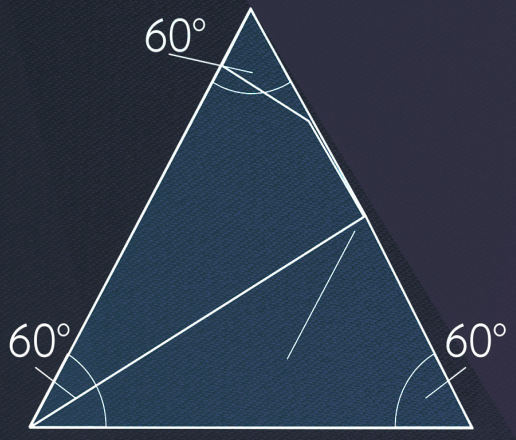
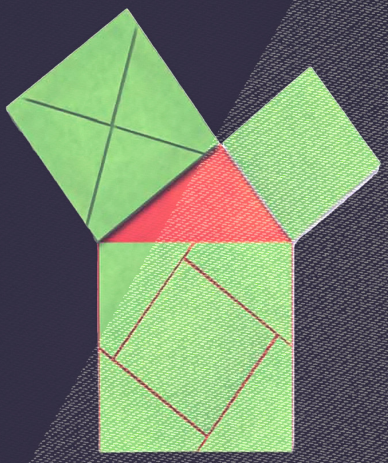
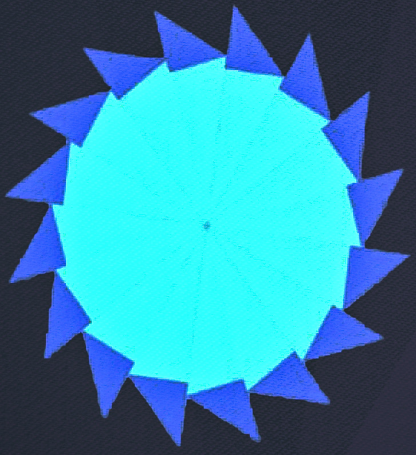
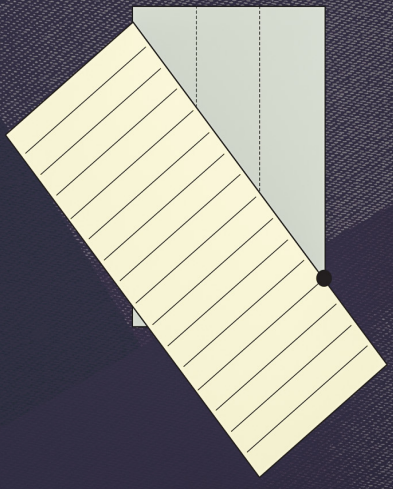
EXPLORE MATHEMATICS WITH ORIGAMI









Daniel Scher and
Marc Kirschenbaum

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Explore Mathematics with Origami

Daniel Scher & Marc Kirschenbaum

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The diagrams in this book were produced with Macromedia's Freehand, and image processing was done with Adobe Photoshop. The Backtalk family of typefaces was used for the body text. Futura was used for the cover and the headers.

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Introduction

For too many learners, mathematics is a jumble of rules and formulas designed for passive consumption. One of our favorite textbook authors, Harold Jacobs, challenges this notion by subtitling his geometry book, *Seeing, Doing, and Understanding*. These three words informed our goals for this collection. To "see" math is to make abstract concepts accessible by recasting them in visual terms. To "do" math requires active engagement, treating the subject like a science course where you perform experiments. And to "understand" math is to make sense of what you notice and wonder as you investigate.

Here we offer the ancient art of origami as a unifying framework for bringing all three aspects of math to life. Origami is a popular pastime where squares, and sometimes other shapes, are folded into animals, human figures, and decorative designs. What may not be apparent is that even simple origami models contain deep mathematical principles baked into their folding sequences. Experts in the field of origami math have used origami to design compact foldable kayaks, shape-shifting surgical robots, and an elegant folding structure for the James Webb Space Telescope.

Geometry is the focus of this collection. You'll learn about triangles, parallelograms, and rhombuses as you fold them from squares. You'll construct the classic Tangram shapes and use them to create and solve puzzles. With the help of classmates and friends, you'll make pentagonal tiles that fit together in surprising ways to cover a floor. And you'll sample other areas of mathematics, including statistics, probability, and exponential growth.

Origami directions are typically quite specific, with landmarks indicating where to place the creases. But in many of these projects, you are free to pick the locations of your folds. These choices help to convey the generality of mathematical results. "The angles of any triangle sum to 180°" may sound ho-hum, but if you and several friends each fold a random triangle and then compare the sums of their angles, it will likely be far more memorable – and amazing – to learn that your results are all the same.

