General Description

Activity
• Four different activities, can be done separately
• Cutting and folding basic structures to explain surfaces and self-assembly, carbon nanostructures.
• The activity finishes when a nano structure is completed and uploaded on facebook.

30 minutes, each workshop
1-6 participants

Needed

table and chairs	paper, printed paper
scissors	needle and thread
coloured pencils (workshop 2)	glue (workshop 4)

Based on
Pull up nets
Nano Origami, Miura folding

Innovative
New area in Science research, combination Science&Arts, learning by doing, DIY

Targetgroup
All, specifically 12-16 years and non science teachers

Objectives

Big idea
How Art and Science can collaborate to think about new possibilities for future applications.
Nano technologies need different kinds of input and collaboration to develop robust applications.

Learning goals
• Surfaces. As the size of a system decreases into the nanoscale the ratio of surface area to volume dramatically increases and the system becomes dominated by the surface and the surface properties rather than the bulk (as in normal systems).
• Self-assembly. Self-organisation processes are where molecules or nano-sized particles spontaneously adopt an overall structure as a result of the local interactions within the initially disordered system. These assemblies are often able to survive and self-repair substantial damage or perturbations.

Main Message
1. Nanotechnology means working at small size scales, manipulating materials to exhibit new properties.
2. Innovative ideas can be evolved by the collaboration between Art and Science.

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Contributing Partners	University Leeds	Simon Wilkins, Rik Drummond-Brydson
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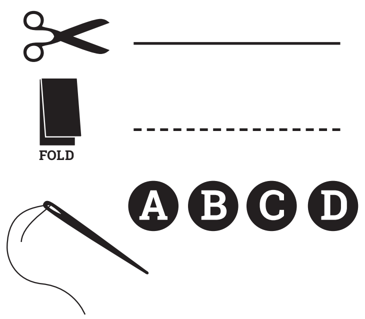
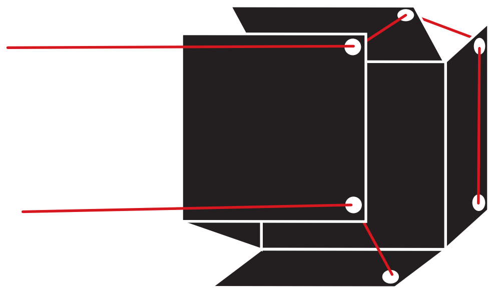
1. Nano Origami
Workshop Surfaces

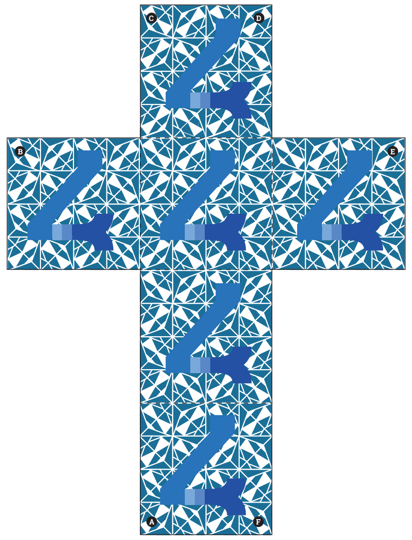
Activity





Step 1

Basic instructions:
1. Cut out the form
2. Fold the black dotted lines.
3. Make holes at the points A, B, C, D, etc.
4. Thread and weave thin string through the holes A, B, C, D, etc.
5. Gently pull up the cube.

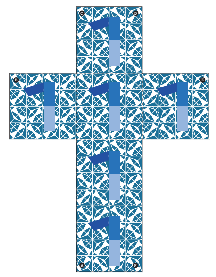


How big is the surface of this cube?
Answer: 6 x 4 = 24

What is the volume of this cube?
Answer: $4^3 = 64$

Step 2

Make these four cubes.



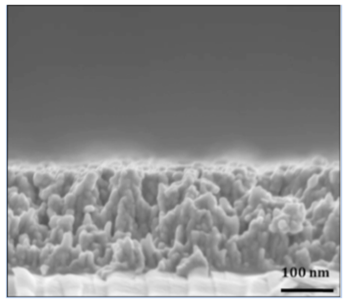
How many of these cube do you need to make the same volume as cube 4?
Answer: 8 cubes

What is the surface you have?
Answer: 6 x 8 = 48

The surface has doubled.

Did you know

If we go to a smaller (nano) level, we gain more and more surface with the same volume.
Modification of a surface by including selected chemicals can produce various desired effects or improvements in the properties of the surface. This is a widely used approach in applications such as catalysis, semiconductor device fabrication, fuel cells, self-cleaning glass and anti-fogging glass lenses.



