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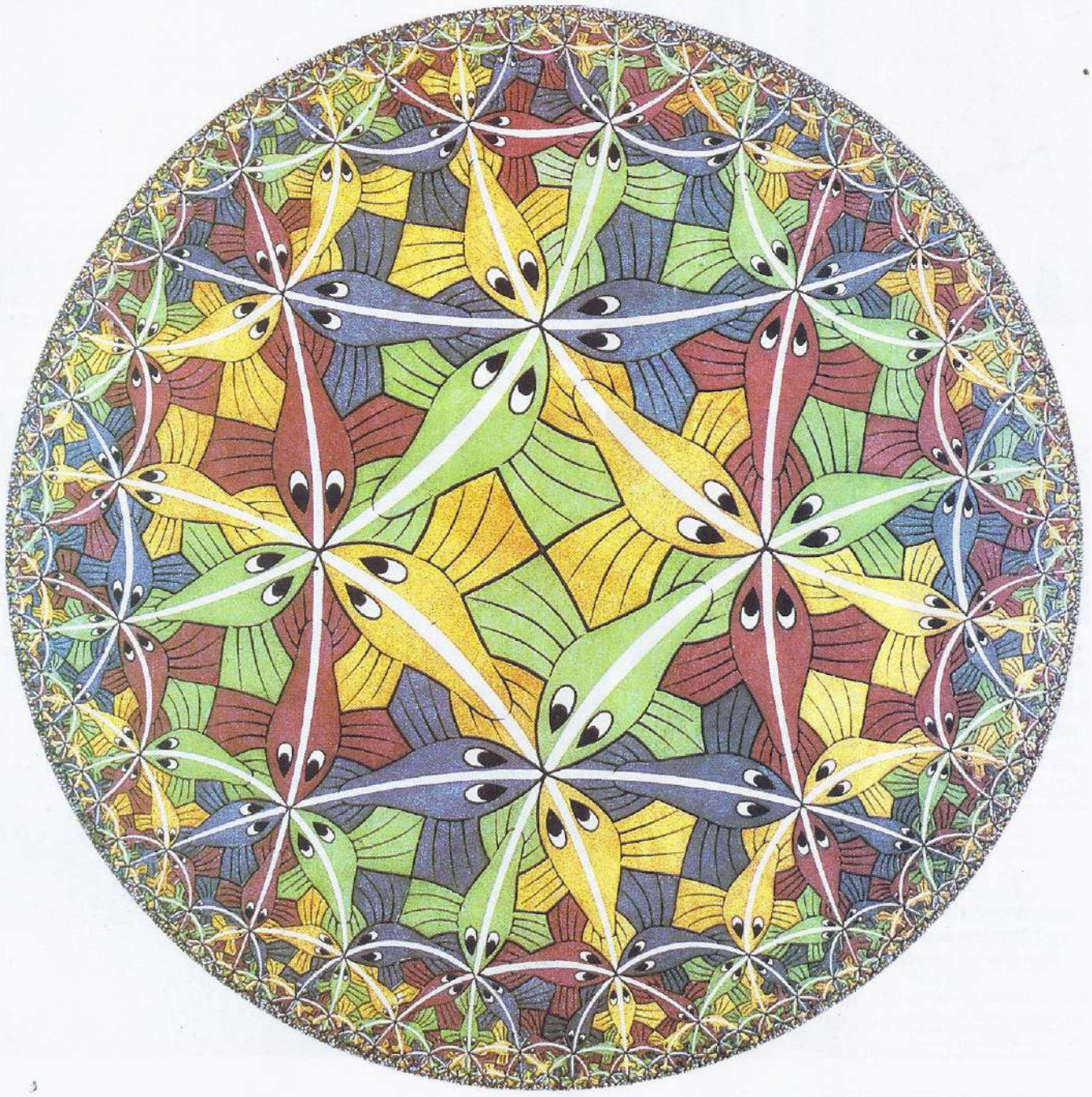
M.C. ESCHER
Working With Shape



On the Cover

In the image on the cover, colorful fish get smaller as they spiral outward. Why are they shrinking? Find out on pages 8–9.

Cover: M.C. Escher (1898-1972), *Circle Limit III*, 1959. Woodcut, second state, in yellow, green, blue, brown, and black, printed from 5 blocks. M.C. Escher's "Circle Limit III" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

Art Meets Math

"I often seem to have more in common with mathematicians than with my fellow artists." –M.C. Escher

What do art and math have in common? In the work of Dutch artist M.C. Escher, the answer is: *a lot!* Born in 1898 into a family of engineers, Escher (left) was raised to think like a mathematician. If you really want to understand Escher's images, keep in mind that they contain more math than meets the eye.