We hope that this collection leaves you eager to delve deeper into the discoveries you make. The geometry textbooks cited in Recommended Reading are excellent resources for a more formal, proof-based introduction to the math.

So, grab some paper, start folding, and explore mathematics with origami!

Paper & Materials

Most of these projects are best done with origami paper. While it may be tempting to use ordinary copy paper or scrap paper, you will miss out on the patterns that form when your paper has a different color on each side. It is also convenient to have your folding materials already prepared as squares.

Fortunately, origami paper is easily found in hobby shops and online, including specialty origami sites (such as The Source, which is part of OrigamiUSA). It is sometimes sold as *kami*, which is the Japanese word for *paper*. The standard size is about six inches (or fifteen centimeters). This size is suitable for the majority of these projects. Most commonly you will find sheets that are white on the rear side and colored on the front – this will work well. Such paper is sometimes known as *duo* or *double-sided* kami.

You may find that the standard six-inch size is too large for the tilings if you choose to fold lots of tiles. For these, the seven centimeter variety may be more comfortable to manage (sold sometimes as three inches, but usually a bit shorter). Your other option is to cut a square in half both ways to yield four smaller squares.

Whenever a rectangle is needed, standard copy paper is ideal. Any paper that you would use for your printer should be an appropriate thickness.

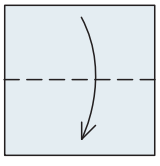
Aside from paper, other materials you'll need should be readily available in school or at home. These include a pair of scissors and a marking pen. For the tilings, you might want to keep some glue handy; any white glue or adhesive designed for paper will work. A less messy alternative is to use double-sided tape.

If you are artistically inclined, you may be curious about the materials used for the photos. Most were prepared with European wrapping paper, known as *kraft* paper, which is the German word for *strong*. Such paper commonly has a shadow stripe that creates a subtle texture. You can find this paper easily in Germany and other European countries, but it is unfortunately tougher to source elsewhere. Of course, other wrapping paper will also produce interesting results. Have fun experimenting with different materials.

Symbols & Terminology

Fold Forward

A dashed line with an open-headed arrow indicates to fold forward in the direction of the arrow. This is often called a v*alley fold* in books devoted to origami.



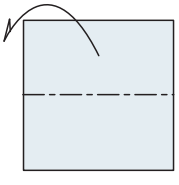
1. Fold forward in half.



2. Completed fold.

Fold Behind

A dashed line with dots along with a closed-headed arrow indicates to fold behind in the direction of the arrow. This is often called a m*ountain fold* in origami books.



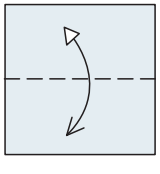
1. Fold behind in half.



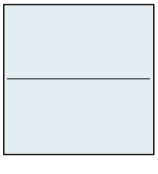
2. Completed fold.

Precrease

A *fold forward* line with a double-headed arrow indicates to p*recrease* (fold and then unfold in the direction of the open-headed arrow). The resulting crease is represented by a thin line.



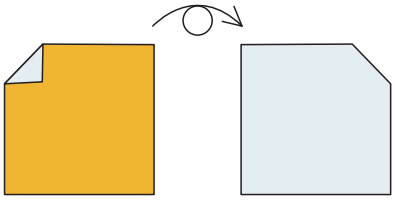
1. Precrease in half.



2. Completed *precrease*.

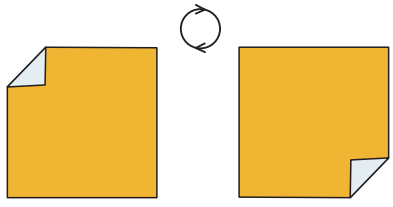
Turn Over

Turn over is indicated by a looped arrow.



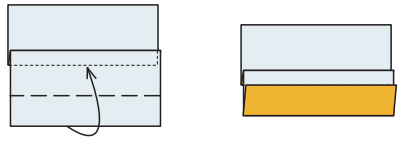
Rotate

Rotate is indicated by a circle with arrows along it.



Hidden / Imaginary Lines

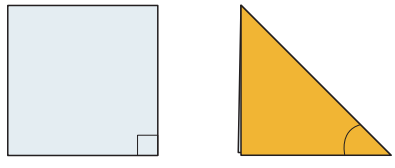
Hidden/imaginary lines are indicated by a thin dotted line.



1. Fold to the hidden edge.
2. Completed fold.

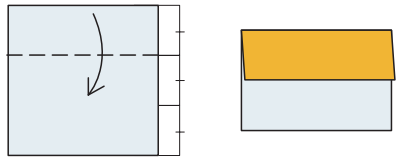
Angle Indicators

Angles are denoted by an arc, and in the case of 90°, by an L-shaped symbol.