Titanium dioxide (Anatase form) cross-section of a surface layer

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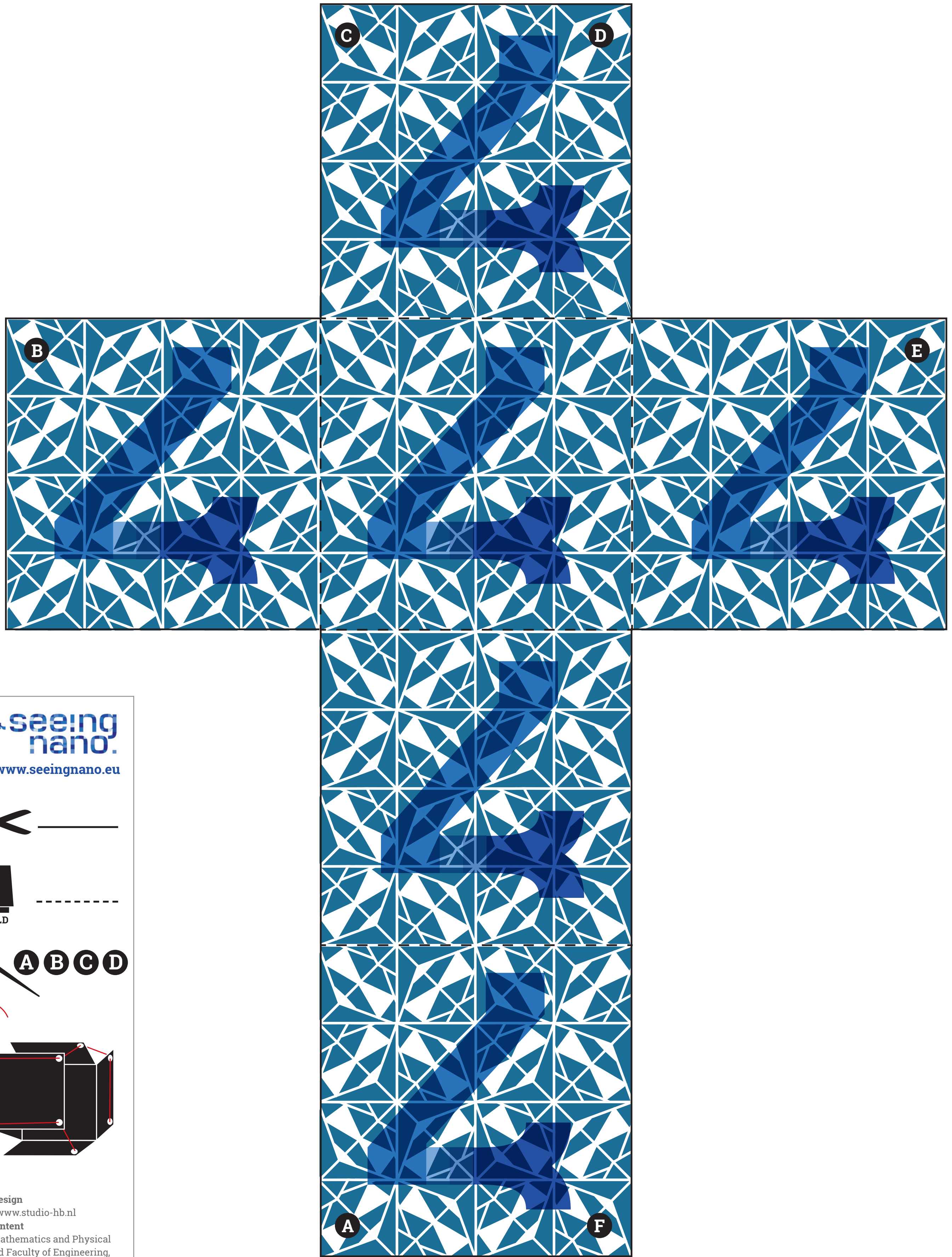

