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Math 2590: Thinking Mathematically I
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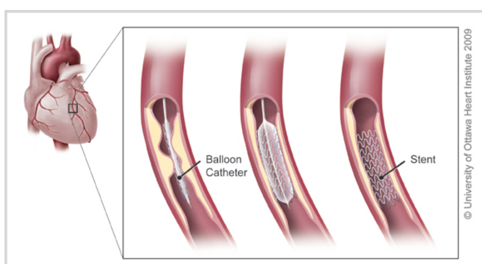
Finding Math in the Folds

Intro:

- Hello, this is Carmen Plank and Nicole Lee doing a podcast for Math 2590.

- What do a paper Blow Up Box and a Medical Stent have in common?

and



,
(Kuribayashi & You, 2003)

- They both use origami techniques!

- Not convinced?

- Over the next few minutes, we hope to show you how math has done its part in connecting the two!

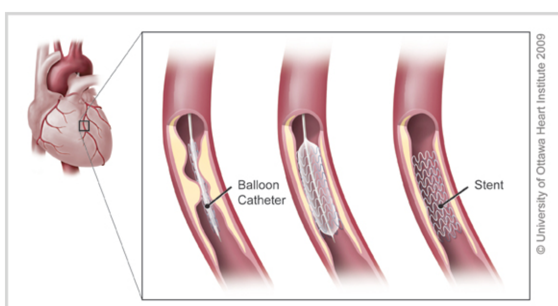
- Origami is an ancient traditional Japanese folk art of paper folding. A flat piece of paper is used to make a paper sculpture without cuts or glue.

(Crazy Frankenstein, N.D.)

- It has captured mathematicians' interests now because of new applications that have been discovered. An example of this is the origami blow up box.

(Origami mobile, 2010)

- The origami techniques involved in making the blow up box are particularly useful when an item is needed to occupy a small amount of space during transportation and/or storage,



- but is then required to easily expand to serve its purpose. Such items include stents in medicine. The stent is a tiny product that is put into a patient's artery in order to hold the collapsed or blocked artery open for optimal blood flow through that said artery.

Body:

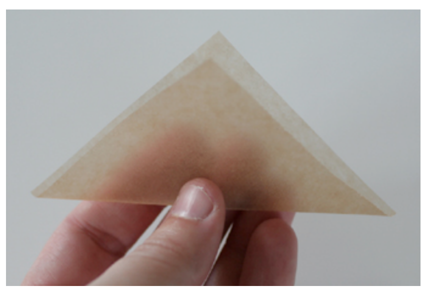
- All origami have mathematical characteristics in its crease patterns,

(Eveillard, N.D.)

that is to say the blueprint of the object you are making, assuming that the paper object you are making must be able to collapse into a flat format.

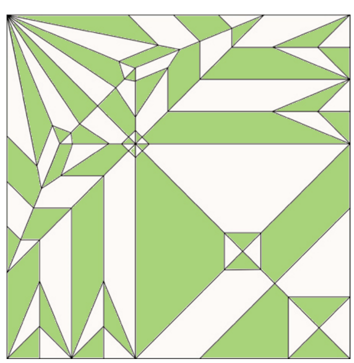
- There are 4 simple laws:

- One. Origami is made of stacking folds and sheets together. This is fairly self explanatory.



(Neuburger, 2008)

- Two. There are always an even number of areas created by any number of folds, which results in two-colourability.

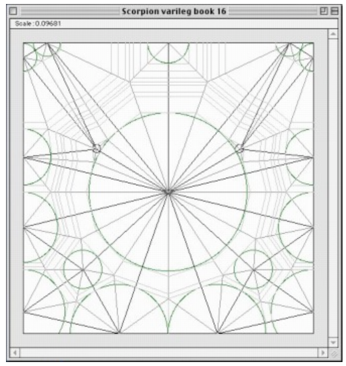


(Diaz, 2010, Photoshop alteration by Nicole Lee)

- Two-colourability means that if you colour the areas designated by the creases alternately with two different colours, it is possible that you will never have two areas of the same colour side-by-side.
- This is because you always create two areas with one fold, and there will always be an even number of areas due to symmetry and on one side of the crease can be coloured with one colour, the other can be the opposite colour.