Divided Brackets

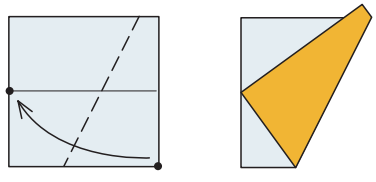
A *divided bracket* with tick marks shows equal divisions.



1. Fold along the 1/3 mark.
2. Completed fold.

Reference Dots

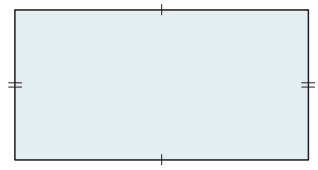
Dots are sometimes used to call attention to a specific landmark.



1. Fold the dotted corner to the dotted crease.
2. Completed fold.

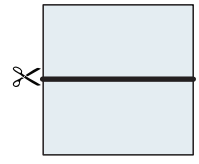
Tick Marks

Tick marks call attention to creases or sides of a shape that are equal in length. Single tick marks and double tick marks are used when there is more than one pair of equal lengths.

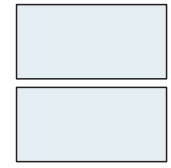


Cut

A heavy line with a scissors icon indicates to cut along that line.

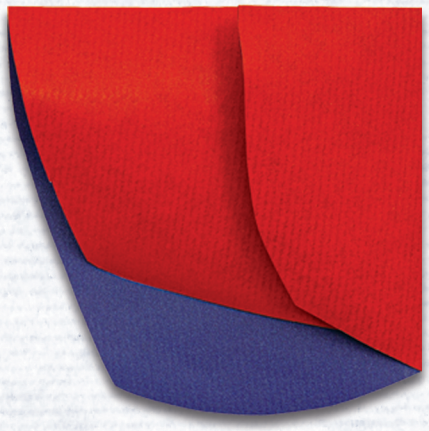


1. Cut the square in half.

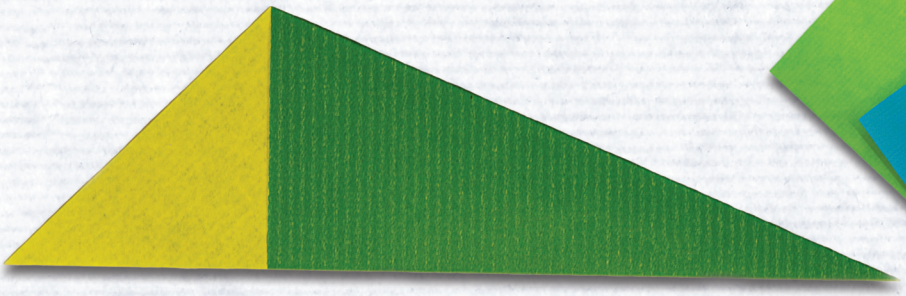


2. Completed *cut*.





Angles



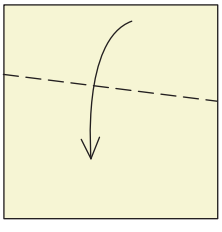




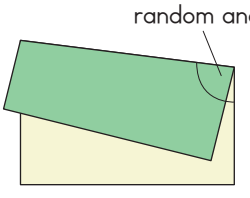


Right Angle

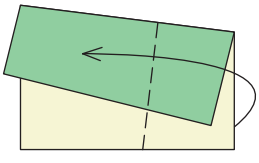
Right angles measure 90 degrees. From the corners of a book to the corners of a window to the corners of a room, right angles are all around us. They are the building blocks of geometric shapes like squares and rectangles and play a prominent role in trigonometry. This model demonstrates how to fold right angles.



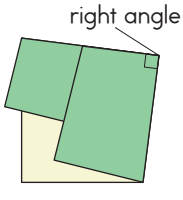
1. Begin with a square. Fold the top edge down at a random angle.



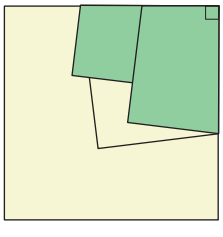
2. The random angle formed by your crease does not affect the process of folding a right angle.



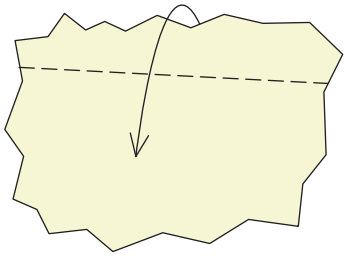
3. Fold the side over as much as desired, being sure to keep the top edges aligned.



4. The corner forms a right angle. This is indicated by the L-shaped right-angle symbol. Place your corner atop another square to see how the corners match up.



5. Since the corners of squares are right angles, the corner you created is also a right angle.



6. This works with any random shape (formed by tearing or cutting a sheet of paper). Fold the top edge down.