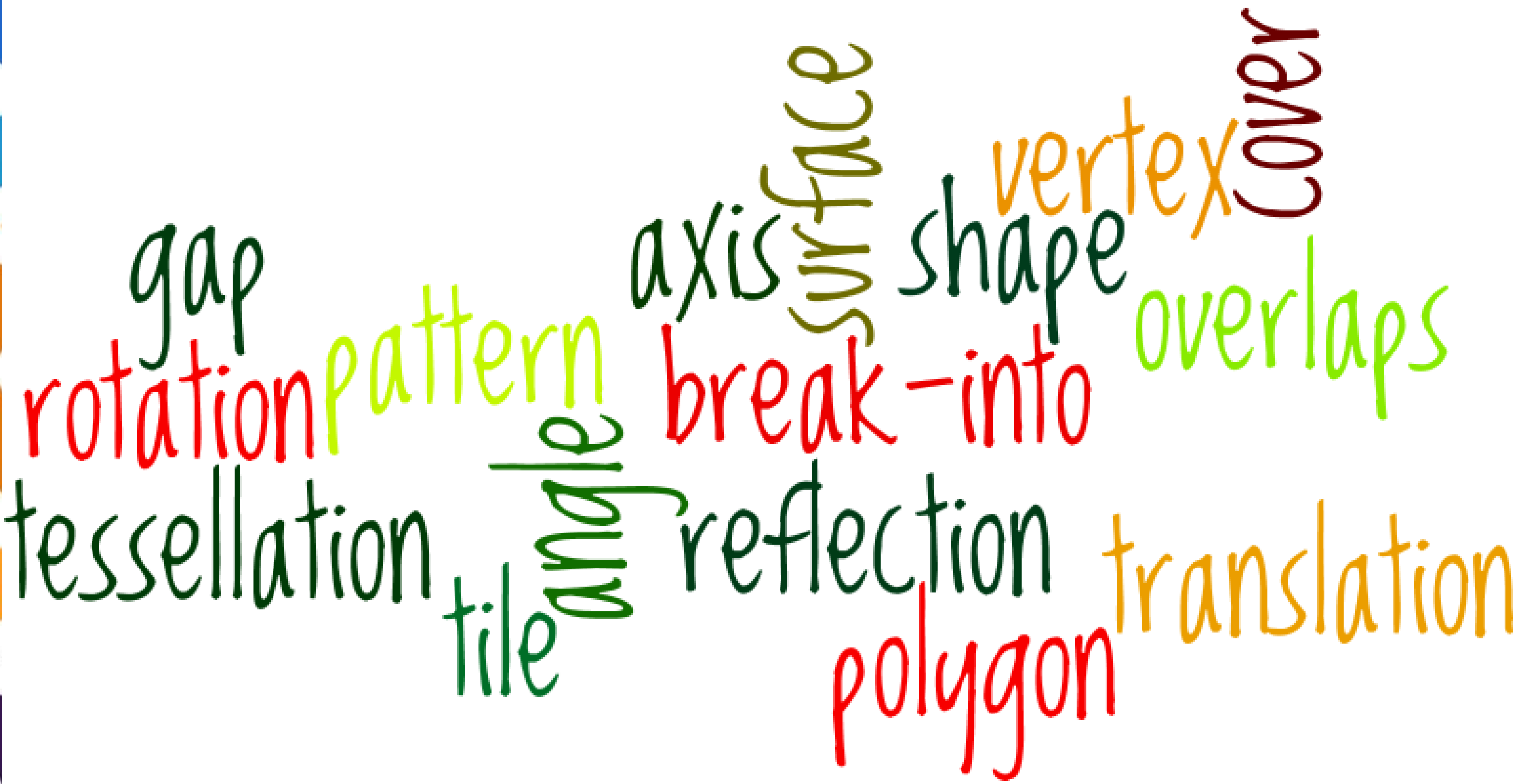
INTEGRATED UNIT 2: GEOMETRY IN THE ALHAMBRA

MOSAICS IN THE NASRID PALACE

KEY WORDS


gap
axis
surface
shape
vertex
cover
rotation
pattern
break-into
overlaps
angle
tessellation
reflection
translation
tile
polygon

GEOMETRY IN THE ALHAMBRA

Let's begin the unit watching the video:

"La Alhambra y las matemáticas"

GEOMETRY IN THE ALHAMBRA

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“La Alhambra y las matemáticas”

Let’s see some examples of mosaics you can find in the Alhambra

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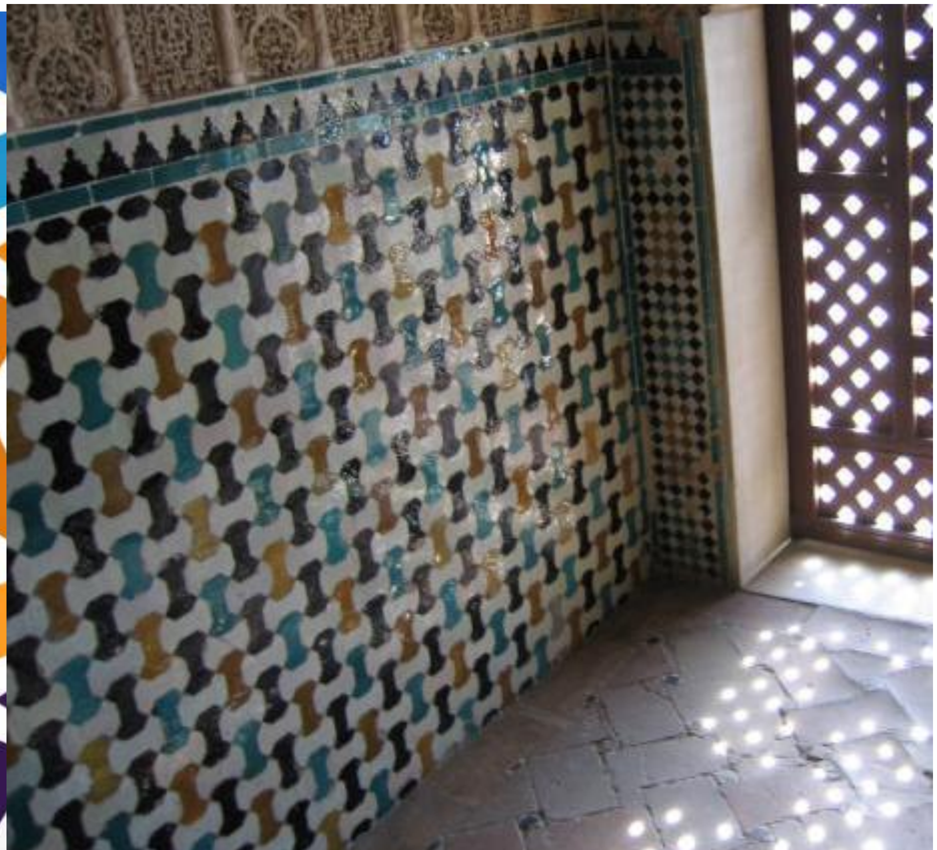

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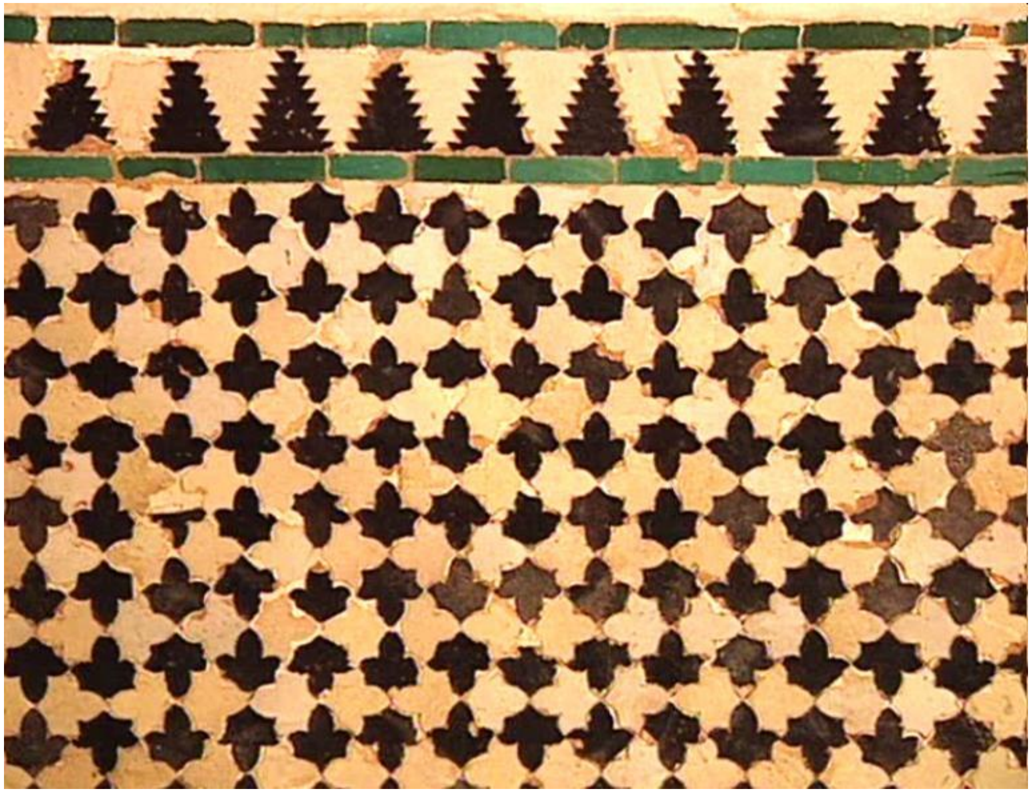