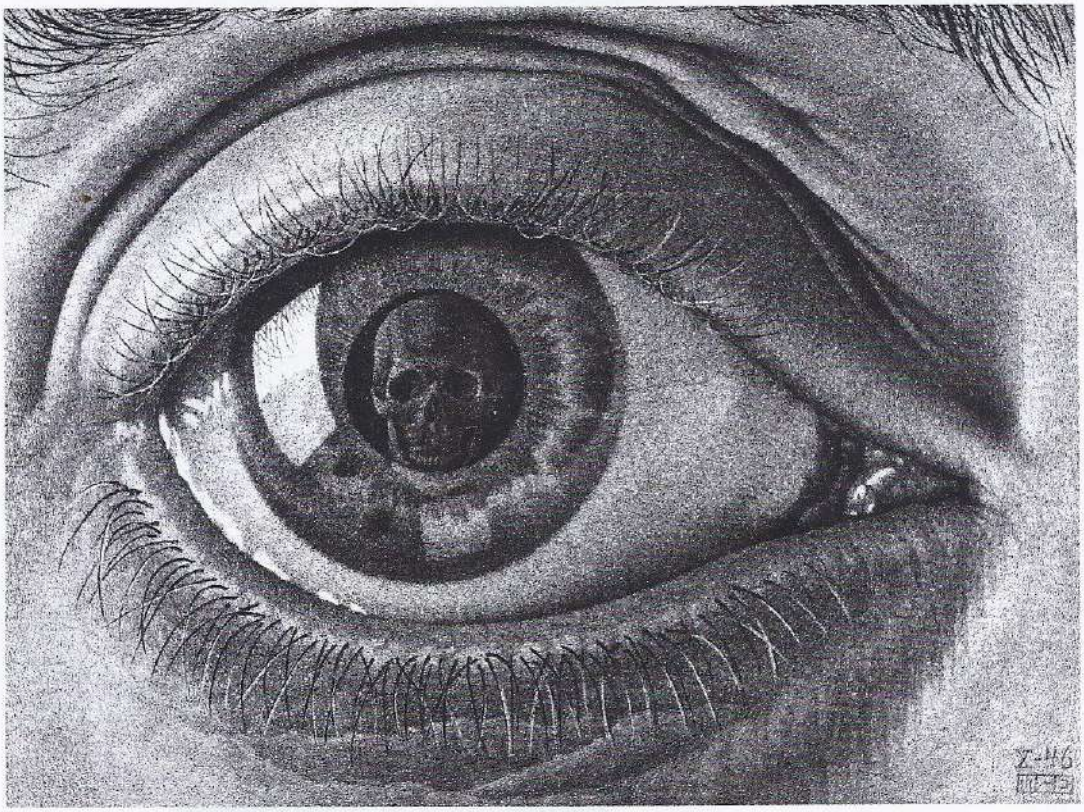
Unexpected Reflections

Eyes need light to see, which is why we can't see in the dark. When you look in the mirror, what you're really seeing is light bouncing off the mirror's surface into your eye, which reads that light as an image.

Light hits the mirror's surface at a certain angle and bounces back at an equal angle in the opposite direction. That's where geometry—the study of angles and surfaces—comes in. Depending on the shape of the mirror, an image can bounce back at angles that either shrink or enlarge it.

▲ **Inspired by math, M.C. Escher (above) made art that, in turn, inspires mathematicians.**

Portrait of M.C. Escher, 1970. M.C. Escher's "Portrait" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.



▶ **Who or what is being reflected in this eye? What idea might this reflected image express?**

Eye, 1946. Mezzotint, 7th and final stage. M.C. Escher's "Eye" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

▼ **Can you find the tessellation in this drawing? Once you've found it, find out how it was made, on pages 4–7.**

Reptiles, 1943. Lithograph, 13 1/8 x 15 1/8 in. M.C. Escher's "Reptiles" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

▲ **How many different viewpoints are shown in this image?**

Other World, 1947. Wood engraving and woodcut in black, reddish brown, printed from three blocks. M.C. Escher's "Other World" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

To make *Eye* (opposite page), Escher took advantage of this effect. He used a **concave** (curving inward) mirror to enlarge his eye so that he could see and draw all of its details. If a concave mirror enlarges images, then a **convex** (curving outward) surface like the eye shrinks them. When Escher looked at his eye in the mirror, he saw his own tiny reflection. Then, he drew exactly what he saw—with one exception. What did he mean to say by replacing his own image with a skull?

Impossible Views

In math, rules describe what is possible. In *Other World* (above left), Escher used the rules of **perspective**—a geometry-based system for showing a **three-dimensional** space on a **flat** surface—to create an impossible situation.

In a roomlike space, arches open onto a lunar landscape. But something seems strange. Where is the ceiling? Where is the floor? In the bottom part of the image, the viewer seems to be looking up from below at a hanging horn, a birdlike figure, and a sky filled with spiral galaxies. In the top part of the image, the viewer looks down from above at the horn, the figure, and the moon's surface. The middle of the image shows the scene from a third angle. By combining three different **points of view**, Escher seems to be asking viewers: If you're seeing the same thing from above, from below, and from the side, then where exactly are you?

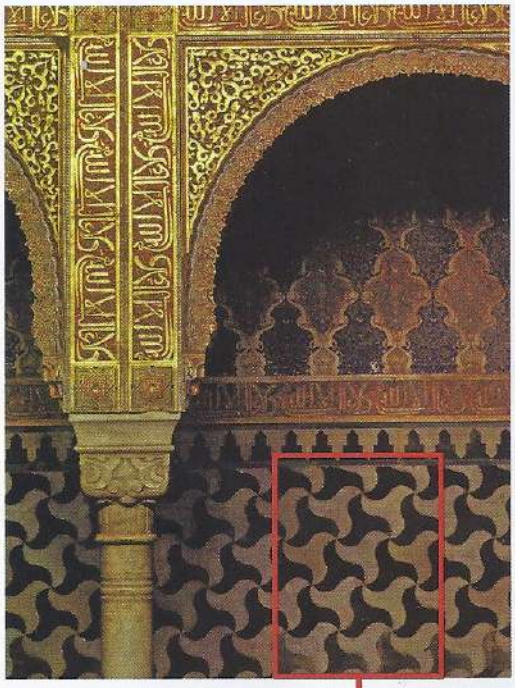
Repeating Reptiles

Can you imagine what something without a beginning or an end actually looks like? Math uses an abstract symbol to represent infinity. But in *Reptiles* (above right), Escher makes the concept a bit easier to picture.

The lizards in this image will walk forever over the same circular path. On one part of their journey, they flatten into a **pattern** of **interlocking shapes** called a *tessellation* (tes-eh-LAY-shun). In math, a *plane* is a flat surface that goes on forever in all directions. A tessellation is designed to fill a plane, so it too is designed to go on forever.

Shape Shifter

M.C. Escher transformed simple shapes into spiraling figures, flying fish, and anything else you can imagine

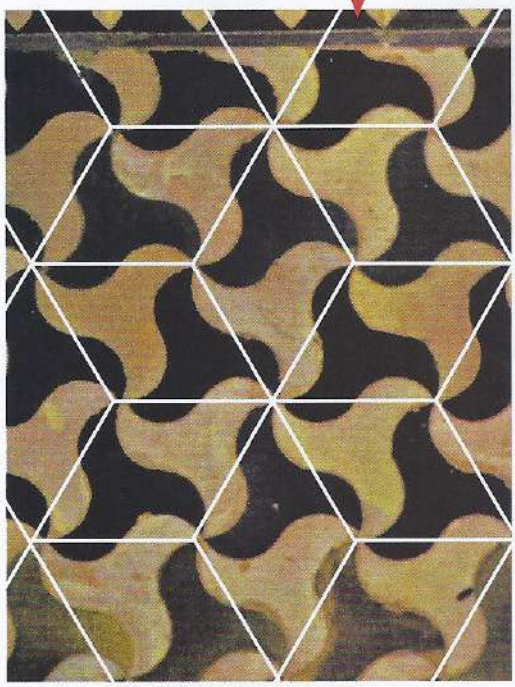


▶ **Behind this arch at the Alhambra, a 14th-century palace located in Spain, is a wall of tessellations. How many different examples can you find?**

