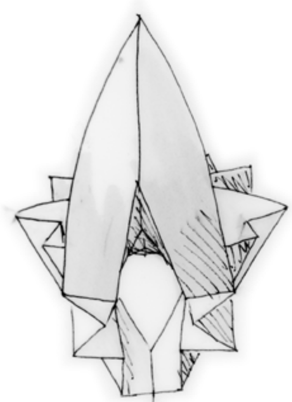


Flight of Fancy

On more than one occasion, a interesting result in Origami lead to a project in a different medium. This transfer of design from one medium to another is always notable because it brings about a new set of parameters determined by the material and the technique used. The pliancy and non-elasticity of paper is replaced by rigidity or brittleness, the color becomes a choice, scale a decision, and often the cost of production changes.



In this particular example, all the properties of paper worked for the design. In the model, the quality of the paper allowed the shape to be formed while the folds remained and the object did not collapse after assembly. What material will keep these properties and yet will be less fragile and last longer? There is not always a ready answer for the material needed, but this does not take away from the grace of the form.



Transformation from The tetrahedron to the Dodecahedon

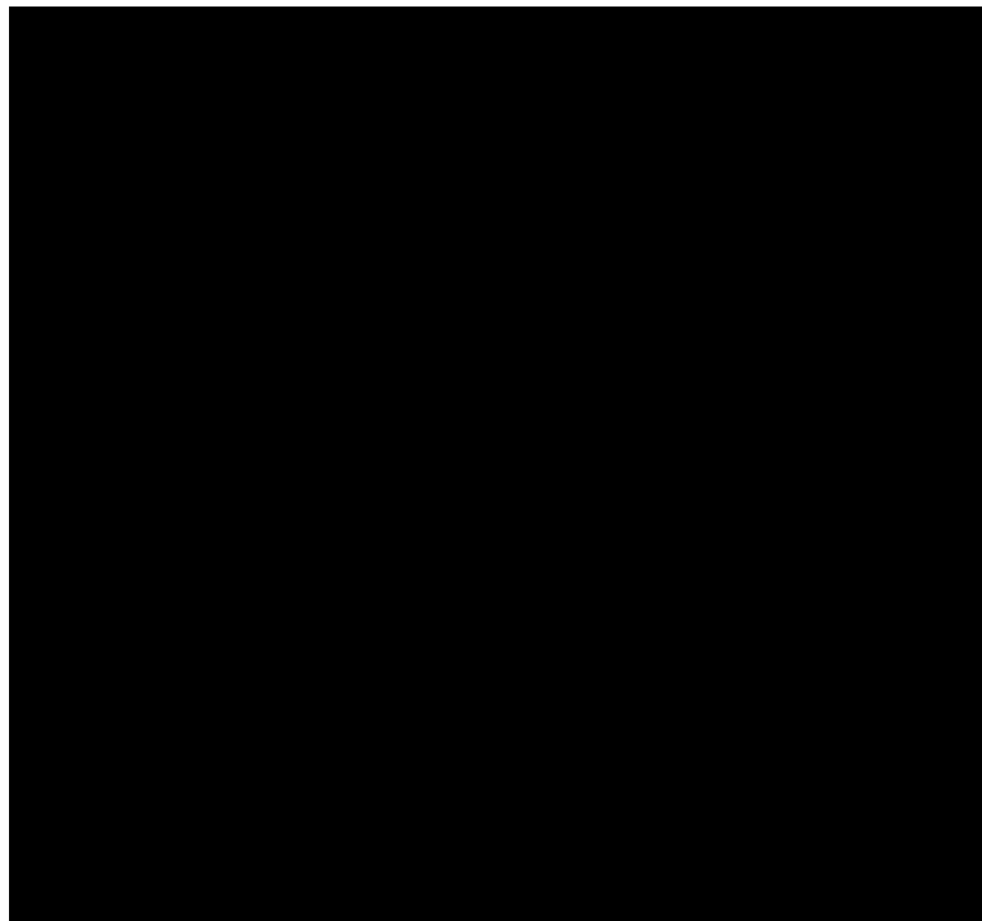
The regular coloring of polyhedra is always an interesting challenge when one is looking at their structure. This is particularly true of the regular polyhedra.

In the present example (click the tetrahedron to see the animation), the plot centered less on the challenge of finding the coloring as it did on comparing the solutions for various figures. The thought process began with the simple observation that a regular tetrahedron whose faces have been subdivided into 3 shapes each has 12 ‘faces’, just like the dodecahedron. From there, the question posed itself whether the two figures have the same coloring solutions. As shown in the animation, the answer is yes, the two shapes both have a 4-coloring solution and they are equivalent.

The animation begins with an ordinary 4-colored tetrahedron. It then progresses to the 4-coloring of the tetrahedron with subdivided face. Each face is shown to have 3 kite shapes defined by drawing the lines going from the center of the triangle to the middle of the edge. At this point, the polyhedron is made of 3-vertices and 4-vertices, unlike the dodecahedron.

To remedy this difference, the lines on the faces are rotated so as to be parallel to one of the edges of the original face. As a consequence, each 4-vertex becomes two 3-vertices, of which there are now 20, just like on a dodecahedron. Interestingly, the distance between all the adjacent vertices is now the same.

The shape now only needs to be defomed so that the internal angles of the faces are 108º (as in a regular pentagon) and voilá! a 4-colored dodecahedron...



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