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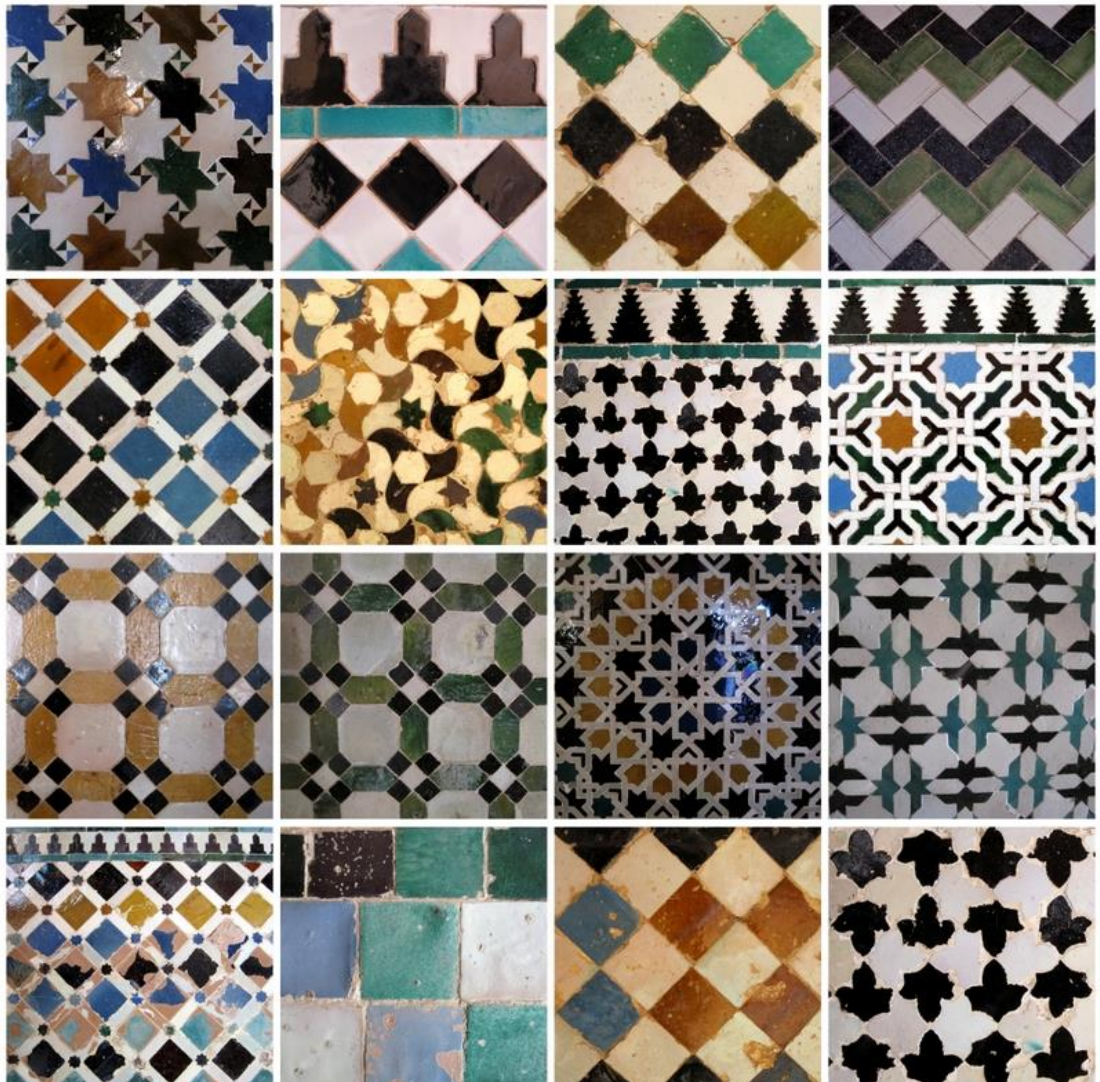

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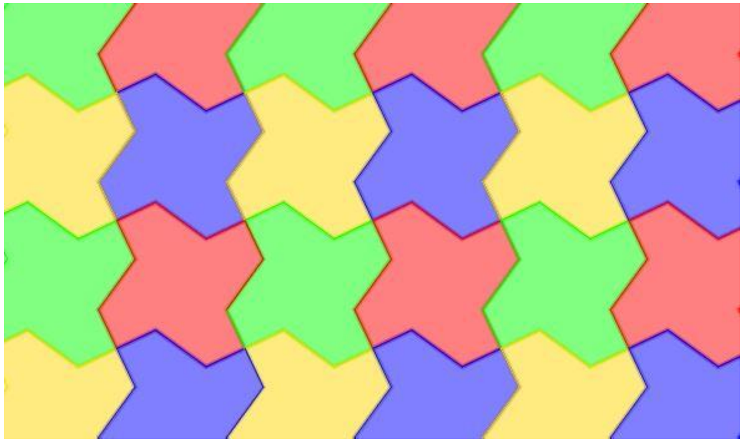

GEOMETRY IN THE ALHAMBRA

In this unit we will learn to construct some of these mosaics and, at the end…

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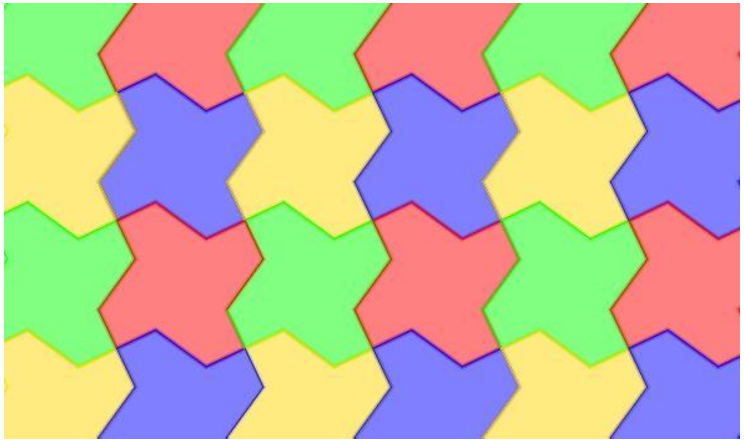

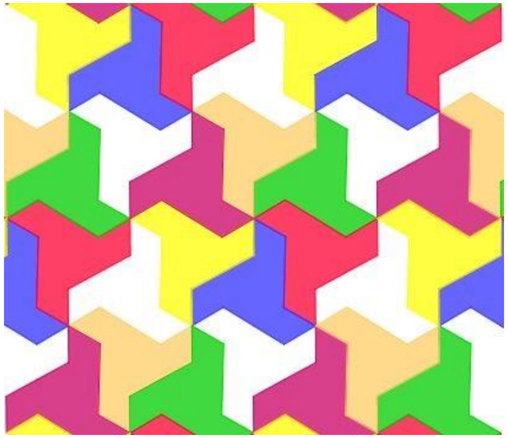

GEOMETRY IN THE ALHAMBRA

Now you know a few things about the relationship between the Alhambra and maths, but you need more information to be ready for this unit:

GEOMETRY IN THE ALHAMBRA

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1) ¿Por qué los árabes usaban tanto la geometría para las decoraciones de sus palacios?

2) ¿Cuál es el número áureo o de oro? ¿Por qué es tan importante?

3) ¿Qué es un rectángulo áureo? ¿En qué lugar de la Alhambra podemos encontrar rectángulos áureos?

GEOMETRY IN THE ALHAMBRA

El informe debe cumplir las siguientes características:

- Los formatos aceptados son: documento de texto (2 páginas como máximo) o presentación.
- Debe tener un título (piensa en uno original).
- Tamaño de letra 12.
- Las respuestas deben ir acompañadas por imágenes, dibujos o gráficos.
- Redacta tus respuestas, el simple “corta-pega” será penalizado.

TASK 2: WHAT IS A TESSELLATION?

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- **Activity 1**: Cover the space on the following rectangle by drawing polygons. Do it your own way. The only rule is to not leave gaps between the polygons.

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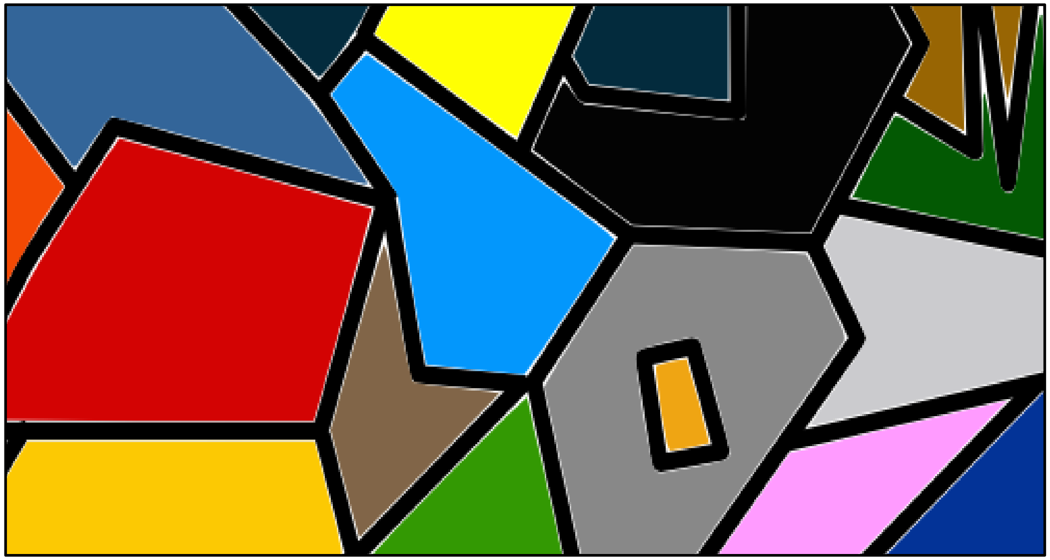
Here you are an example:



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- For practical reasons, for example, when you have to cover the ground with paving stone, it is easier and cheaper to get all the tiles having the same shape.
- When you cover a surface with a pattern of tiles with no gaps or overlaps, this is called a TESSELLATION or TILING.

What about if you use regular polygons?

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You can make tessellations by using …

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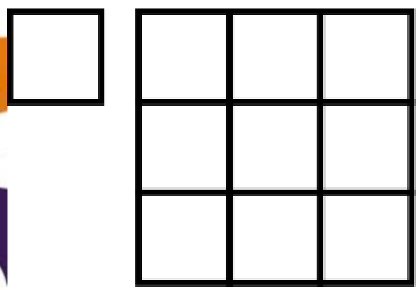
squares,



What about if you use regular polygons?

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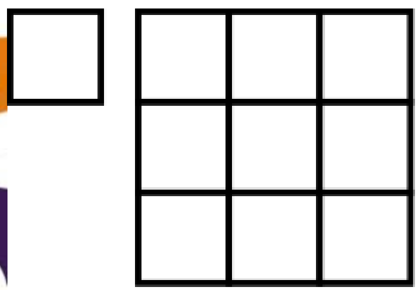
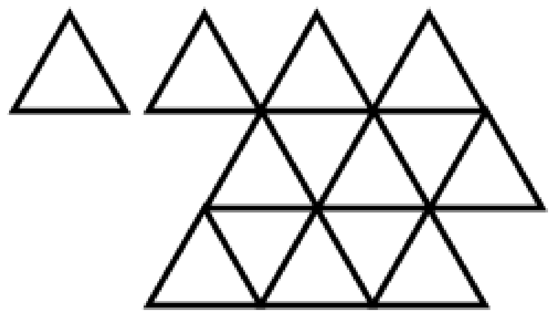
squares, equilateral triangles

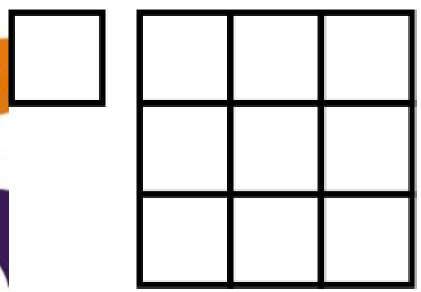


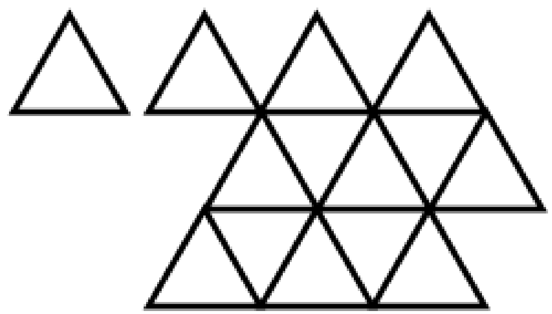


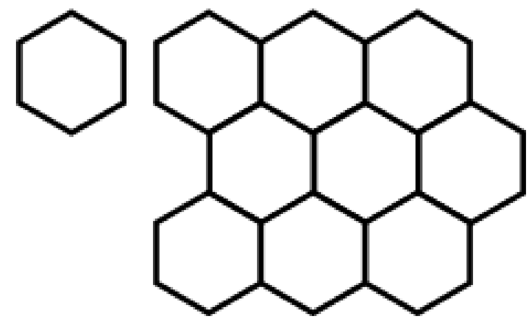
What about if you use regular polygons?