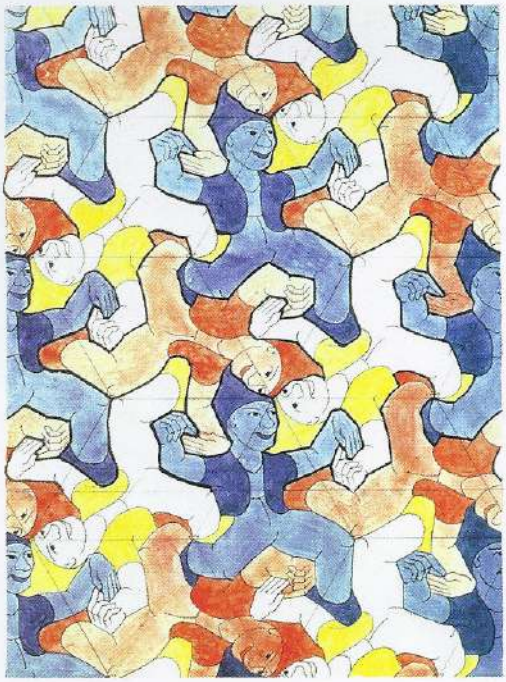
Palace of the Alhambra, Granada, Spain. Detail of wall tiles in the baths (photo), Islamic School, 14th century. The Bridgeman Art Library International.

One of Escher's childhood friends claimed that when Escher was a boy, he made sandwiches by carefully placing cheese slices side by side so that the edges of the slices touched but did not overlap.

Escher might not have known it at the time, but he was working with *tessellations*: patterns made up of shapes that line up edge to edge without creating gaps or overlaps. Tessellations are also called *tilings*. Imagine the tiles in your bathroom, and you're visualizing a tessellation.



▶ **Compare this close-up of an Alhambra tessellation with Escher's tessellation to its right. What do they have in common? What shape is being repeated in both images?**



Symmetry Drawing E21. M.C. Escher's "Symmetry Drawing E21" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

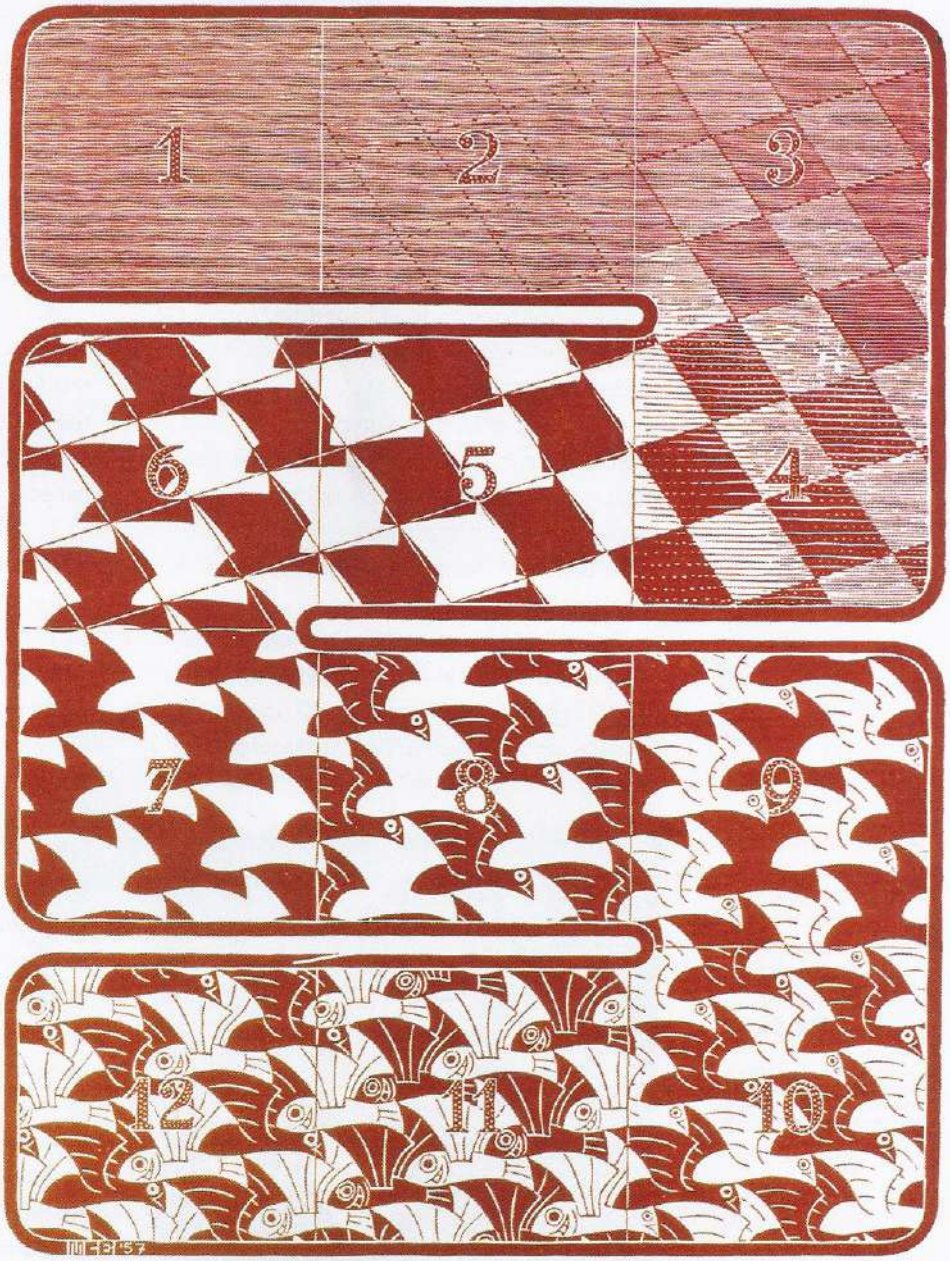
But chances are, the tiles in your bathroom aren't very exciting. In 1922, on a trip to Spain, Escher saw tiles that inspired him for the rest of his life. These tiles were in the Alhambra (shown on the opposite page, with the full image on top and a detail below it), a palace built by the Muslim princes who ruled Spain during the 14th century. Many Muslims believe that since Allah (God) is the creator of life, it's a sin to copy Allah by creating images of living things. Because of this, Islamic artists often limit themselves to working with **abstract shapes**.

Escher was amazed by the rich variety of patterns that covered most of the Alhambra's walls, floors, and ceilings. But he felt that something was missing, so he decided to do what no artist had ever done: make tessellations out of recognizable images.

The swirl of colorful **interlocking** figures on the opposite page (bottom right) is an example of Escher's revolutionary tessellations. It might look complicated, but Escher created it by starting with a simple grid of **congruent** (same shape and size) diamonds. If you look closely, you'll see the faint outline of the grid. The same grid could have been used to make the Alhambra tessellation to the left of Escher's. In both tessellations, every diamond contains the same image.