(Diaz, 2010)

- Three. At any given vertex, the maximum difference between the number of mountain and valley folds is 2.
- Valley folds are creases formed by holding the bottom two corners and folding the paper away from you. When you lay the paper on a flat surface, it should resemble a valley. Mountain folds are creases formed by holding the corners at the top of the paper and folding the paper towards you. When on a flat surface, the crease should elevate, just like a mountain!
- If the difference between mountain and valley folds equals 3 or more, a 3D extension would be created, and the object will not collapse into a flat format.
- Four. All angles around the intersecting creases that have the same colour from the two-colourability rule will sum to 180 degrees.



(Lang, 2010)

- Let's try this. Draw a circle around any point of intersecting creases, and number the angles in the center of the circle starting from one and going around in order until you reach the angle you started at.

- Now, measure those numbered angles with a protractor.

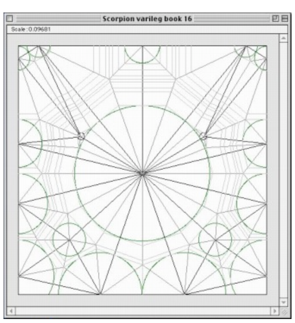
- If you add the odd numbered angles, the total sum of those odd numbered angles should be 180 degrees.

- Similarly, the sum of the even numbered angles should add up to 180 degrees.

- It means that, at any given vertex, all the angles add up to 360 degree circles.

- This rule of packing circles results in the structure being nice and symmetrical.

- If you look at the origami blueprint, it is made up of many circles, which revolve around the points that all fold lines converge into. Like this:



which, when folded will become:

(Lang, 2010)

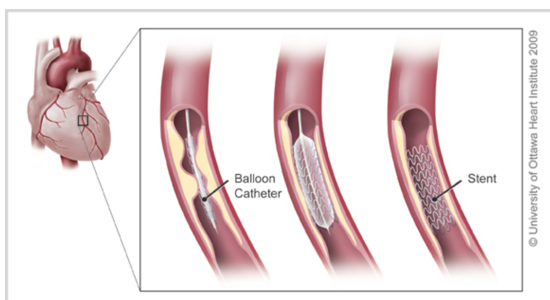
- Those are the underlying rules that govern all origami structures.

- Lets talk about the actual creases. There are seven folding techniques to determine where the fold will be (Hull, 2003). In other words, seven different ways to fold the paper and create a crease, seven, that's it! These techniques are called the seven Hazita-Justin Axioms (Hull, 2003). They lie beyond the scope of this presentation, but with the seven types of folds in combination with the four governing laws of crease patterns, you can create almost anything you would like!

or

(Lang, 2010)

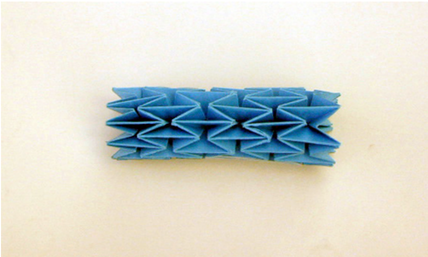
- Now, if we bring this now into the present day: Think of a stent.



- How does it fit so nicely through the patient's veins, but expand into full size once it reaches it's destination? As a matter of fact, when you have anything that needs to be small for transportation, but large when it reaches its destination, how does this work?

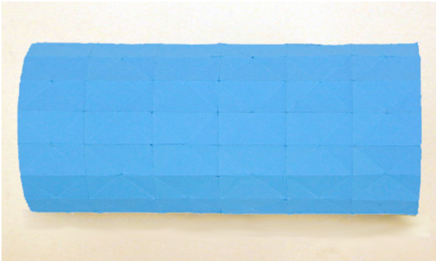
- You fold it!