You can make tessellations by using …

squares, equilateral triangles and hexagons.







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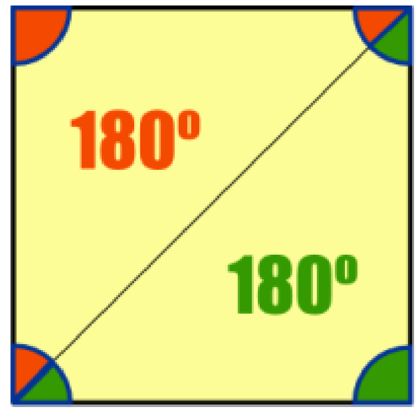

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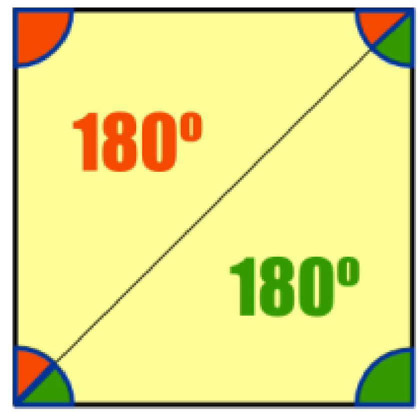

$$= 180^\circ + 180^\circ = 360^\circ$$

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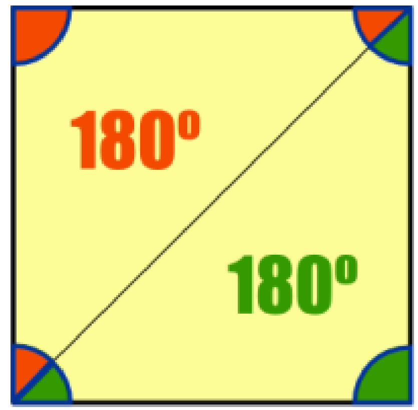

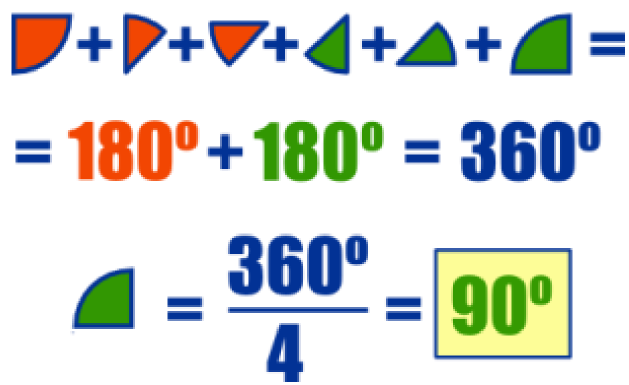

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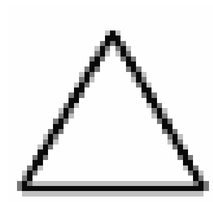
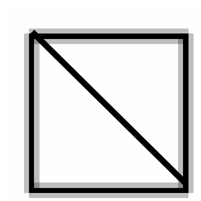
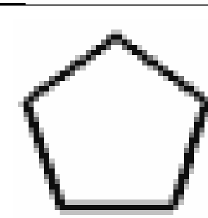
Complete this table and figure out a general rule.

Shape	**Sides**	**Break it into triangles**	**Sum of Interior Angles**	**Each Angle**
Triangle	3		180°	60°
Square				
				

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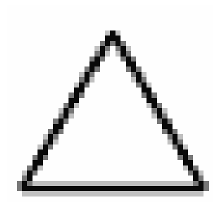
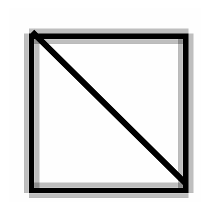
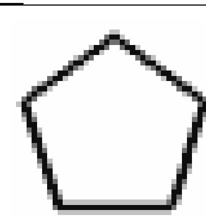
Triangle	3		180°	60°
Square	4			
				

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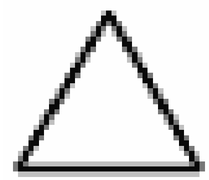
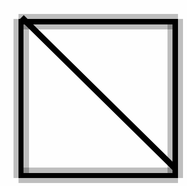
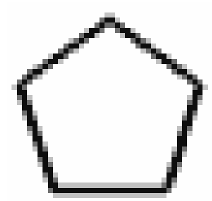
Triangle	3		180°	60°
Square	4		$2 \cdot 180° = 360°$	
				

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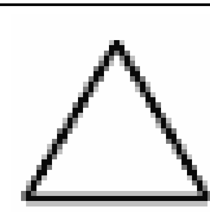
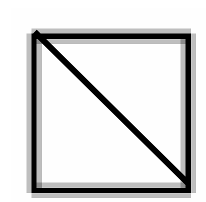
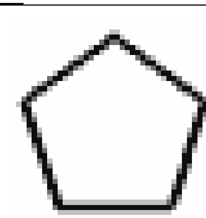
Triangle	3		180°	60°
Square	4		2·180° = 360°	360°/4 = 90°
				

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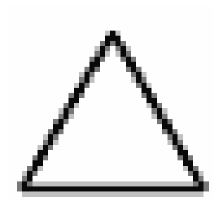
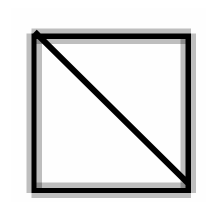
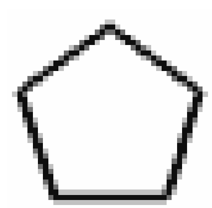
Triangle	3		180°	60°
Square	4		$2\cdot180° = 360°$	$360°/4 = 90°$
Pentagon				

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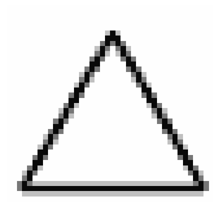
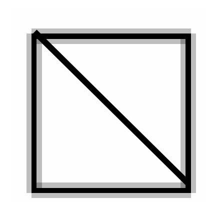
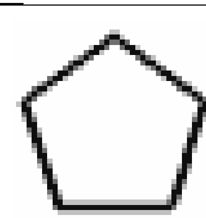
Triangle	3		180°	60°
Square	4		$2 \cdot 180^\circ = 360^\circ$	$360^\circ/4 = 90^\circ$
Pentagon	5			

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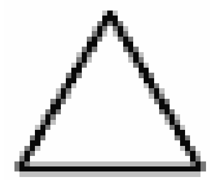
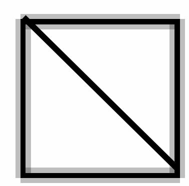
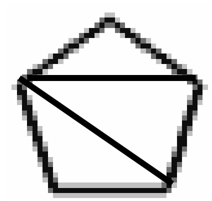
Triangle	3		180°	60°
Square	4		$2 \cdot 180° = 360°$	$360°/4 = 90°$
Pentagon	5			

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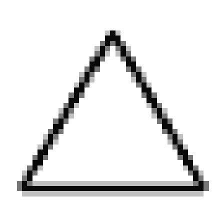
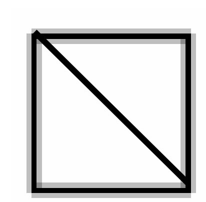
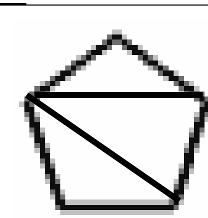
Triangle	3		180°	60°
Square	4		2·180° = 360°	360°/4 = 90°
Pentagon	5		3·180° = 540°	

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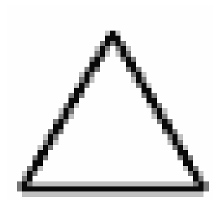
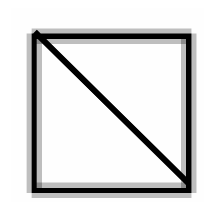
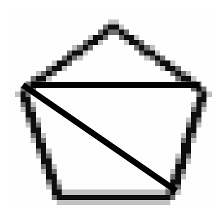
Triangle	3		180°	60°
Square	4		$2 \cdot 180^\circ = 360^\circ$	$360^\circ/4 = 90^\circ$
Pentagon	5		$3 \cdot 180^\circ = 540^\circ$	$540^\circ/5 = 108^\circ$

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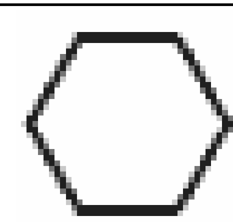
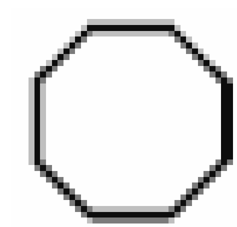
Hexagon				
Octagon				
…	…	…	…	…
Any Polygon	n			

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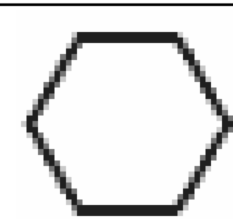
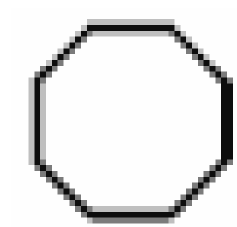
Shape	Sides	Break it into triangles	Sum of Interior Angles	Each Angle
Hexagon	6			
Octagon				
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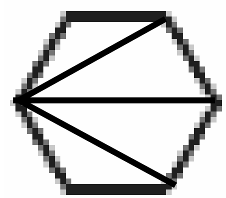
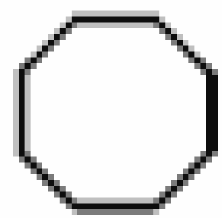
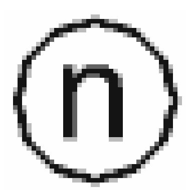
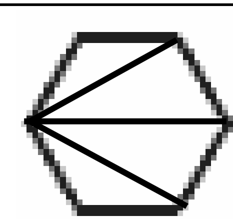
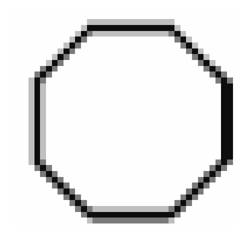
Hexagon	6			
Octagon				
…	…	…	…	…
Any Polygon	n			

- What are the interior angles of the regular polygons?

