SCARAB AMULET
BEHIND THE DESIGN

Design geometries

Recall that a design geometry describes the restrictions of the angles and/or endpoints of the creases in a model's base. These limitations are intended to simplify the design process and folding sequence.

The most common design geometries and the sorts of models that usually get designed from them are:

- 22.5° geometry – crease angles are multiples of 22.5°. Many traditional bases fall into this category.
- Pure box pleating – crease angles are multiples of 45°. Useful for simple models and many inorganic subjects.
- Generalised box pleating – crease endpoints lie on a square grid. Suitable for many complex figures with fine details, and/or where stretches allow more efficient paper usage than pure box pleating.
- Hex pleating – crease endpoints lie on a triangular grid, which I'll refer to as a **hex grid**. Suitable for complex figures where the optimal arrangement happens to include angles that are close multiples of 30°.
- No restrictions. This allows for optimal arrangements and very specific shapes.

Other, less common, design geometries (such as ones restricting angles to 18°, 15°, or 11.25°, or rectangular grids) pop up occasionally, but generally don't have as many general sensible use cases (at least when starting from a square).

I usually have the smoothest design journey when I adhere to the vague suggestions above, but that's not a reason to limit yourself. For one thing, you'll often learn the most about why things have become the standard when you go against them. Plus, every situation is different, and you are unlikely to discover new things by trying what's been done before.

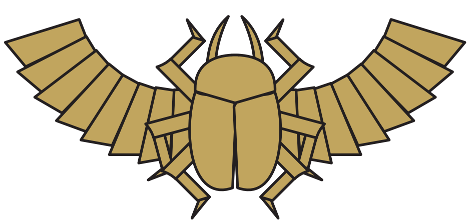
Hex pleating

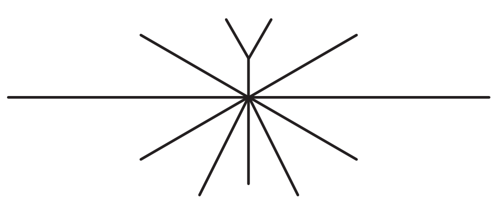
You might notice from my summary above that hex pleating is an outlier because it's hard to intentionally design a model where hex pleating is the most suitable design geometry. This is because it's very dependent on the arrangement for the subject in question.

Hex pleating is awkward for several reasons, as we'll discuss later. But if you want to learn origami design, you should be prepared for the situations when it does arise. In this chapter, we'll see an example of how hex pleating pops up naturally, and how to mitigate some of the complexities of hex pleating.

Scarab Amulet

There are lots of realistic origami insects, so let's try something a bit different. You can find ancient depictions of scarabs with wide wings in amulets and engravings, which is a unique origami subject (as far as I know). Sometimes the scarab is missing legs, but we'll go with all six here:





Left: Wide-winged scarab. Right: The scarab's tree.

The scarab's tree is pretty typical for an insect. But we're missing key information about the subject: if we want vertical pleats along the wings, then we need extra paper along the wings, which can be incorporated into the tree with a comb.

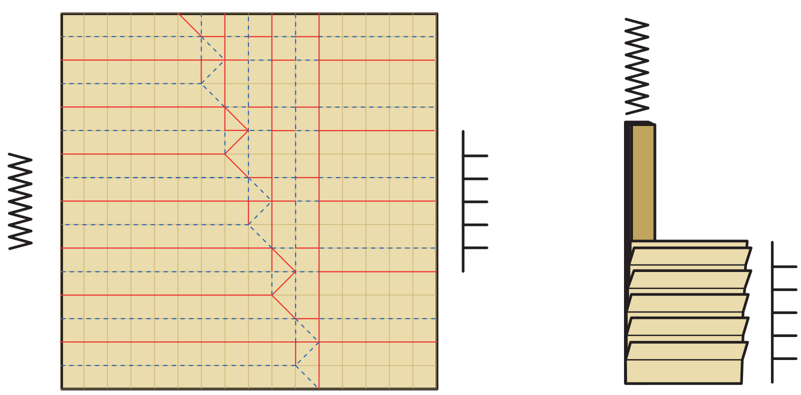
Left: Stick figure of a 1,2-comb. Right: The Scarab's tree, with combs along the wings to account for the extra paper needed for the pleats.

The bigger problem is that we need the wings to be wide all the way along the flap. Tree theory will underestimate the amount of paper needed for the wings, so these will need some special consideration. As these are also the largest flaps, the placement of the wings will be the dominant factor in considering the arrangement and, by extension, the design geometry of the model.

With this in mind, let's take a deeper look at some of the mathematics of combs.

Angled comb converters

In *Folding Fantasy: Volume 2*, we briefly saw a standard method for converting a 1,0-comb into a 1,1-comb. This is the technique used for making the wing feathers of the Phoenix (see steps 181 and 182 on page 83), and a simplified general form is shown below.