But how did Escher transform diamonds into dancing figures? To explain his process, Escher created the print on the right. If you let your eye move from box 1 through box 12 of the image, you'll notice a change happening. Areas of static turn into a checkered grid. In boxes 5–7, Escher started to bend the sides of the diamonds to create new shapes. Compare the tops and bottoms of the new shapes. Now, compare their left and right sides. Notice that whatever changes Escher made to one side, he also made to the opposite side, so that the new shapes still fit together. In boxes 8–10, Escher added details to turn the shapes into birds. In box 11, he reimagined the shapes as flying fish. Finally, in box 12, birds and fish fly past each other in opposite directions.

▼ Escher created the print below to show how he transformed simple shapes into representational images. Follow the numbers to see diamonds change into birds and birds change into fish.



Regular Division of the Plane I, 1957-1958. M.C. Escher's "Regular Division of the Plane I" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

Connecting the Pieces

Find out how M.C. Escher fit figures together to create endless patterns

Games like chess or checkers begin with a few pieces and a few rules. But from these simple starting points, players can create a huge variety of plays. For Escher, tessellations were the ultimate game. There were pieces: **polygons** (closed geometric shapes made up of three or more straight sides). There were also rules: Shapes had to fit together without any gaps or overlaps to form an endlessly **repeating pattern**.

The object of Escher's game was to invent new and surprising tessellations. He transformed polygons into every kind of creature he could imagine. Then, he made many copies of his creations and fit them together like puzzle pieces.

Escher kept his inventions in sketchbooks like the one shown in *Reptiles* (below and on page 3). He eventually created 137 unique tessellations—enough to fill five sketchbooks!

▶ **"My objects, once brought to life, make their own way. If they want to, they can return to the plane and disappear into their place of origin."**
–M.C. Escher

Reptiles, 1943. Lithograph, 13 1/8 x 15 1/8 in. M.C. Escher's "Reptiles" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

In the tessellation on the opposite page—the one Escher playfully brought to life in *Reptiles*—lizards cartwheel around each other.

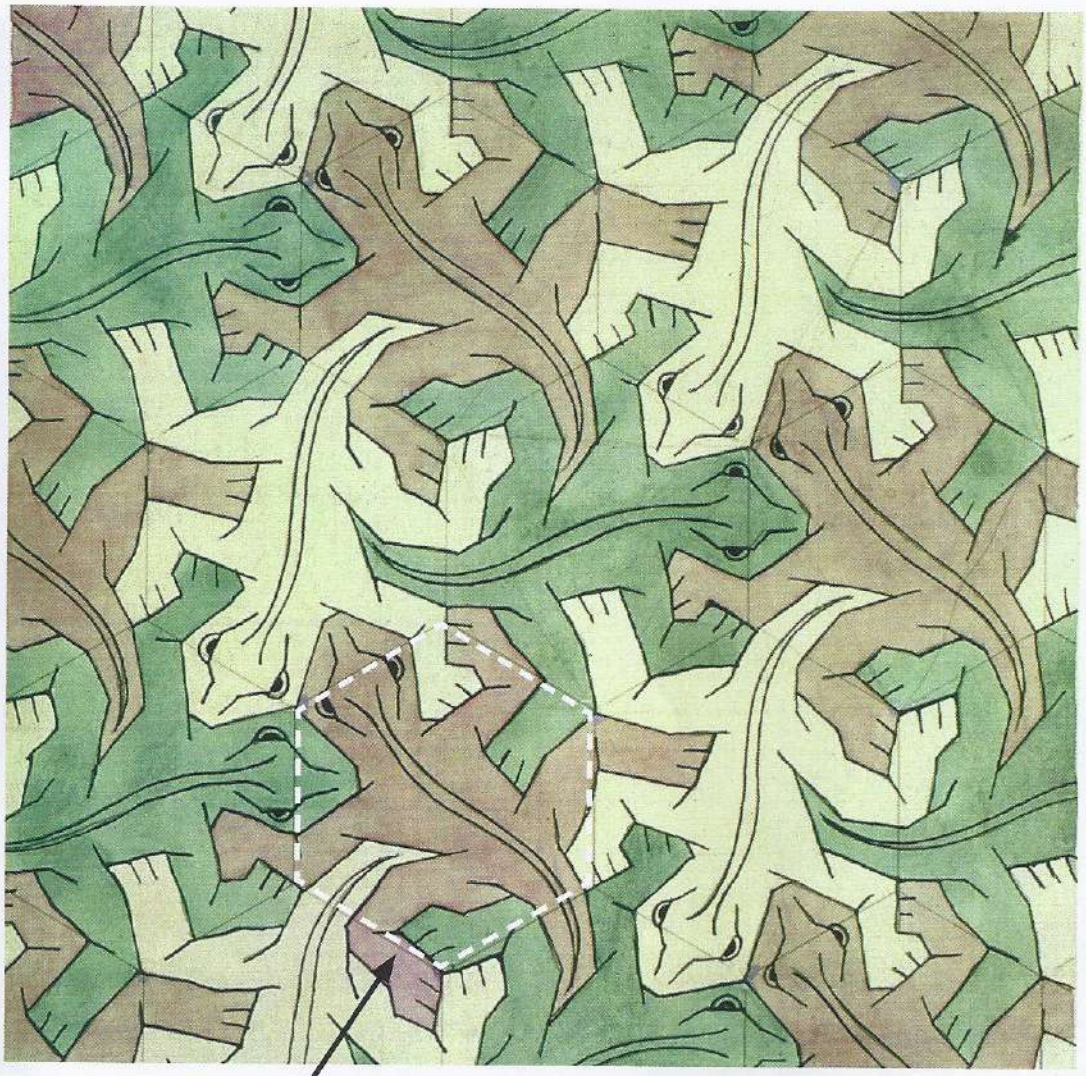
To understand how Escher made this image, start by comparing the tessellations on pages 4 and 5. Escher began both by changing diamonds into recognizable images, but these tessellations look different because their pieces fit together differently.

In the tessellation on page 4, figures spin like pinwheels as they lock together. In math, this is called **rotation** (see page 7). In the tessellation on page 5, birds and fish fly past one another in straight rows. In math, this is called **translation** (see page 7).