Complete this table and figure out a general rule.

Shape	**Sides**	**Break it into triangles**	**Sum of Interior Angles**	**Each Angle**
Hexagon	6		$4 \cdot 180 = 720^{\circ}$	
Octagon				
…	…	…	…	…
Any Polygon	n			

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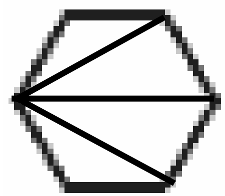
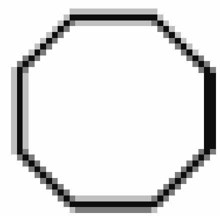
Hexagon	6		4·180 = 720°	720°/6 = 120°
Octagon				
…	…	…	…	…
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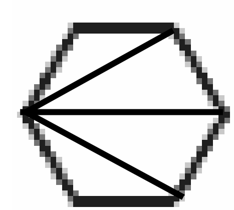
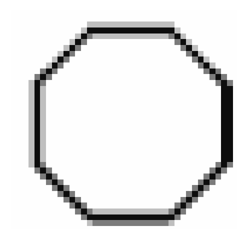
Hexagon	6		$4 \cdot 180 = 720°$	$720°/6 = 120°$
Octagon	8			
…	…	…	…	…
Any Polygon	n			

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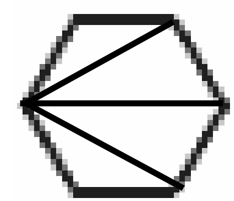
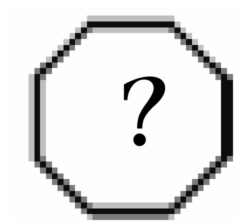
Shape	**Sides**	**Break it into triangles**	**Sum of Interior Angles**	**Each Angle**
Hexagon	6		$4 \cdot 180 = 720^\circ$	$720^\circ/6 = 120^\circ$
Octagon	8			
…	…	…	…	…
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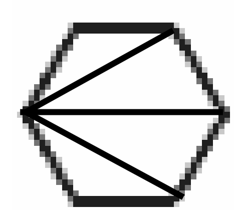
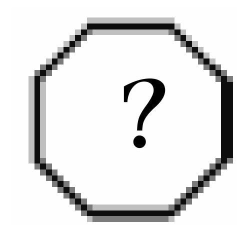
Shape	**Sides**	**Break it into triangles**	**Sum of Interior Angles**	**Each Angle**
Hexagon	6		4·180 = 720°	720°/6 = 120°
Octagon	8		6·180° = 1080°	
…	…	…	…	…
Any Polygon	n			

- What are the interior angles of the regular polygons?

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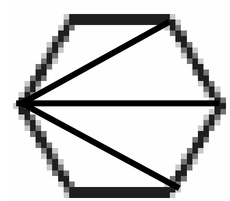
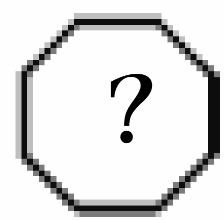
Shape	**Sides**	**Break it into triangles**	**Sum of Interior Angles**	**Each Angle**
Hexagon	6		4·180 = 720°	720°/6 = 120°
Octagon	8		6·180° = 1080°	1080°/8 = 135°
…	…	…	…	…
Any Polygon	n			

- What are the interior angles of the regular polygons?

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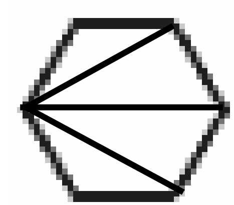
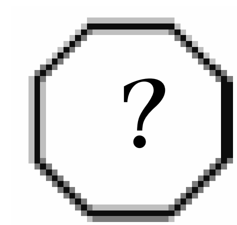
Shape	Sides	Break it into triangles	Sum of Interior Angles	Each Angle
Hexagon	6		$4 \cdot 180 = 720^{o}$	$720^{o}/6 = 120^{o}$
Octagon	8		$6 \cdot 180^{o} = 1080^{o}$	$1080^{o}/8 = 135^{o}$
…	…	…	…	…
Any Polygon	n		$(n-2) \cdot 180^{o}$	

- What are the interior angles of the regular polygons?

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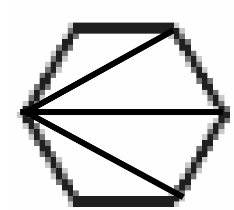
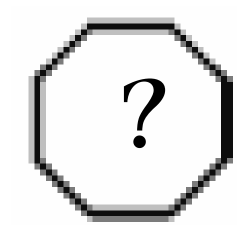
Shape	Sides	Break it into triangles	Sum of Interior Angles	Each Angle
Hexagon	6		$4\cdot180 = 720^\circ$	$720^\circ/6 = 120^\circ$
Octagon	8		$6\cdot180^\circ = 1080^\circ$	$1080^\circ/8 = 135^\circ$
…	…	…	…	…
Any Polygon	n		$(n-2)\cdot180^\circ$	$(n-2)\cdot180^\circ/n$

- What are the interior angles of the regular polygons?

So the general rule is:

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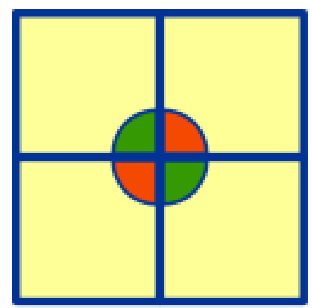
So what happen if we get together regular polygons to make a tessellation?



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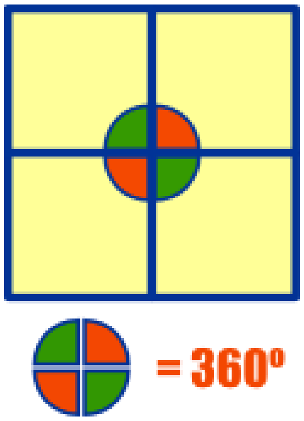

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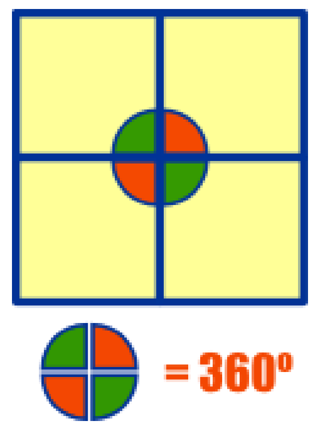

- The addition of the interior angles of the polygons that share one vertex must be 360º.

Then it is impossible to use any other regular polygons but squares, equilateral triangles and hexagons

Then it is impossible to use any other regular polygons but squares, equilateral triangles and hexagons because the only ones whose interior angles are divisors of 360º are:

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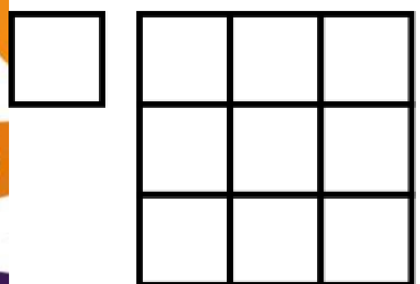
squares



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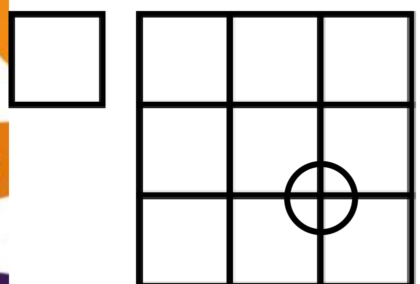

$90^\circ \cdot 4 = 360^\circ$

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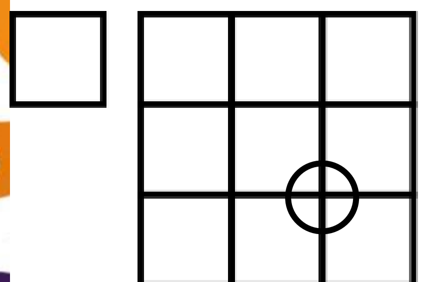
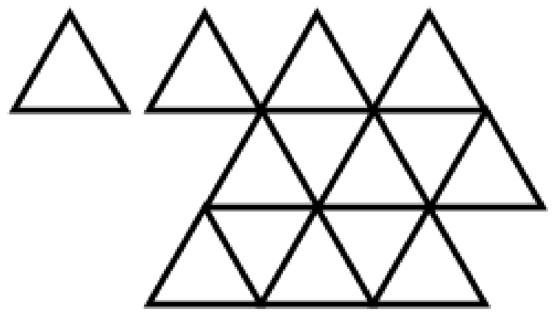


equilateral triangles



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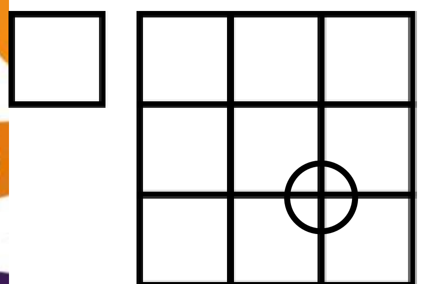

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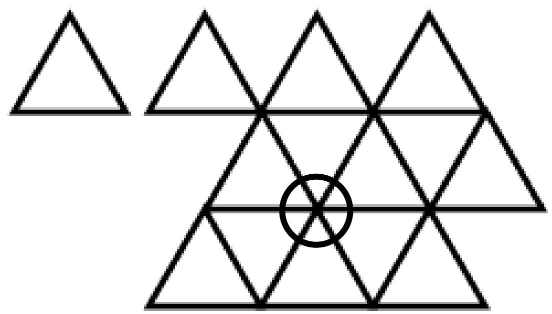