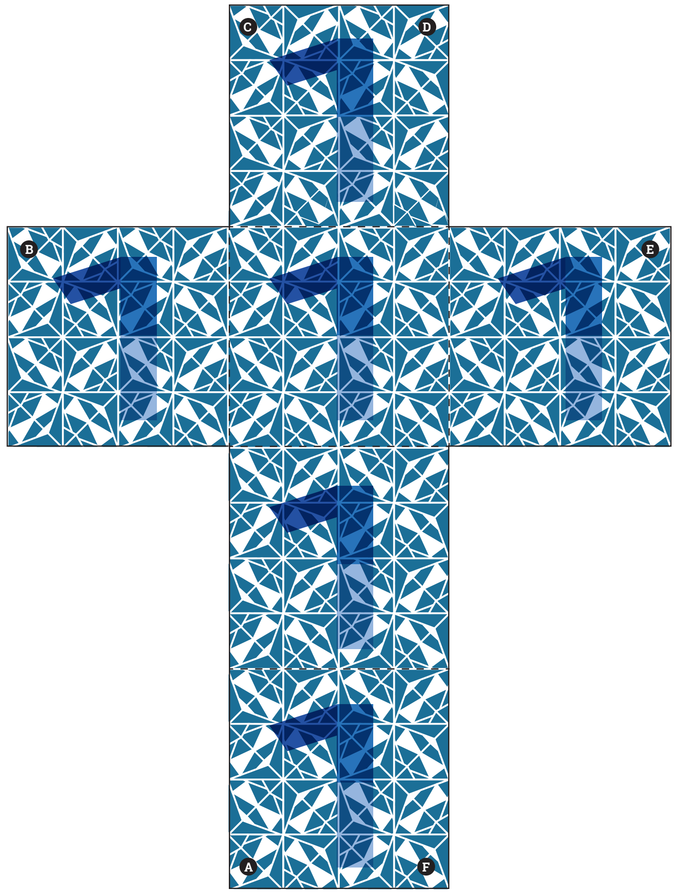

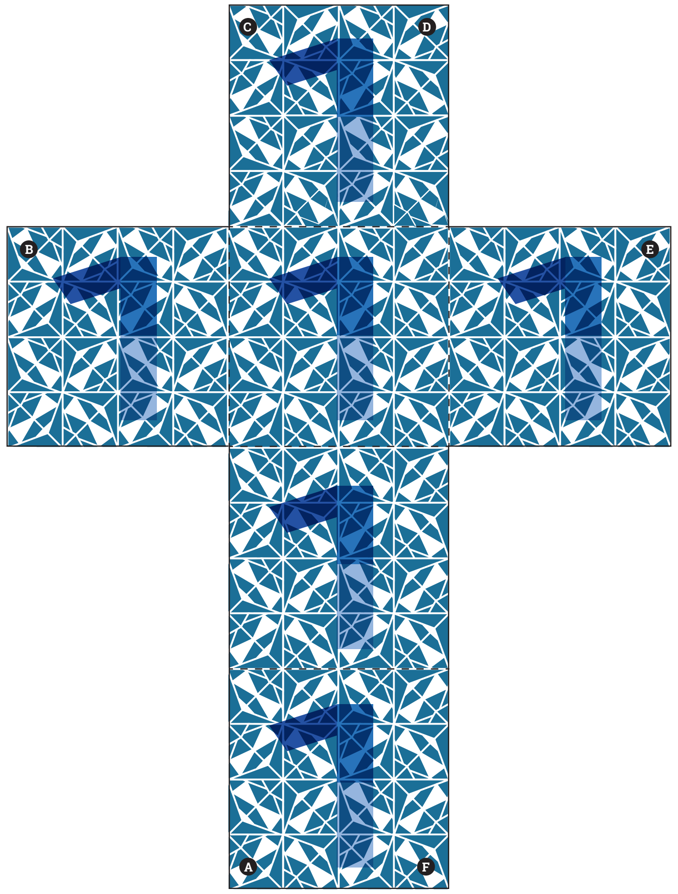

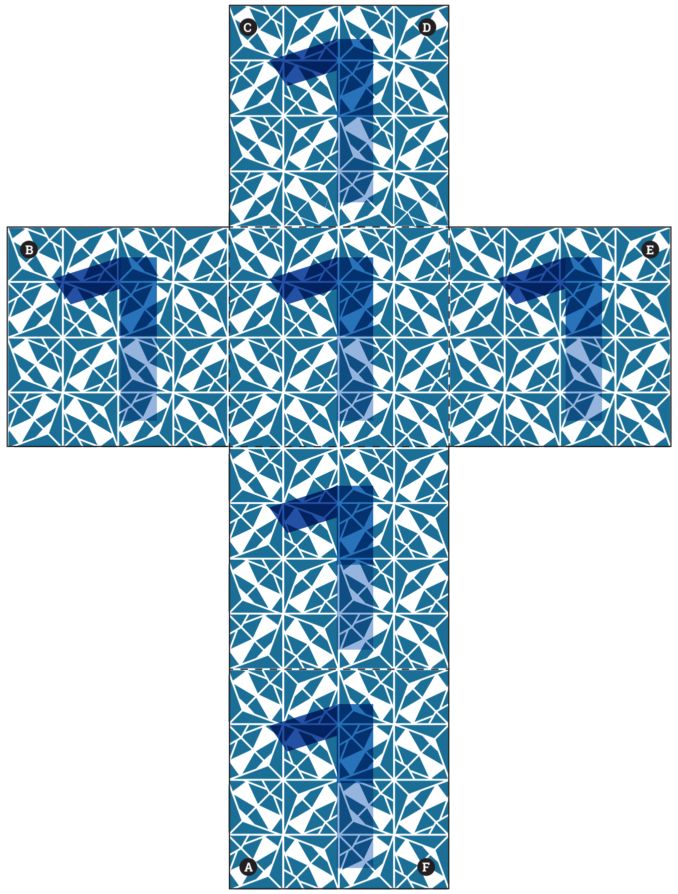

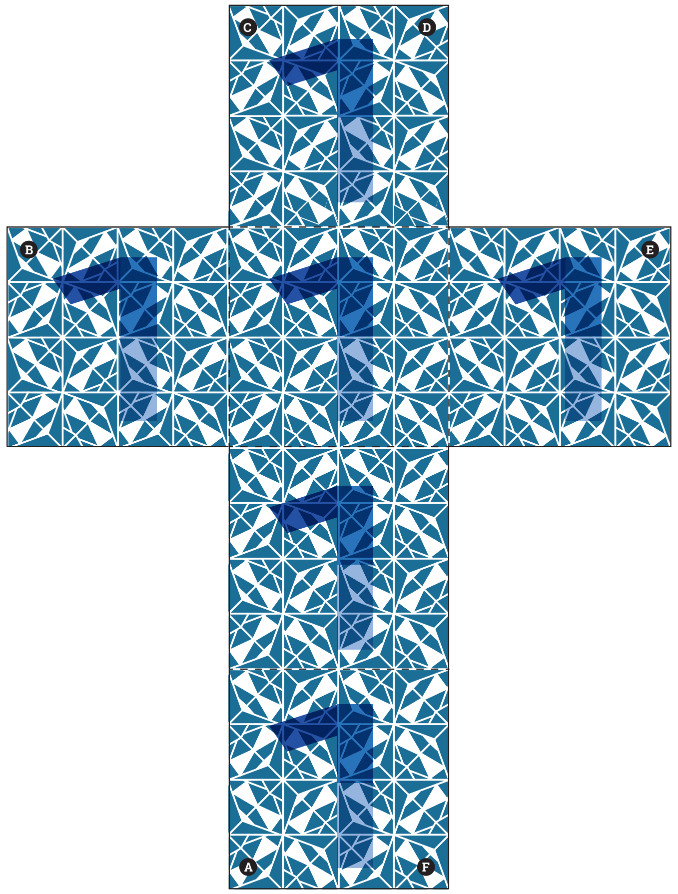

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2

FOLD

3 A B C D

4

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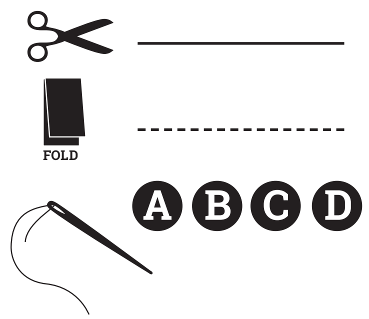
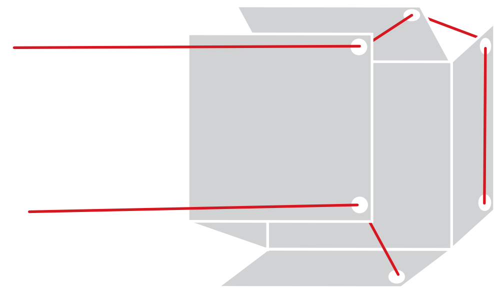
2. Nano Origami

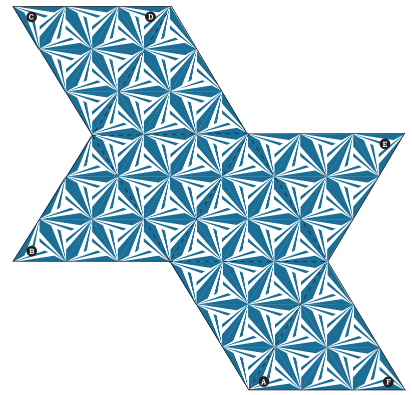
Workshop Pull up nets

Activity





Step 1



1. Cut out the net for your pull-up octahedron.
2. Fold the black dotted lines.
3. Make holes at the points A, B, C, D, etc.
4. Thread and weave thin string through the holes A, B, C, D, etc, in that order to link the polygons together.
5. Gently pull up the net to make your octahedron.

Step 2

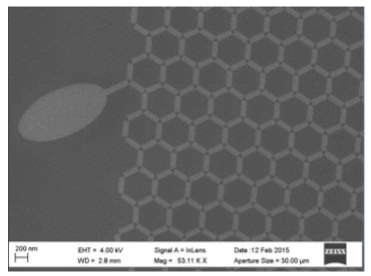
Cut out and decorate the outside of your dodecahedron.