To make the image on the opposite page, Escher drew a grid of hexagons. (Look closely, and you'll see the outlines of the grid.) Want to know how he changed hexagons into reptiles? Place some tracing paper over the white dotted hexagon. Starting from the hexagon's top corner, trace the black **contour line** that separates the red and white lizards to the top left corner. Rotate your tracing clockwise onto the hexagon's left side, and you'll see that it lines up perfectly.

Escher's trick for changing hexagons into reptiles is the same trick he used to change diamonds into birds: Whatever changes he made to one side, he also made to another. Only, instead of working with opposite sides, he did it with **adjacent** sides, forcing figures to spin.

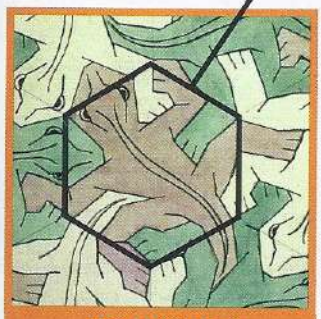
Now that you know how Escher made the tessellation on the opposite page, can you guess how he made the one on page 4?



◀ Can you point out the rotation in this image? How about the translation?

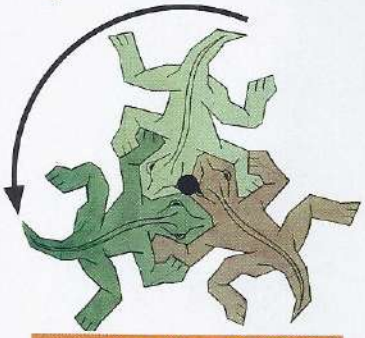
Symmetry Drawing E25. M.C. Escher's "Symmetry Drawing E25" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

Definitions



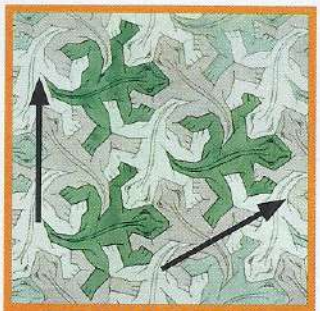
POLYGON

In math, a polygon is a flat, closed figure formed by three or more straight lines. Escher began his tessellations by transforming polygons into recognizable images.



ROTATION

This term describes when a figure is turned like a wheel around a central point. In the tessellation above, reptiles change color as they rotate.

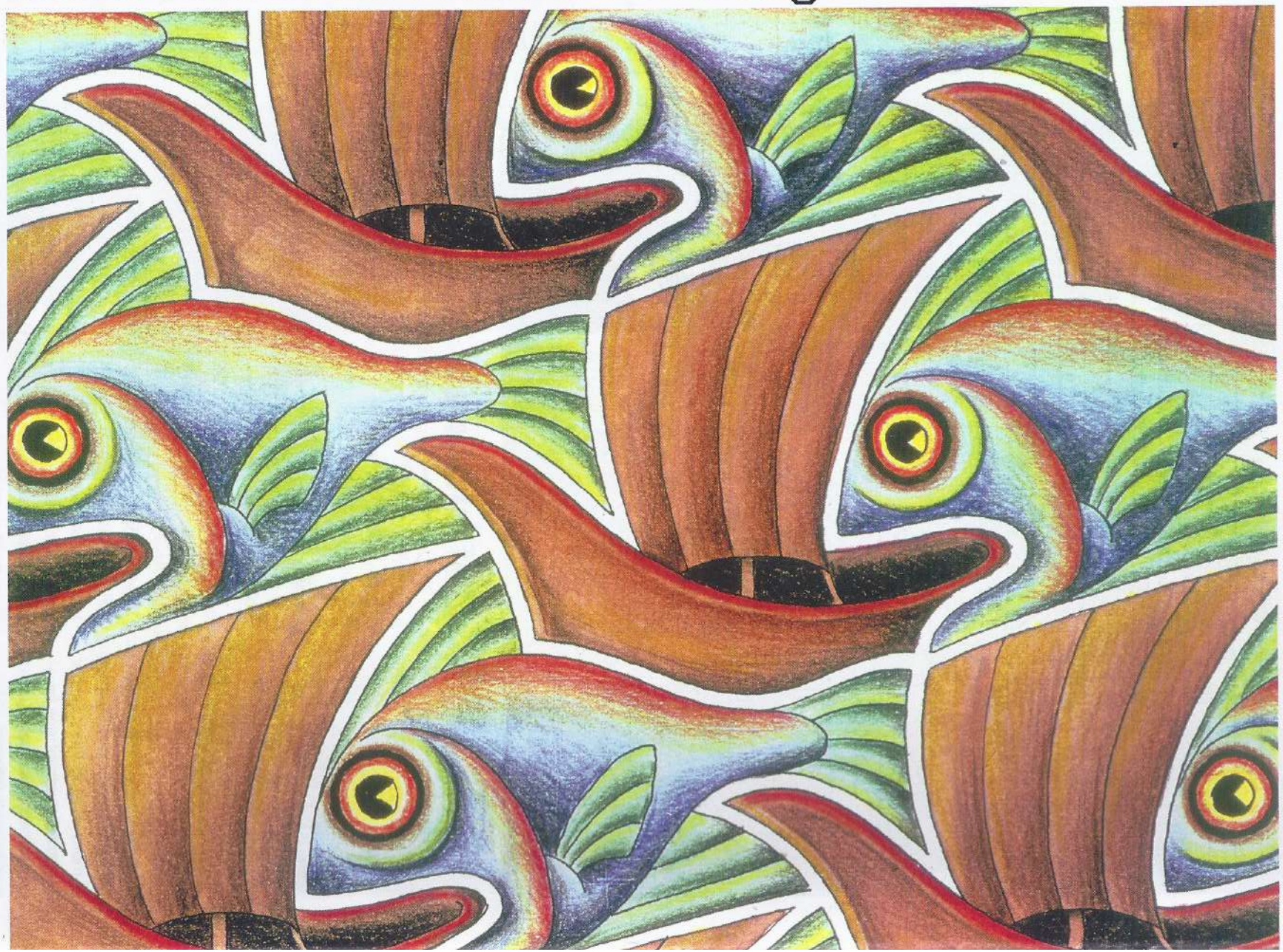


TRANSLATION

Translation describes when a figure is moved into a new position without rotating. All of the green lizards in this pattern are translating.

MASTERPIECE OF THE MONTH #4

M.C. Escher: Waves of Images



▲ **"I try to express that we live in a beautiful and orderly world." –M.C. Escher**

Symmetry Drawing E72. M.C. Escher's "Symmetry Drawing E72" ©2009 The M.C. Escher Company-Holland. All rights reserved. www.mcescher.com.