$60^\circ \cdot 6 = 360^\circ$

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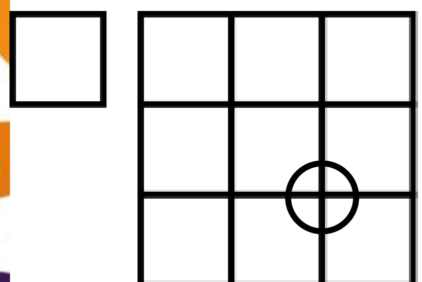
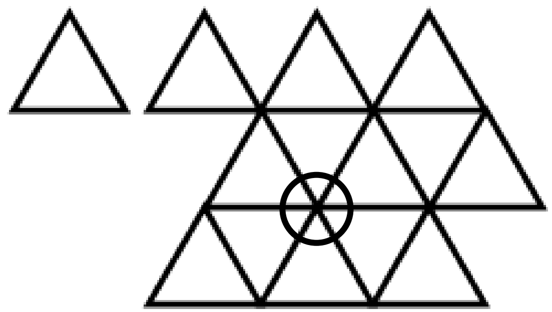
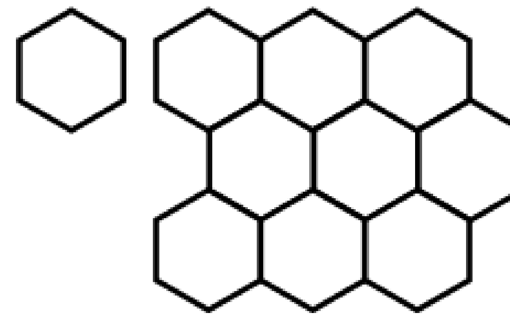
squares



equilateral triangles



and hexagons

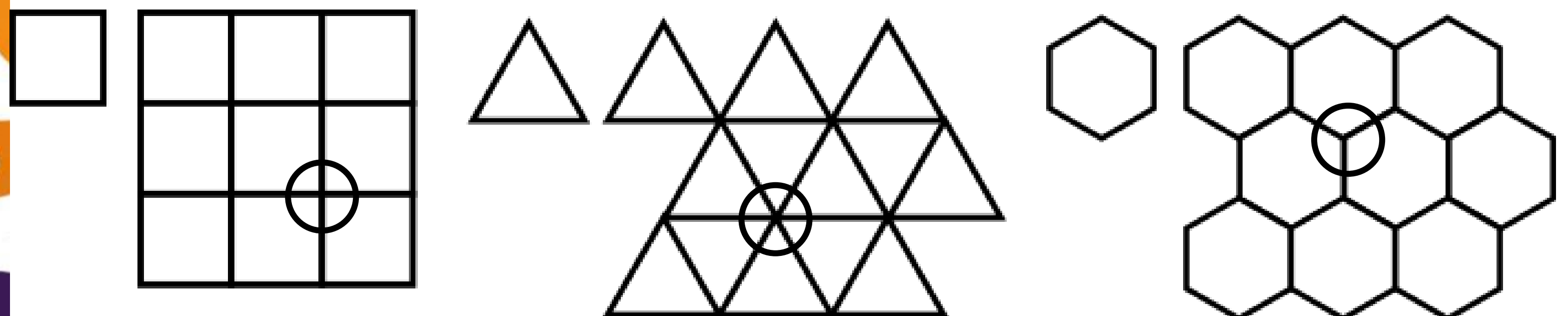


$90^\circ \cdot 4 = 360^\circ$

$60^\circ \cdot 6 = 360^\circ$

Then it is impossible to use any other regular polygons but squares, equilateral triangles and hexagons because the only ones whose interior angles are divisors of 360º are:

squares | equilateral triangles | and hexagons



$90^{\circ} \cdot 4 = 360^{\circ}$ | $60^{\circ} \cdot 6 = 360^{\circ}$ | $120^{\circ} \cdot 3 = 360$

- Activity 3: Geometric transformations

Let's watch this video:

[Colin Dodds - Geometric Transformations (Math Song)]

- Activity 3: Geometric transformations

Let's watch this video:

Colin Dodds - Geometric Transformations (Math Song)

These are geometric transformations:

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

ROTATION

"turn it 'round"

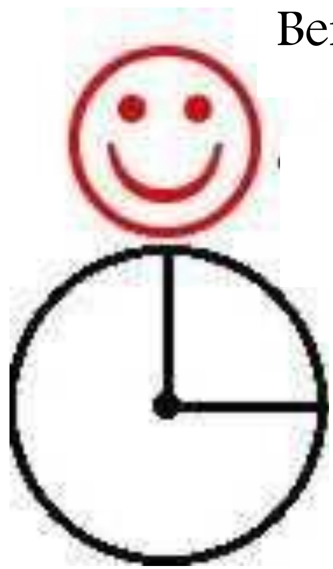
ROTATION

“turn it 'round”

ROTATION

"turn it 'round"

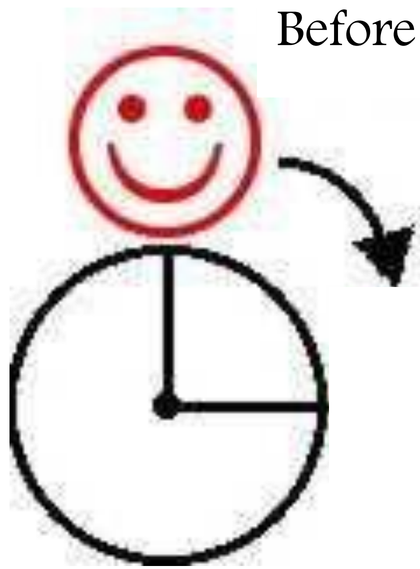
Before rotation



ROTATION

“turn it 'round”

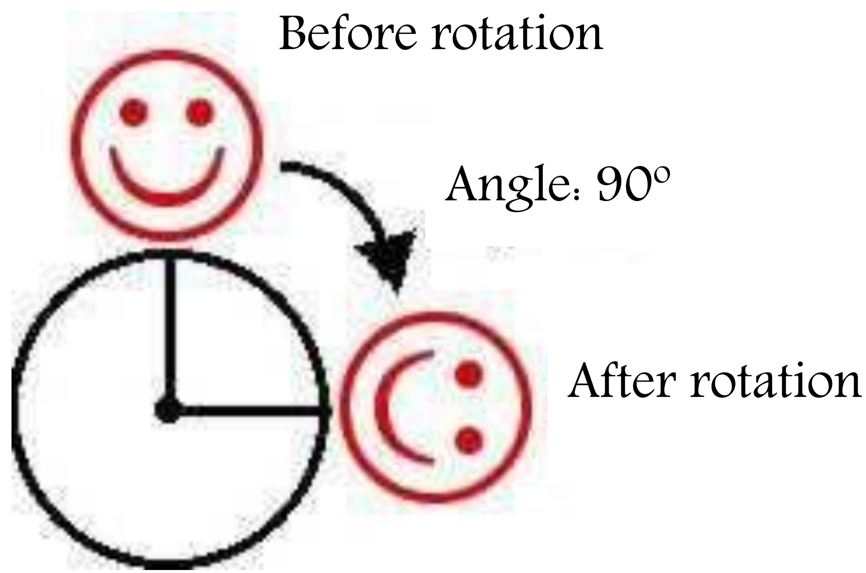
Before rotation



Angle: 90°

ROTATION

"turn it 'round"



TRANSLATION

"shift it left, right, up, or down"

TRANSLATION

"shift it left, right, up, or down"

TRANSLATION

"shift it left, right, up, or down"

TRANSLATION →

"shift it left, right, up, or down"

TRANSLATION

"shift it left, right, up, or down"

TRANSLATION

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TRANSLATION

"shift it left, right, up, or down"

TRANSLATION

"shift it left, right, up, or down"

↓

TRANSLATION

"shift it left, right, up, or down"

TRANSLATION

"shift it left, right, up, or down"

Before translation

TRANSLATION

"shift it left, right, up, or down"

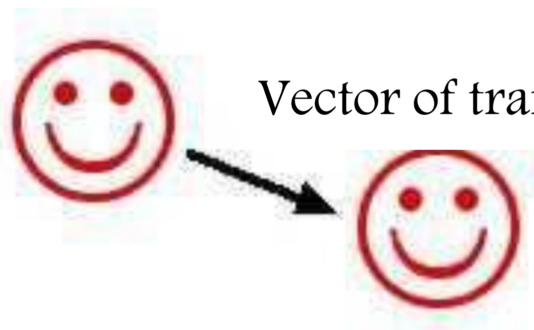
Before translation

Vector of translation

TRANSLATION

"shift it left, right, up, or down"

Before translation



Vector of translation

After translation

REFLECTION

"copy it across an axis of symmetry"

REFLECTION

"copy it across an axis of symmetry"

REFLECTION

"copy it across an axis of symmetry"

"copy it across an axis of symmetry"

REFLECTION

REFLECTION

“copy it across an axis of symmetry”

Before reflection 

-

REFLECTION

"copy it across an axis of symmetry"

Before reflection 

Axis of symmetry

REFLECTION

“copy it across an axis of symmetry”

Before reflection 

Axis of symmetry

 After reflection

Now answer the questions about geometric transformations on the worksheets.

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

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The ancient artisans knew the restriction about the regular polygons and tried to make prettier tessellations by…

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- using different colours

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

The ancient artisans knew the restriction about the regular polygons and tried to make prettier tessellations by…

- using different colours
- making some distortion to the original tile

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

The ancient artisans knew the restriction about the regular polygons and tried to make prettier tessellations by…

- using different colours
- making some distortion to the original tile
- repeating it alongside the whole surface

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

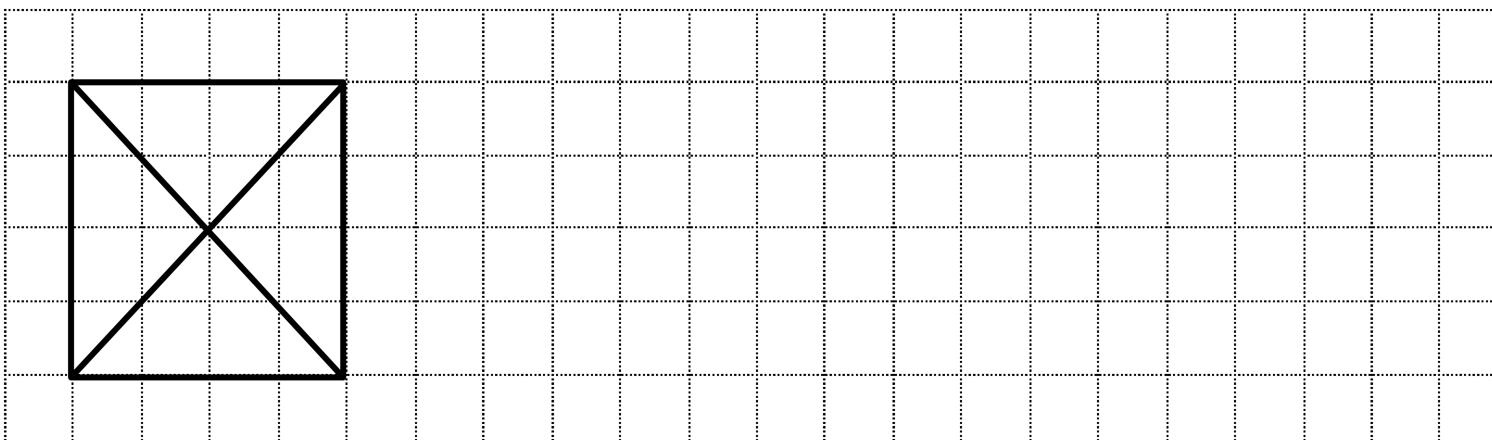
Take a look at this video to find out how the “hueso nazarí” is constructed and repeat the construction