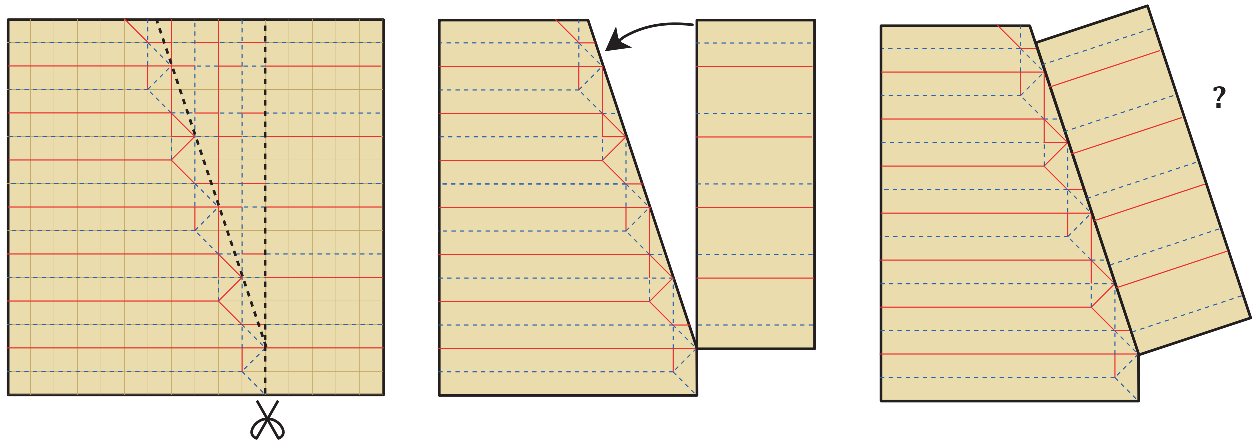


Crease pattern and folded model showing a common 1,0-comb to 1,1-comb converter.

The main issue with this crease pattern is that there are several vertical pleats (in the top centre of the crease pattern), which add thickness to the flap. These pleats make up over an eighth of the square's area above, so it may be worth seeing if we can find a more efficient alternative.

So where does this inefficiency come from? It's because the upper flaps of the 1,1-comb are much further from the pleats in the 1,0-comb than they need to be.

On the crease pattern, we can see a repeating pattern along a diagonal, which suggests that we might want to consider rotating the 1,1-comb on the right half of the crease pattern so that it aligns with this diagonal line instead. That would reduce the distance between the upper flaps of the comb.

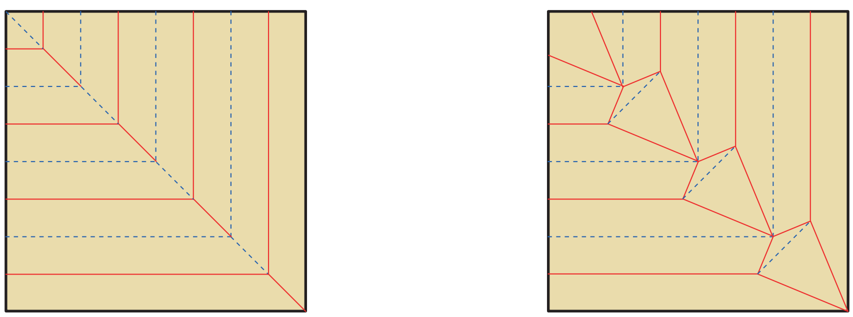


Cutting and rotating the combs to try to reduce the wasted paper between them. Is the crease pattern on the right usable?

The idea looks promising, but the crease pattern is not foldable. For one thing, we can see that the pleats don't align; this is because the repeating diagonal section has an irrational distance of $\sqrt{10}$, so integral pleats won't be suitable. Let's investigate other options to see what will work in general.

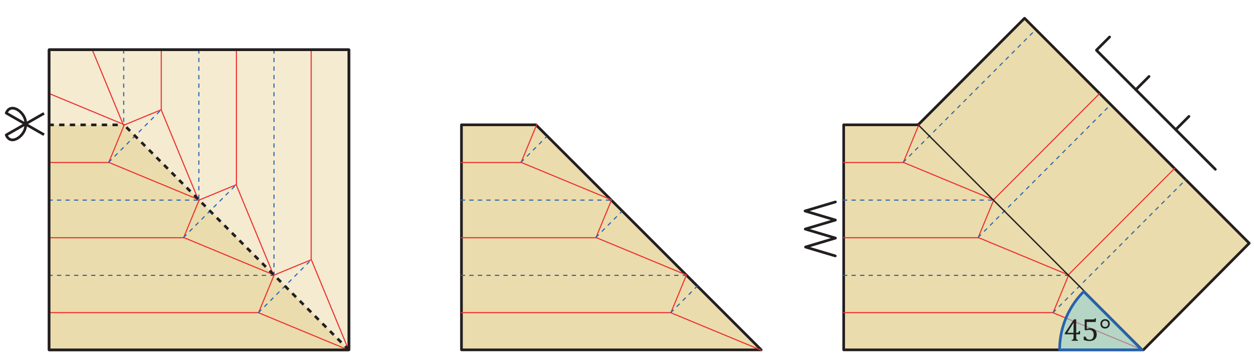
A 45° comb

A common type of flap in box pleated models is shown in the crease pattern on the left below. A frequently-used manipulation of the corners along the diagonal gives the comb on the right.



Left: A common box-pleated flap at a raw corner. Right: Spread-sinking along the diagonal and pulling out corners gives a comb and allows the layers to be spread symmetrically.

Currently, the pattern is symmetric along the diagonal, but we can remove the top right half and extend the fold-lines to make the comb more apparent. This also helps to analyse the comb numerically.



Extending the comb. This turns out to be approximately a 1,5-comb.