As Escher got better at making tessellations, he started experimenting further. Unlike the tessellations on pages 4–7, the one above was formed from two shapes instead of one and offers viewers hints of a story. The complex tessellation on the cover visually answers a classic mathematical question: If you're walking toward a door and shrink to half your size each time you take a step, will you ever reach the door? Assuming you were more than one step away from the door to begin with, the answer is *no*. Just as $1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}$ and so on will never add up to 2, your shrinking strides will never get you to that door and out of this strange situation. The colorful fish in the cover image shrink as they rotate outward. As they near the edge of the circle, they become too small to see. But it has been mathematically proved that, at the rate they're going, they'll never reach that edge.

Reflections of Escher

Contemporary artists play with reflection, pattern, and perspective

Leandro Erlich

In the photograph above, people hang from a building and look like they might fall at any moment. But don't worry. They're just taking part in an art **installation** created by contemporary artist Leandro Erlich.

To construct the installation, Erlich placed a life-size image of a building flat on the ground, then positioned a mirror at a 45-degree **angle** from the image. Since mirrors reflect everything at an equal and opposite angle, the building appeared to be standing upright at a 90-degree angle (45 + 45 = 90).

Viewers who went to see the installation quickly figured out how to make themselves part of the art. They climbed up walls and doorways. They swung from balconies and hung from ledges. And they did it all while lying safely on the ground.

▼ Leandro Erlich.

Jim Drain and Ara Peterson

An object reflected in one mirror is reflected once. An object reflected in two mirrors is reflected twice. But if those two mirrors are also reflecting each other, then the object is multiplied so many times that its reflection becomes a **repeating pattern**. That's the idea behind a *kaleidoscope* (kuh-LYE-da-skope), a tube of mirrors you can look through to see patterns that change whenever you move it. To create the forms on the right, contemporary artists Jim Drain and Ara Peterson first built a giant kaleidoscope by joining three triangular mirrors edge-to-edge. They then created changing patterns by playing movies in front of it.

To make the images they saw permanent, the artists decided to turn them into sculptures. Each of these spherelike forms is made of **congruent triangles** with identical shapes painted on them. What might these sculptures have in common with M.C. Escher's tessellations?

▲ Jim Drain and Ara Peterson.

▲ Darina Karpov.

Darina Karpov

Contemporary artist Darina Karpov hates feeling trapped, so she makes art that breaks rules—including the rules of **perspective.**

Perspective is based on the idea that objects look smaller as they get farther away from the viewer. Imagine railroad tracks. As the rails get farther away, they seem to get closer together until they meet at a point on the horizon. In a perspective drawing, all lines that are **parallel** in the real world—like rails—get closer and closer together until they meet at a point on the **horizon line.**

For a demonstration, check out Escher's *Other World* on page 3 (left). If you use a ruler to extend the diagonal lines in that image, you'll see they all meet at one point on the horizon line, which is also the literal horizon where the sky and moon meet.

Compare Escher's image with Karpov's (below), and you'll see that when you follow the rules of perspective, like Escher did, objects seem to fit neatly into place. But if you break the rules, like Karpov did, you get chaos.

Karpov began her drawing by using a ruler and pencil to lay down random lines. She then used those lines to draw **geometric forms** in false perspective. The result is a space with no logic or order to it and no horizon.

The choppy waves in the bottom right of the image never meet the cloudy sky at the top left of the image. In fact, the waves and clouds look so much alike that it's hard to tell which way is up and which way is down.

Karpov added to the confusion by playing with **scale.** Her images range from huge to tiny, but their size has no connection to how close to, or far from, the viewer they are.

When she was done with the image, she called it *Loophole*—a word that means "a way of escaping the rules."

"I make art to escape the rules of physical reality."
—Darina Karpov

Leandro Erlich: *Bâtiment*, 2004. 314.9 x 236.2 x 472.4 in. Installation view: Nuit Blanche, Paris, 2004. ©The artist, courtesy Sean Kelly Gallery, New York.

Leandro Erlich in the studio (detail). Photo by: Luna Paiva. ©The artist, courtesy Sean Kelly Gallery, New York.

Jim Drain and Ara Peterson: *Hypnogogia*. Installation view. Courtesy Deitch Projects.

Jim Drain and Ara Peterson, courtesy Deitch Projects.

Darina Karpov: Courtesy the artist.

Darina Karpov: *Loophole*, 2008. Graphite, color pencil on paper, 51 3/4 x 41 in. Courtesy the artist and Pierogi Gallery.

Shaping the World

Carla Dusel turns nature into geometric patterns

Eighteen-year-old Carla Dusel has her own way of looking at nature. "I see a different pattern in each set of branches, and endless geometric shapes in each snowflake," she says. Carla uses her unique vision to create digital artwork like *Sewage*, her award-winning piece on the opposite page.

A graduate of Pious XI High School in Milwaukee, Wisconsin, Carla is now a freshman at Milwaukee Area Technical College. Her dream is to someday become an art teacher. "My art teachers helped me understand who I was as an artist and to believe in myself," Carla says. "I'd like to do that for others."

How did you first get involved in art? When I was little, I carried a digital camera everywhere. I'd take hundreds of pictures and choose my favorites. In middle school, I branched out from photography into other art classes, and my interest grew from there.

Why do you work with nature imagery? I hike constantly, and once a year I go camping with family friends in the woods bordering Canada. I love hearing wolves howl at night and seeing how bright stars can look without any city lights around. When you're in school, hiking isn't a part of everyday life, but my art lets me take a bit of nature with me everywhere I go.

Why do you turn nature into patterns? When I was younger, I had a lot of panic attacks, and the only thing that calmed me was drawing patterns. After a while, I started making patterns from my photographs. I loved losing myself in the shapes I created. It helped calm my mind.

What inspired you to create your award-winning piece? I was inspired by the subject, a sewage pipe. I wanted to show that beauty can exist in a gross environment.

How did you make the image? With all of my work, I begin by downloading a photograph from my camera onto my computer. I then use Photoshop (a digital-imaging program) to cut up the image, duplicate it, get rid of pieces I don't need, then put what's left back together like a puzzle. To make the piece [on the opposite page], I adjusted the colors, then mirrored the same picture four times.

What's your favorite part of the piece? I love how the leaves crawl through the center of the image. They remind me of vines you might find growing on marble inside a richly decorated palace or castle.