http://concurso.cnice.mec.es/cnice2006/material105/Mosaicos/hueso.htm

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

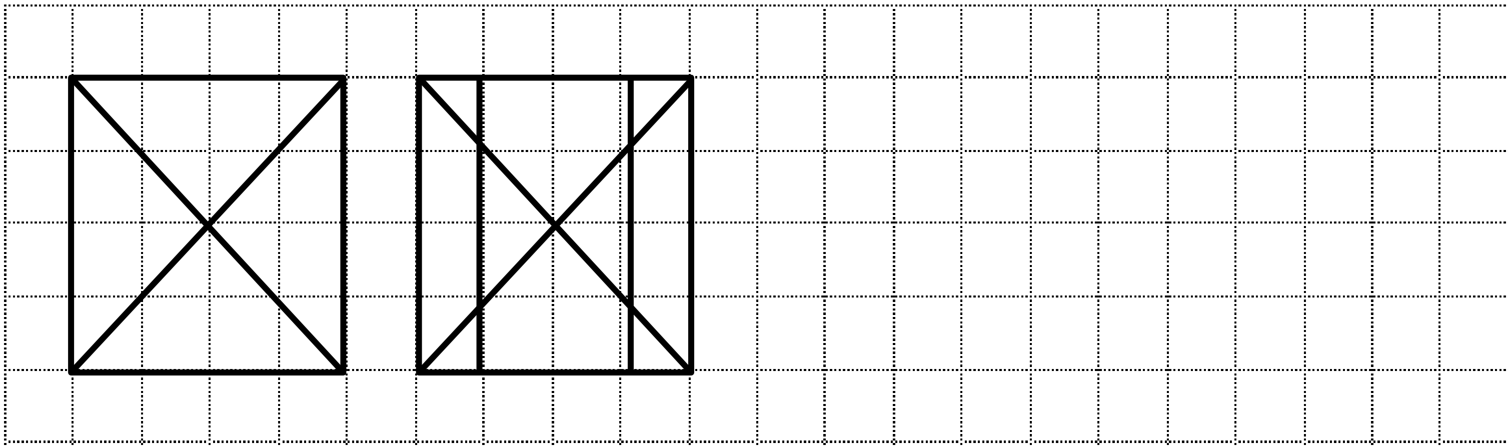
1) Draw the diagonals of the square:



TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

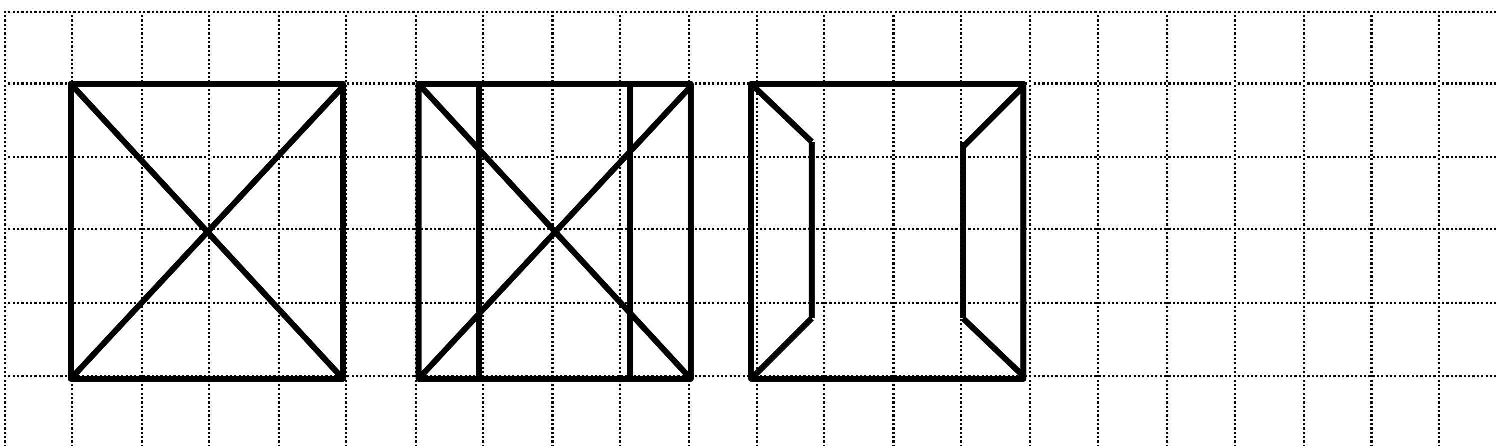
2) Draw two parallel lines to the sides:



TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

3) Remove some lines:



TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: "El hueso nazarí"

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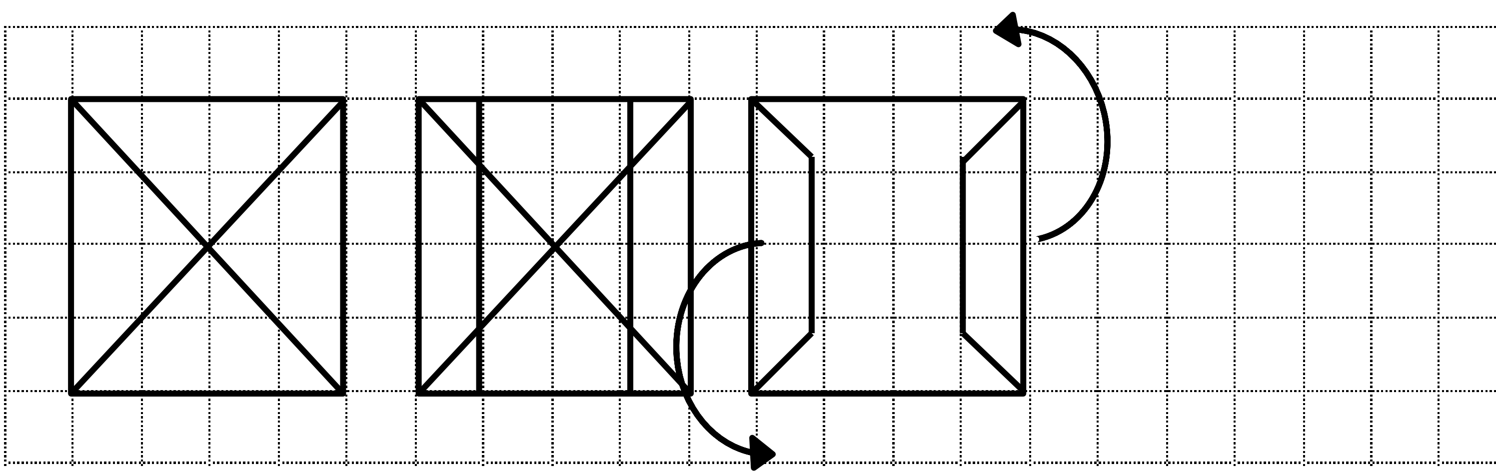
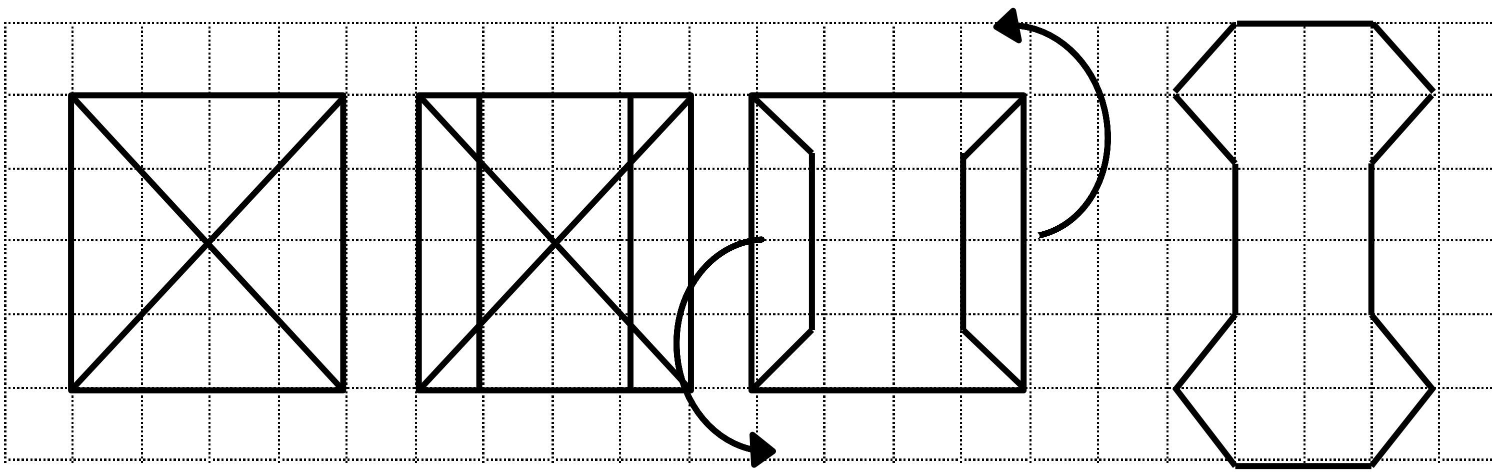
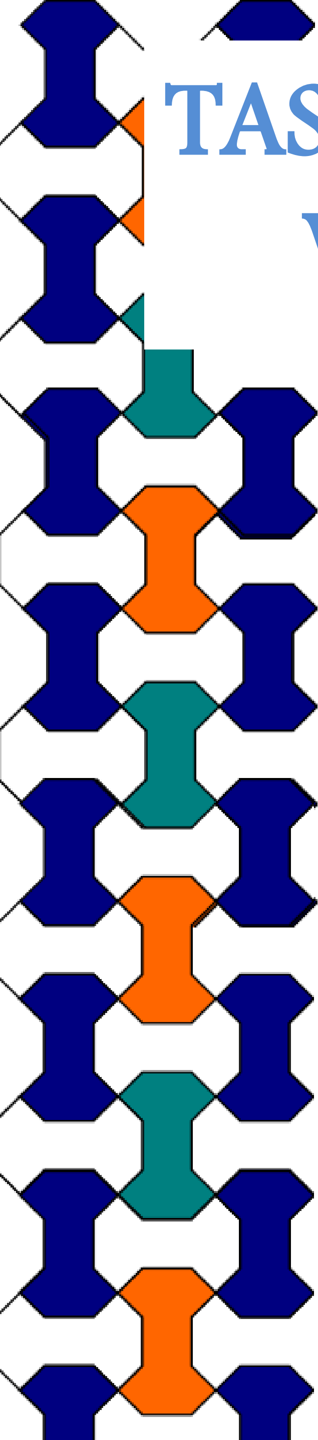