- The little blow up box that we covered earlier was utilized in 2003 when Zhon You and Kaori Kuribayashi developed an origami stent,



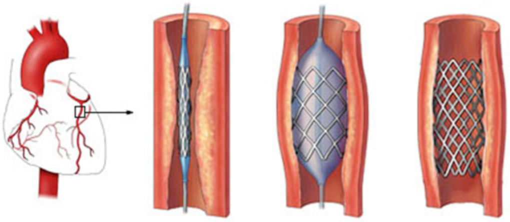
(Wertheim, 2005)

which, when enlarged,

,

(Wertheim, 2005)

could be used to unclog arteries and veins (Kuribayashi & You, 2003). Using the mathematics of the origami blow up balloon, the stint is able to travel through artery/ vein of a patient until it reaches the clogged site. When it reaches the clog, the stent is inflated to a larger diameter. As a result, it opens up the vein/artery allowing blood to flow through. This was put into action in 2005. But it was this piece of origami that allowed the stent to work!!



(University of Ottawa, 2009)

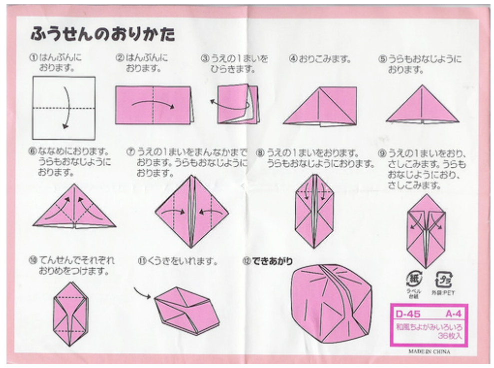
- Through our presentation, we covered the four governing laws of paper folding as well as seven types of possible folds. We hope to have shown you how something as simple as paper folding has quite complex mathematical principles governing its very being.

- We were surprised to find how an art form that was developed for its aesthetic beauty so long ago holds a greater purpose now. Moreover, that that purpose is potentially to save a life. We hope you enjoyed our presentation!

Thank you for listening! Until next time, Nicole and Carmen!

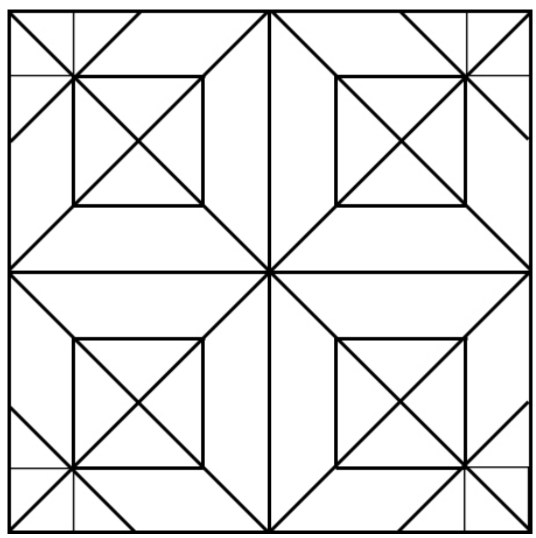
Equations After pod cast

1. i. Construct the 'blow up box' using the link: <http://www.youtube.com/watch?v=lvqIdQn90WQ> (Gh0stlee, 2010), or the image provided below



(Retrieved from <http://farm1.static.flickr.com /154/396055144_1f1c713bfa.jpg>

ii. Dismantle the Blow Up Box, you will need it for the succeeding exercises. It should look like this:



(Cred. Nicole Lee)

2. 2-Colourability. Fold the blow up box and then dismantle it. Using the crease patterns as your guide, colour the blueprint in 2 colours alternately. How many areas are there? How many folds? Why do you think the 2-colourability rule works?

3. Circle Packing. i) Draw a circle around an area of intersecting creases that you see. ii.) Number the angles inside the circle. iii) With your protractor, measure the angles within the circle, keeping track of the odd and even numbered angles.
   (a.) What is the pattern you notice? (b.) Why is this pattern important to any structure in origami?

4. Fold your square paper in half, and in half, and so on. If one fold creates two areas, and two folds create four areas, how many areas will be created for n lines? Keep in mind the symmetry of origami.

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