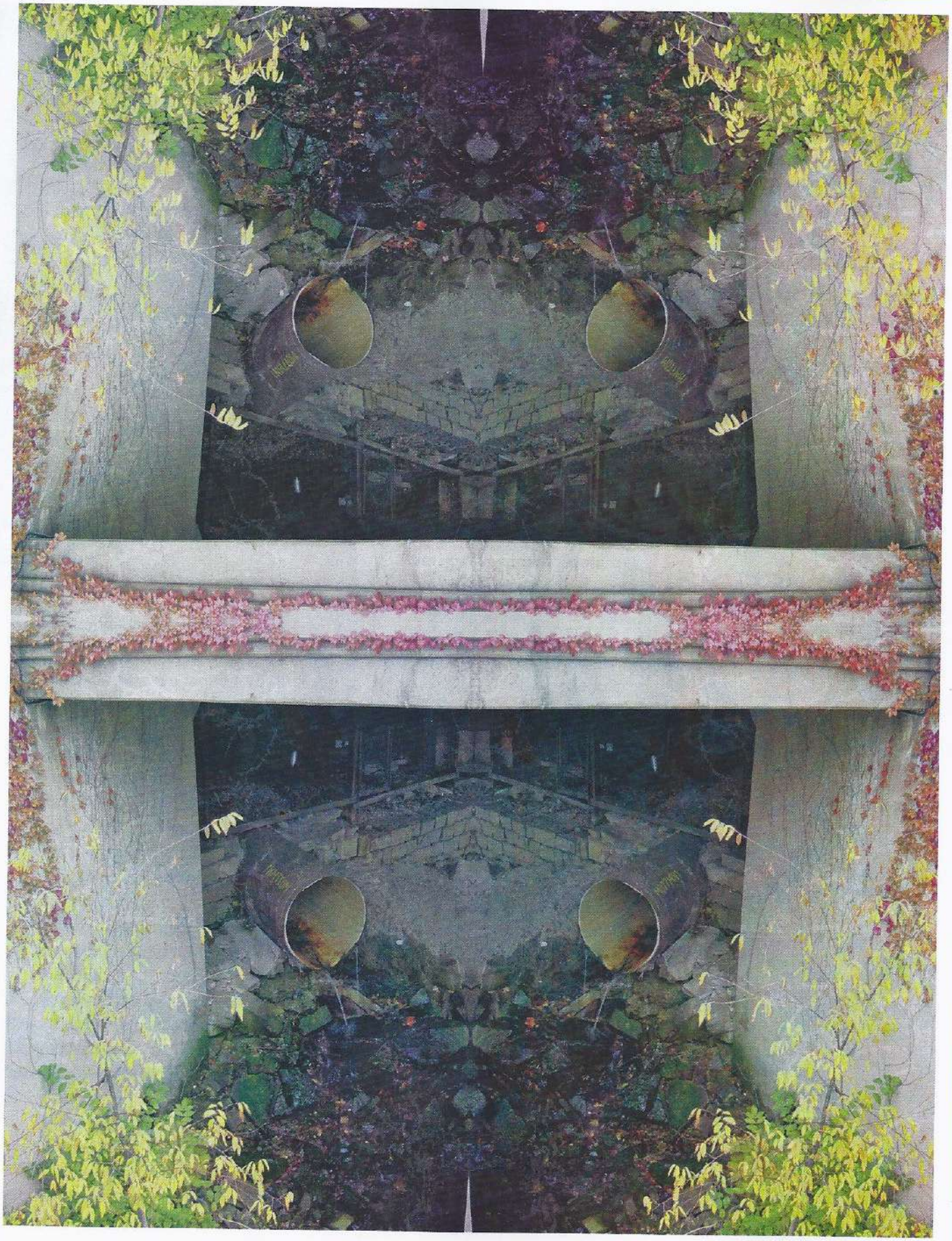
What was your biggest challenge? In geometry, if you're trying to find an angle and you're off by one degree, then you're wrong. You've got to be perfect. With my art, the angles also have to be perfect, or else your eye will go to the spot that doesn't line up.

Do you have any advice for aspiring artists? Art isn't the simplest thing in the world, so don't be afraid to ask for advice.

↑ Scholastic Art Award winner Carla Dusel.

"I start with patterns that already exist and bring them out so that everybody can see them."
–Carla Dusel

Carla won an Art Portfolio Silver Award from the 2009 *Scholastic Art & Writing Awards*. To find out more about this program, ask your teacher to call 212-343-6892, or go to **www.scholastic.com/artandwriting**.



Carla Dusel: Courtesy the artist; Carla Dusel, *Revenge*. Courtesy the artist.

Create a Tessellation

Transform simple squares into fantastic tessellating images

MATERIALS

- Reproductions of M.C. Escher's tessellations (for inspiration)
- 3"-x-3" Post-it notes
- No. 2 pencils
- Pencil sharpeners
- Vinyl erasers
- Tracing paper
- Newsprint
- Removable transparent tape
- Scissors or X-Acto knives
- 12" x 18" or larger 60 lb sulphite paper
- Colored pencils

You've seen in this issue how M.C. Escher created tessellations by changing geometric shapes into representational images. For this workshop, you'll transform a square into a representational image and use your creation to make a tessellation.

STEP 1 Transform the Square

Cut a piece out of the left side of a Post-it note. Mark where you plan to cut by drawing a line from the top left corner to the bottom left corner. The line can be curving, geometric, or both. Use scissors or an X-Acto knife to cut along the line.

To create a shape that will tessellate through translation (see Kat's and Elizabeth's tessellations), slide the cut-out piece to the right side of the Post-it and carefully attach it with tape. Repeat this process with the top and bottom sides. To create a shape that will tessellate through rotation (see Kim's and Kimberly's tessellations), rotate the cut-out piece clockwise onto an adjacent side and carefully tape it into place. Do the same for the two remaining sides. Experiment with making different shapes. Draw recognizable images inside of them. Images can resemble a person, an animal, or an object. **TIP: The simpler your shape, the easier it will be to turn it into a recognizable image.**