Did you know

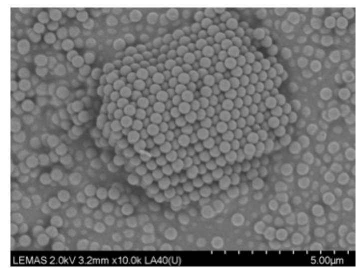
Larger scale cohesive structures can arise spontaneously as a result of many weak interactions between molecules or particles. The structures formed are dependent on the conditions, such as temperature or pressure. These can survive and even self-repair after damage.
In biology we see self-assembly at the nanoscale. Researches work on how to use this self-assembly to build things at a large scale.

Examples are Pull-up nets and origami.
Have a look how pull up nets work: http://mathsbot.com/activities/pullUpNets

General information about self-assembly and the interdisciplinary research at the MIT, with nice examples:
http://www.selfassemblylab.net/index.php



'Spin-ice' magnetic metal alloy nanorods in a 2-dimensional self-organised array



Metal oxide self-organisation into a 3 -dimensional structure (University of Leeds/Aston University)

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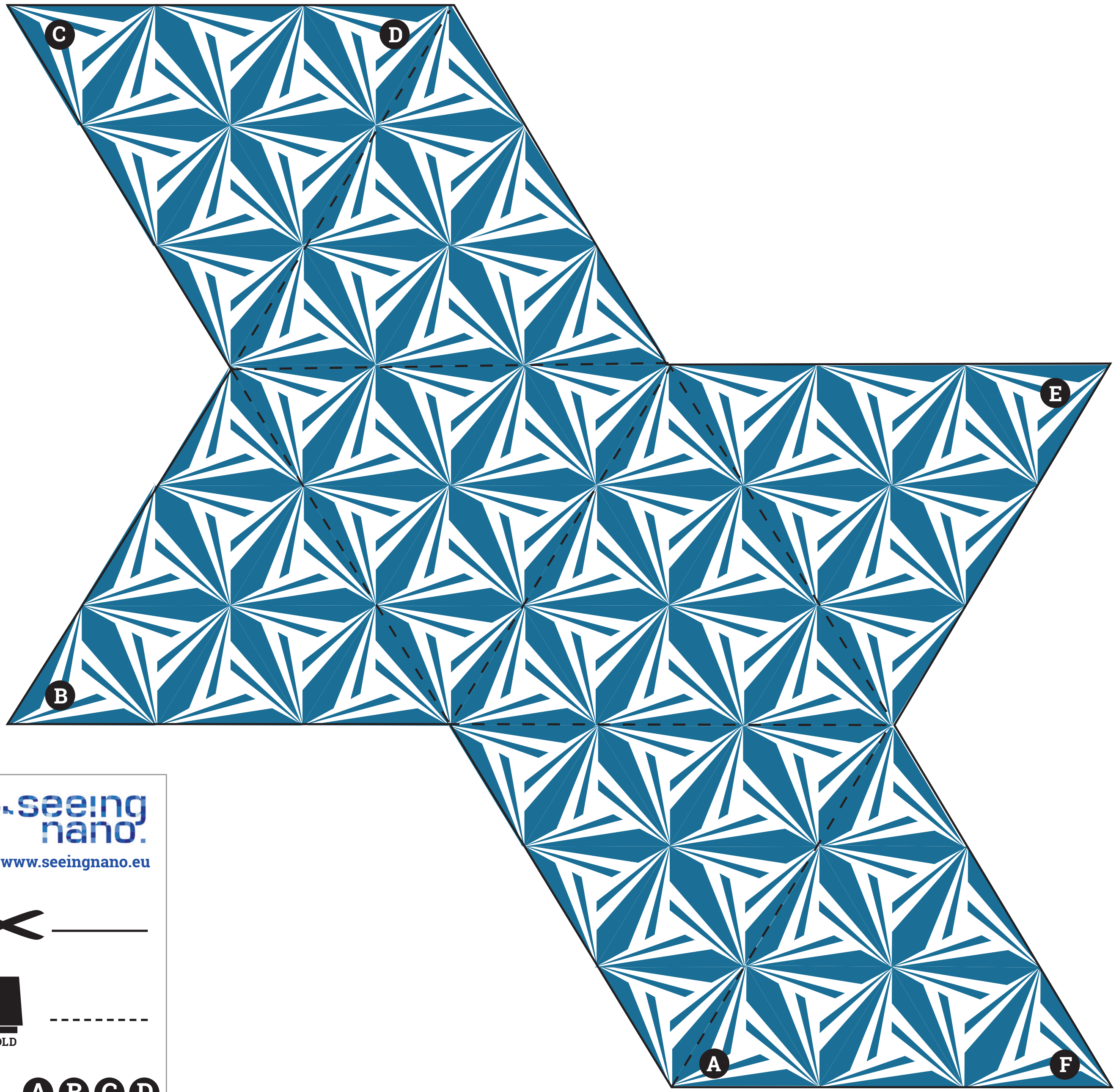
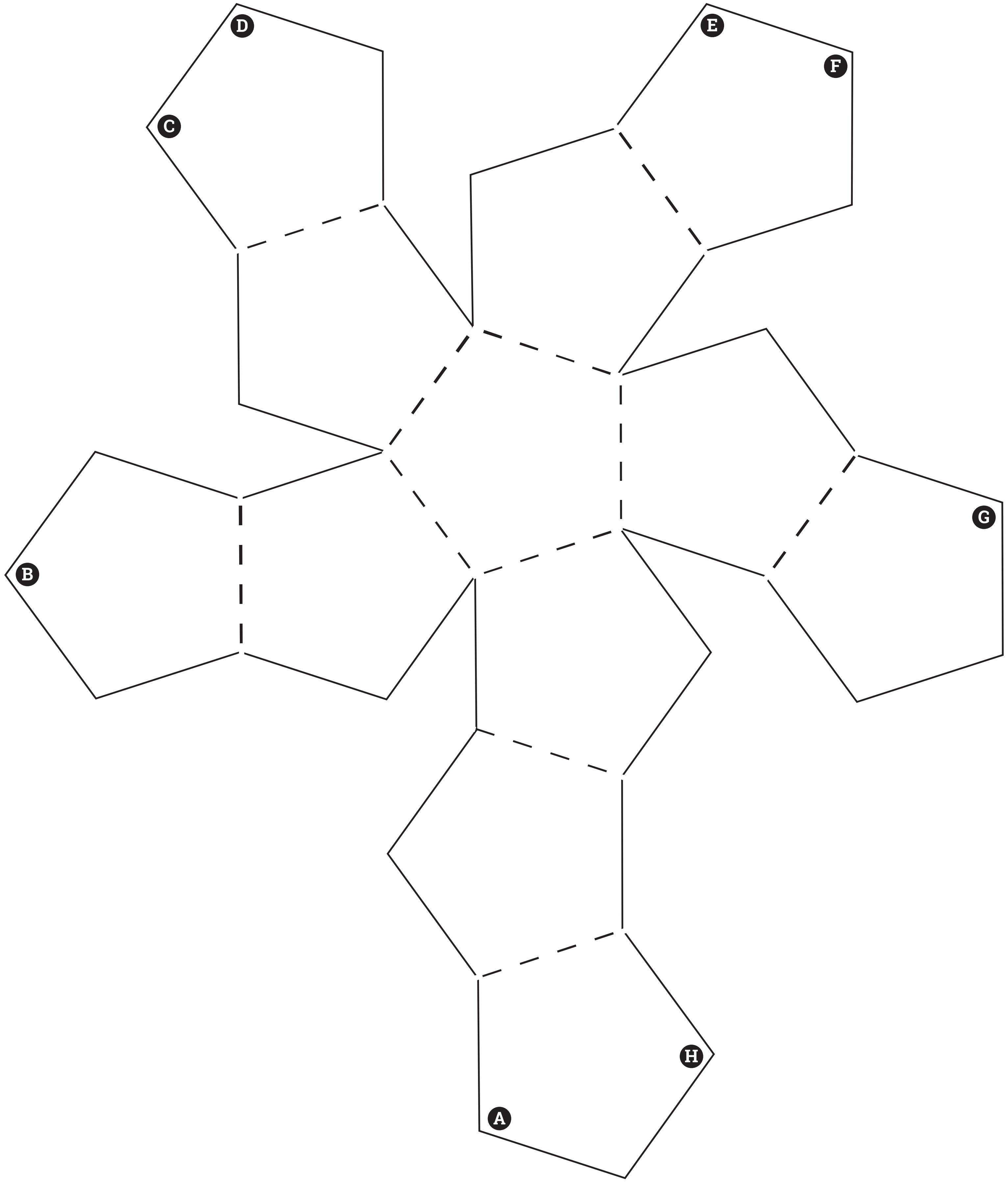
OCTAHEDRON



DODECAHEDRON



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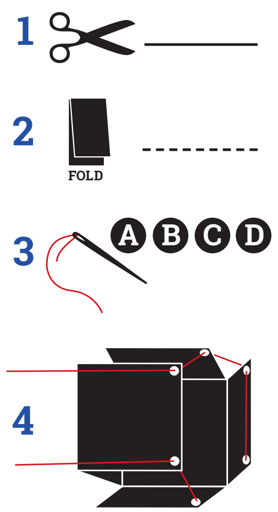

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3. Nano Origami
Workshop Miura folding

Activity

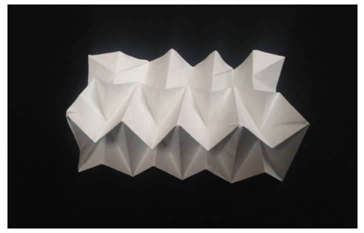
FOLD DOWN - - - - - - - - - -

FOLD UP . . . .