TASK 3. WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

4) Complete the bone:

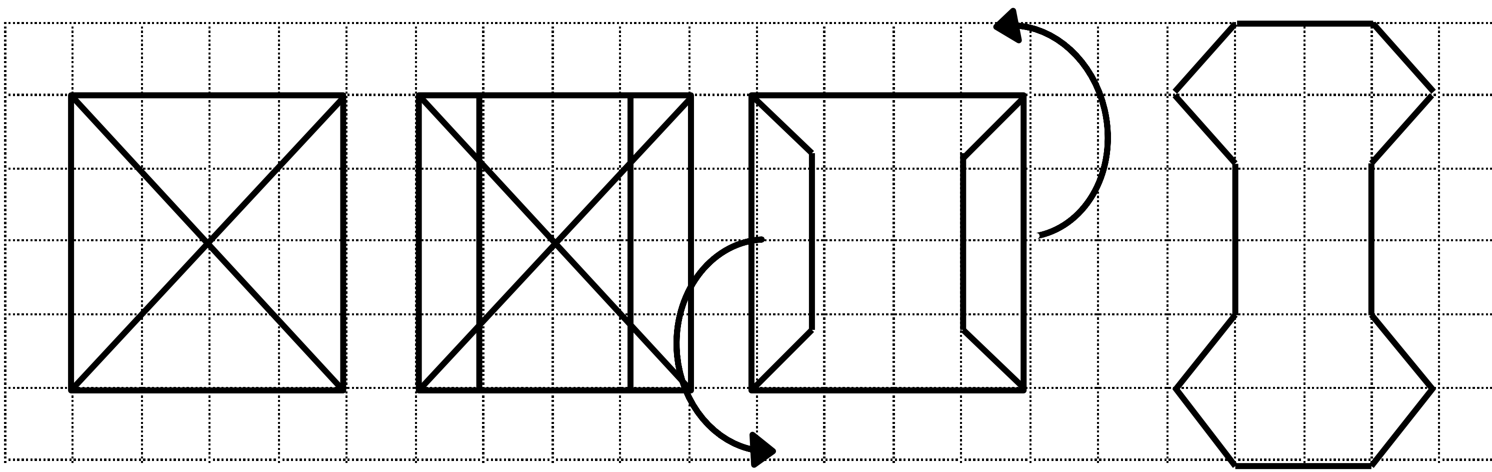




TASK 3. WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 1**: “El hueso nazarí”

Draw the bone using the pattern on your grid and colour it to your own liking.



TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 2:** "El avión nazarí"

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 2:** "El avión nazarí"

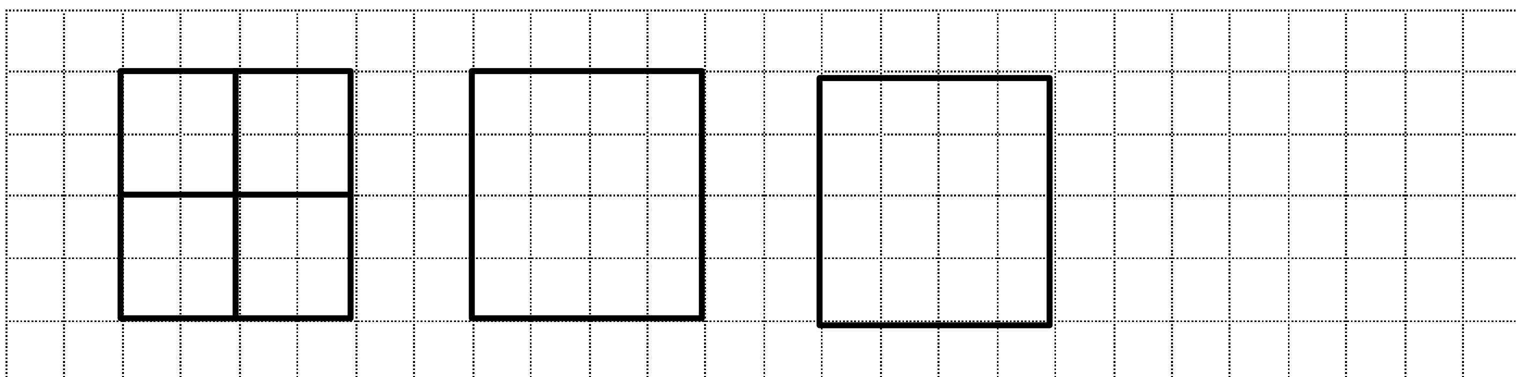
You can see the construction of the plane in this link:

http://concurso.cnice.mec.es/cnice2006/material105/Mosaicos/avion.htm

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 2:** "El avión nazarí"

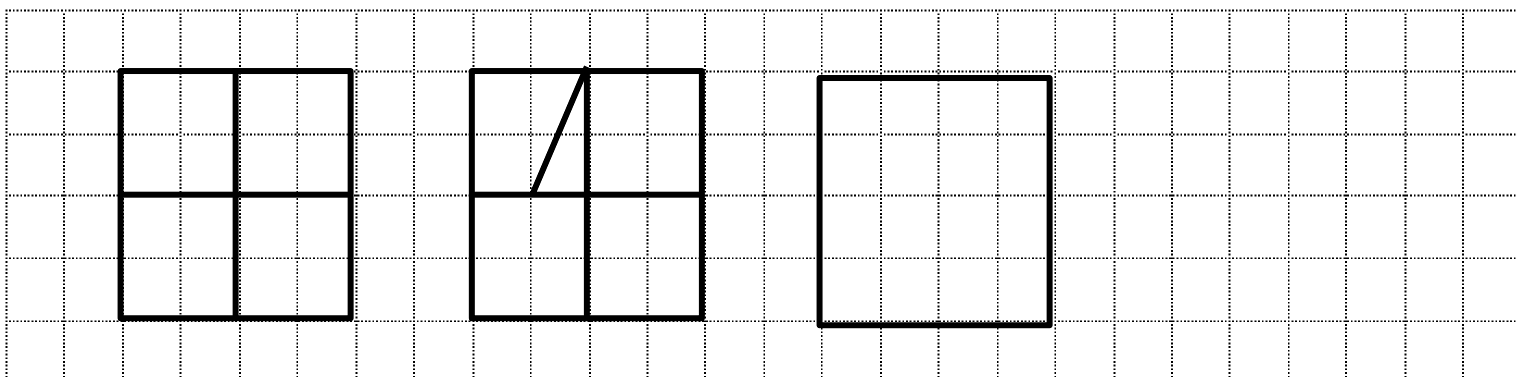
1) Draw two perpendicular lines



TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 2:** "El avión nazarí"

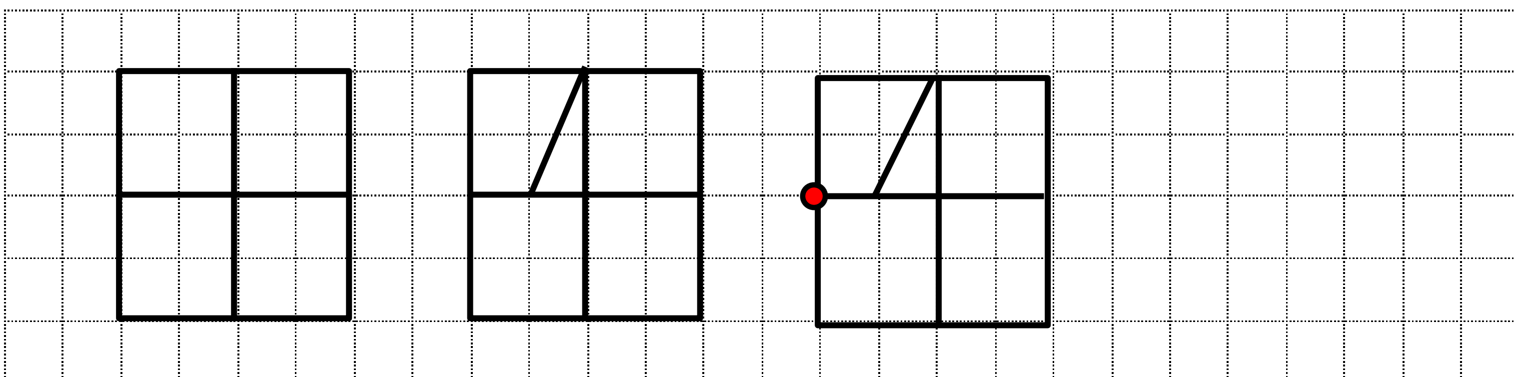
2) Draw a segment like this:



TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 2:** “El avión nazarí”

3) Rotate the triangle 90° clockwise from this centre:



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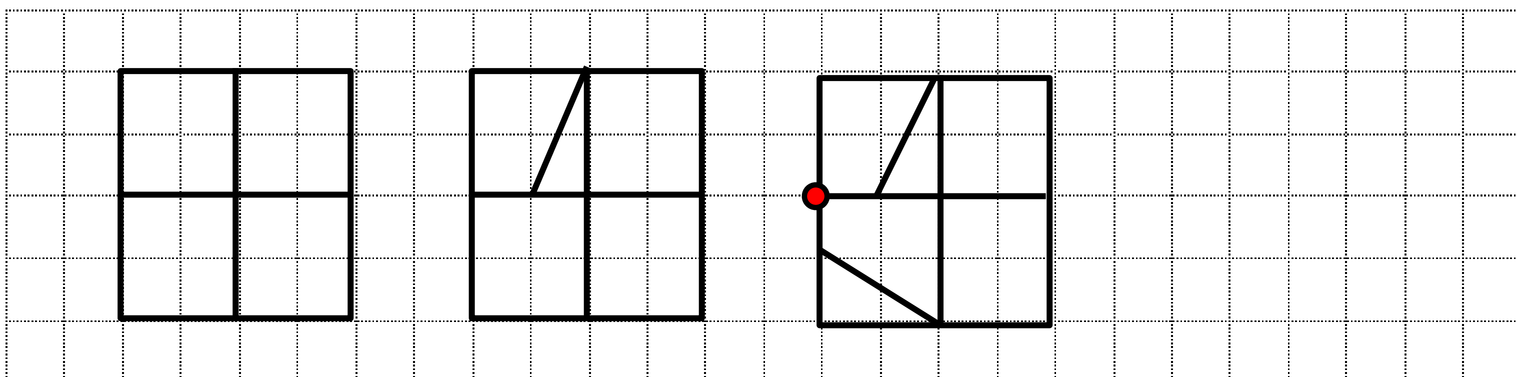
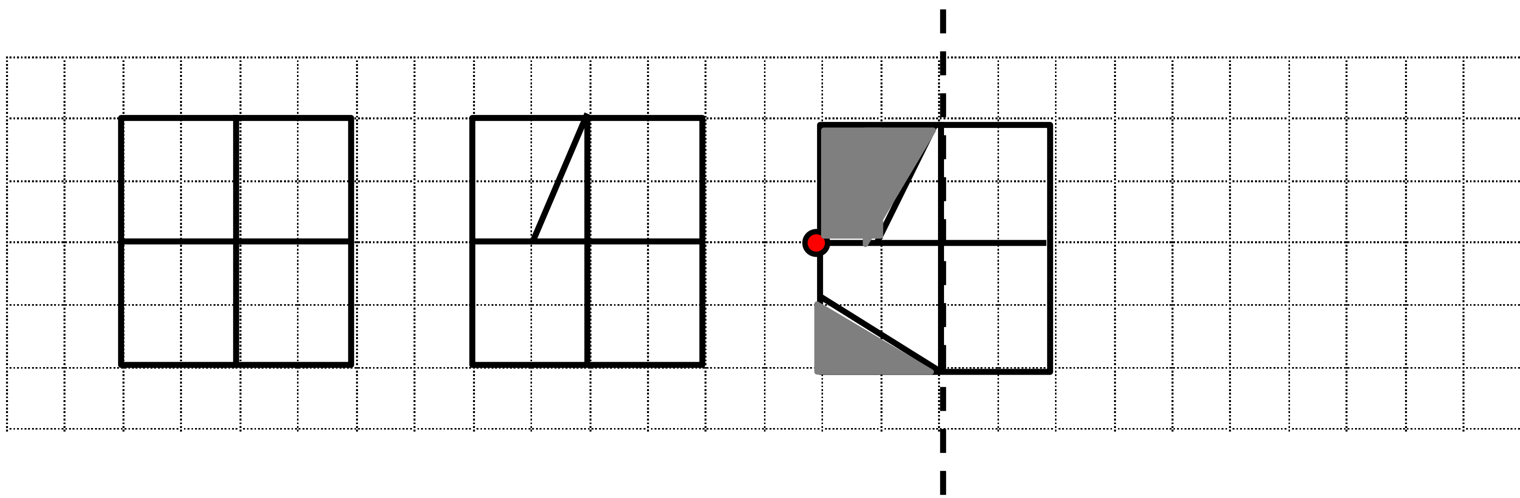


TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 2:** "El avión nazarí"

4) Apply a reflection from this axis and complete the plane:



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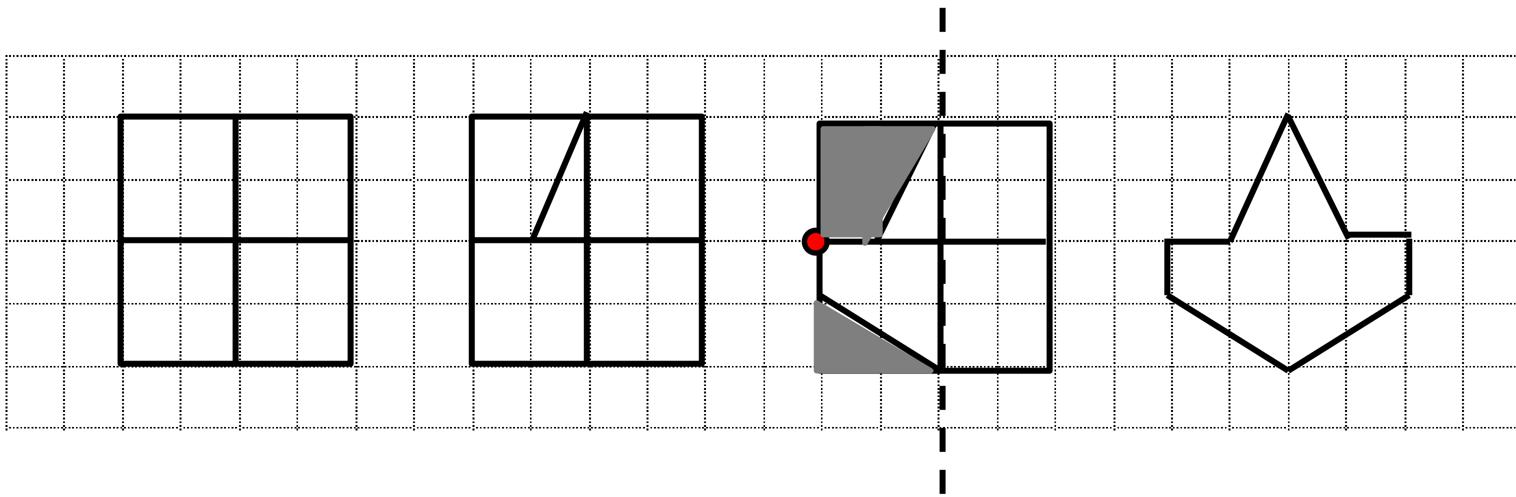

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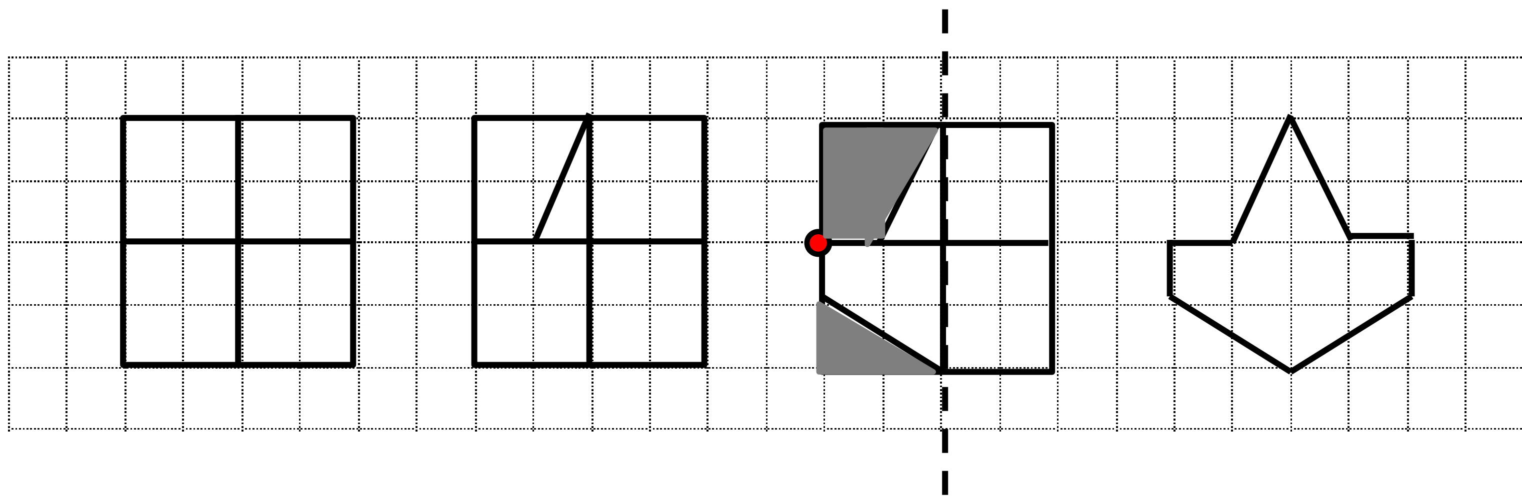
- **Activity 2:** “El avión nazarí”

Draw the plane using the pattern on your grid and colour it to your own liking.



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- **Activity 3:** "La pajarita nazarí"

For the third tessellation we use a property of an equilateral triangle:

It has rotational symmetry by 60º, that is, you can turn an equilateral triangle by 60º and get the same shape.

TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 3:** "La pajarita nazarí"

If you translate that property to our triangle tessellation:

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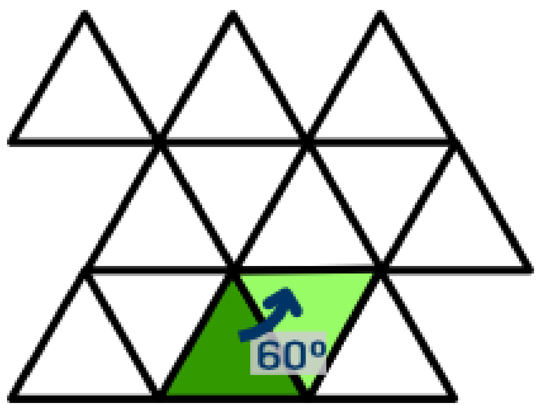

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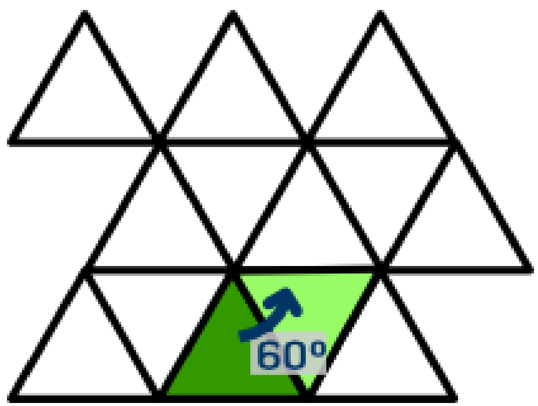

Any transformation you do to one side of a triangle can be replicated by rotating it 60° and there'll be no gaps.

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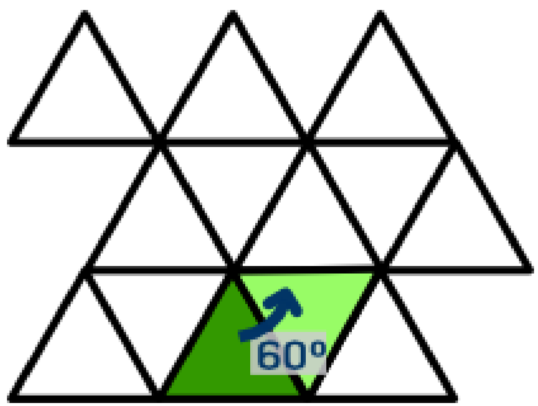

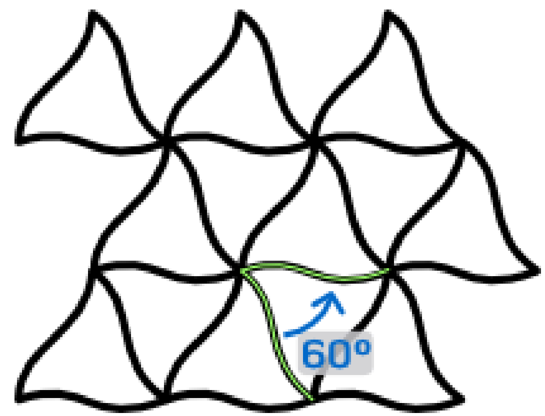

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TASK 3: WHAT TESSELLATIONS CAN WE FIND IN THE ALHAMBRA?

- **Activity 3:** "La pajarita nazarí"

Here you can see the construction of the "pajarita":

http://concurso.cnice.mec.es/cnice2006/material105/Mosaicos/pajarita.htm