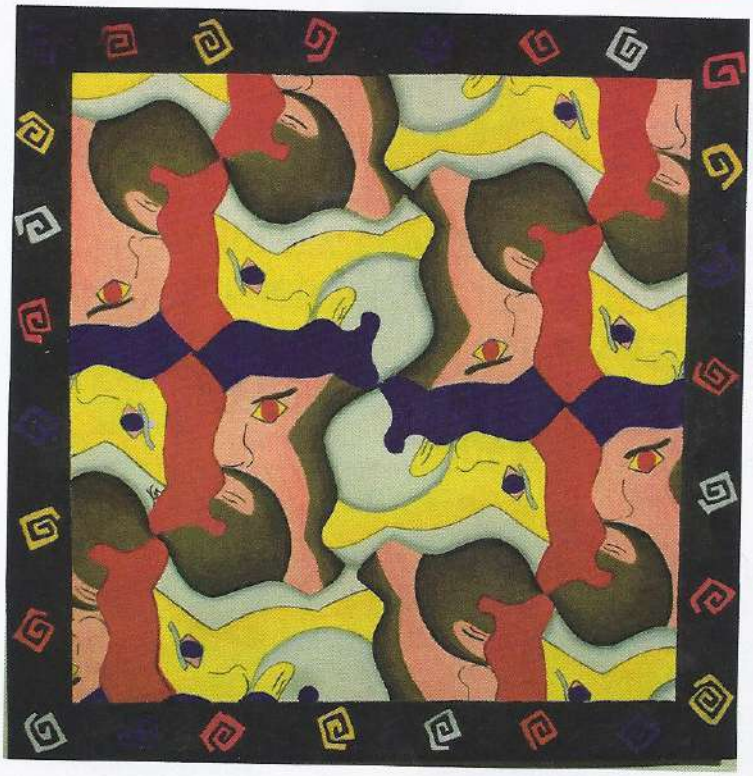
STEP 2 Tessellate

Place a scrap of tracing paper over the shape you'd like to tessellate, then trace the shape's outside edges and interior details. Turn the tracing paper over onto a sheet of newsprint and use a pencil to carefully trace your shape onto the tracing paper's underside. Turn the tracing paper over again and place it on a sheet of sulphite paper. Retracing your initial lines while pressing down firmly should transfer your shape onto the sulphite. When you're finished, slide or rotate the tracing paper into the next position and trace again. You can keep adding shapes until the entire sulphite page is covered, or leave patches of background exposed. **TIP: Taping the tracing paper down will prevent it from moving.**

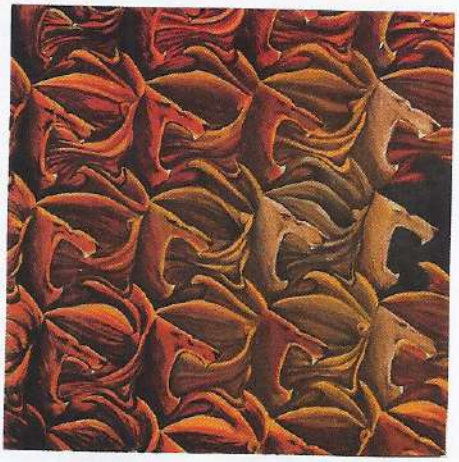
STEP 3 Add Color

Use colored pencils to add color to your tessellations. Use tracing paper if you

→ **Kim's Tessellation**
Kim created a shape that tessellates through **rotation.** She filled the border of her image with spinning spirals that **echo** the rotating heads inside.



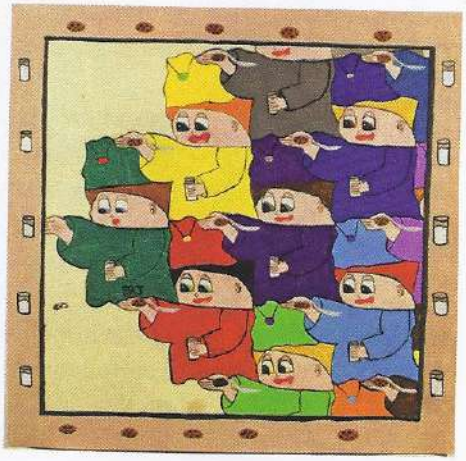
↓ **Kat's Tessellation**
Kat created a lion shape that tessellates through **translation.** Her lions seem to be rushing forward in the same direction. She left one area of **negative space** to focus the viewer's attention.



→ **Kimberly's Tessellation**
Kimberly created a butterfly shape that tessellates through **rotation.** Her simple blue background forms a nice contrast to the complex designs that decorate the butterflies.

want to experiment with different colors. Consider creating areas of solid color (see Elizabeth's tessellation), or blending colors to create gradations (see Kat's tessellation). If the colors don't provide enough contrast, consider adding outlines (see Elizabeth's tessellation). When you're done, crop your image to the desired size. **TIP: To keep colors clean, apply light colors before dark ones.**

→ **Elizabeth's Tessellation**
Like Kat's lions, Elizabeth's figures tessellate through **translation.** Like the lions, they also seem to be moving toward something: in this case, glasses of milk to go with their cookies.



Pattern Designer

Julia Rothman makes a living by creating patterns that decorate objects we see every day. Find out about her job and how she got started.

↓ How many different images did Julia use in each of the patterns below?

All photos and artwork on this page courtesy of Julia Rothman.

CAREER PROFILE: PATTERN DESIGNER

Salary: First-year pattern designers make an average of $34,000, depending on location and experience.

Education: Most pattern designers have a bachelor's degree in textiles or design.

Getting Started Now:

- Build a portfolio by making artwork for school events. "I always designed posters for school plays," says Julia.
- Meet working artists in your area who can advise you on applying to schools and internships. "Call or e-mail them," Julia says. "They'll probably be happy to talk to you."
- Use what you learn in other classes. "You might read something in history class that inspires you," says Julia. "You never know what will shape your art."

ART MAGAZINE: What is your job?
JULIA ROTHMAN: I design patterns for fabrics, stationery, and any other surface that can hold a pattern. I'm a freelancer, so I'm my own boss and work from home.

AM: How did you get started?
JR: In college, I built a portfolio by doing unpaid illustration work for a magazine. After college, I worked as a freelance illustrator. One of my clients asked me to design a pattern, and I loved doing it! Soon, I was making patterns for lots of clients.

AM: What is your design process?
JR: Let's say a client wants a robot pattern for a set of sheets. I'll draw some robots, scan the drawings into my computer, and arrange them into a basic tile shape. Then, I'll repeat the tile to create a pattern. The client will usually ask me to do some revision. Sometimes, clients are satisfied after just one revision. Other times, it takes five or six revisions to make them happy.

AM: What inspires you?
JR: The world around me is my biggest inspiration. If I see a bunch of chairs randomly pushed together, I'll probably go home and try to draw a pattern of the chairs.

AM: What skills do you need to succeed as a freelance designer?
JR: Nobody knows you exist unless you tell them, so you need to promote yourself. I send my patterns to companies I want to work for. You also have to be very focused. People tell me they could never work from home because they'd watch TV all day. But I get up early and start working. Sometimes I don't even change out of my pajamas first.

AM: What's the best part of your job?
JR: I love seeing my work on things. As a kid, I always noticed the patterns on sheets. I even traced them. I wondered who designed them, but never imagined that one day I'd be that person!

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