Step 1

1. Fold the lines according to their position upwards or downwards.
2. A Miura folding will appear.

Step 2



Try to make different foldings.
More folding principles you can find on the website.
https://youtu.be/3qkqVN0C00o

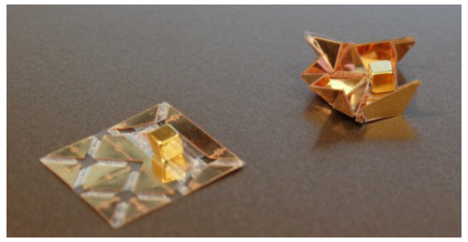
Did you know

The Japanese astrophysicist Koryo Miura invented this folding.
Nanostructured origami is rapidly transitioning from an elegant technique to fabricate exquisite structures to a platform for integrating novel functionality into crystalline nanomembranes. Nanomembranes, with mechanical properties of typical sheets, can be bent, rolled, and twisted, to return to their original shape, while maintaining their single-crystal nature. The field has advanced from semiconductor bilayer microtubes 15 years ago to quite complex 3D kirigami and origami shapes that demonstrate the potential of 3D devices with unique electronic, optoelectronic, or electromagnetic function.
Thin sheets of crystalline inorganic materials provide new function.
Flexibility and strain engineering provide ability to create origami-like structures.
3D nanostructures are transitioning from art to novel technologies and functionalities.

http://www.popsci.com/engineers-origami-inspiring-scientific-creativity

Scientists and artists work together to find new ways of folding, using the old technique of origami
http://ns.umich.edu/new/multimedia/slideshows/20695-nano-origami-project-combines-
http://www.engin.umich.edu/college/about/news/stories/2012/august/nano-oraigami-project-uses-art-to-advance-engineering

MIT June 2015
http://www.betaboston.com/news/2015/06/11/mits-tiny-origami-robots-hint-at-future-dissolving-nano-surgeons/

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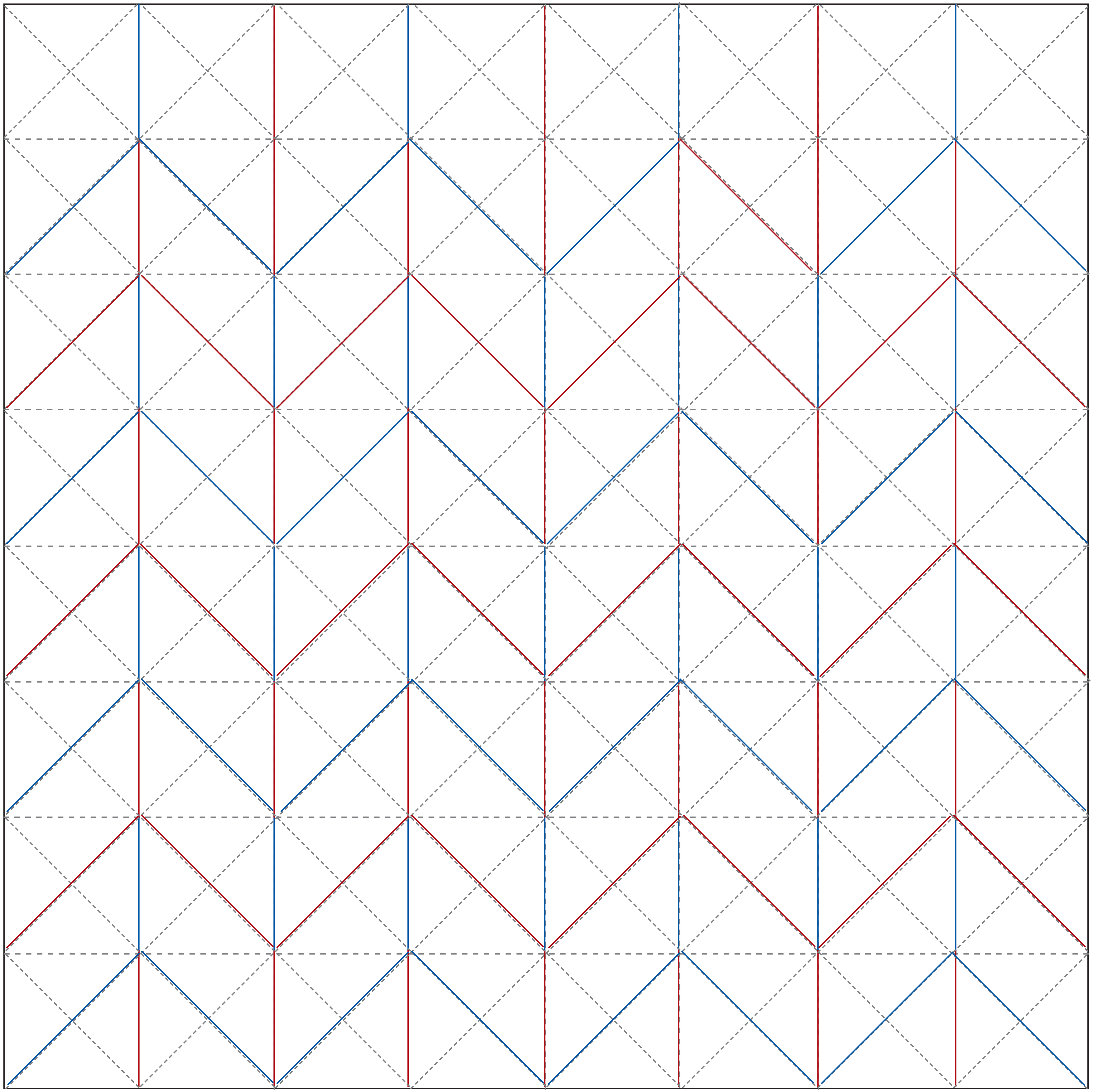

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1

2

FOLD DOWN

FOLD UP

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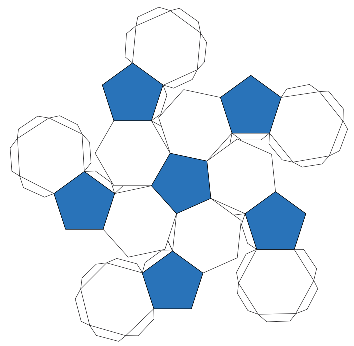
4. Nano Folding

Workshop Carbon Nanostructures (Fullerenes)

Activity

Step 1

1. Cut out the three elements.
2. Fold the black lines.
3. Glue the different parts together.

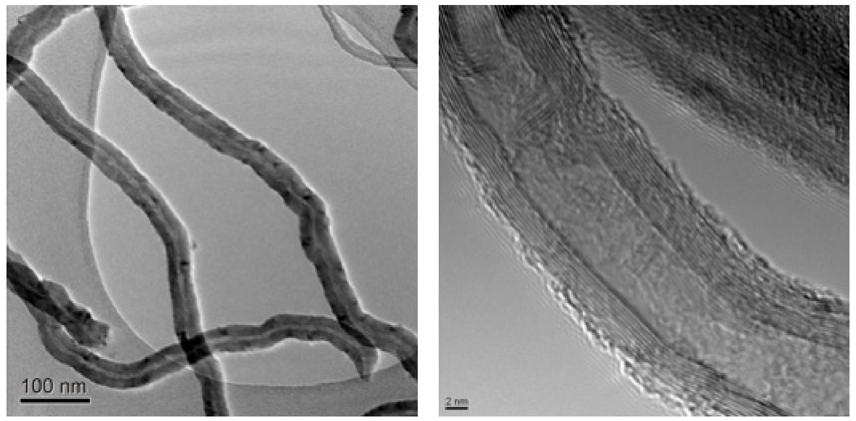


Did you know

Carbon fullerenes are structures which are rarely found in nature and have a similar structure to the graphite form of carbon. When manufactured, they may form structures such as geometric spheres ('buckyballs'), tubes (carbon nanotubes; CNTs) and flat, flexible sheets (graphene). They are made from a particular type of carbon – carbon bonds (known as sp2), which gives them their unusual properties. They are of great interest to scientists and industry due to their special properties, such as very high mechanical strength, electronic and heat conductance and reactivity.

Buckyballs are geometric structures which can occur naturally in small amounts in soot. The structure of the ball which contains 60 carbon atoms (C60) is similar to a football comprising twenty hexagons and twelve pentagons. Others may also include heptagons.

Carbon nanotubes are forms ('allotropes') of carbon with a cylindrical shape, either open-ended or closed with a buckyball-like hemisphere at each end. The length to diameter ratio can be extraordinarily large (over 100,000,000 : 1) and they can have a single layer of atoms or multiple layers which give them different properties, such as extremely high electrical and thermal conductivity. Among many potential applications, the nanotubes can be incorporated in objects such as car bumpers and tennis rackets to give very low weight and high strength; in plastics to conduct electricity or in electronics to dissipate heat.



The same carbon nanotubes at two different magnifications

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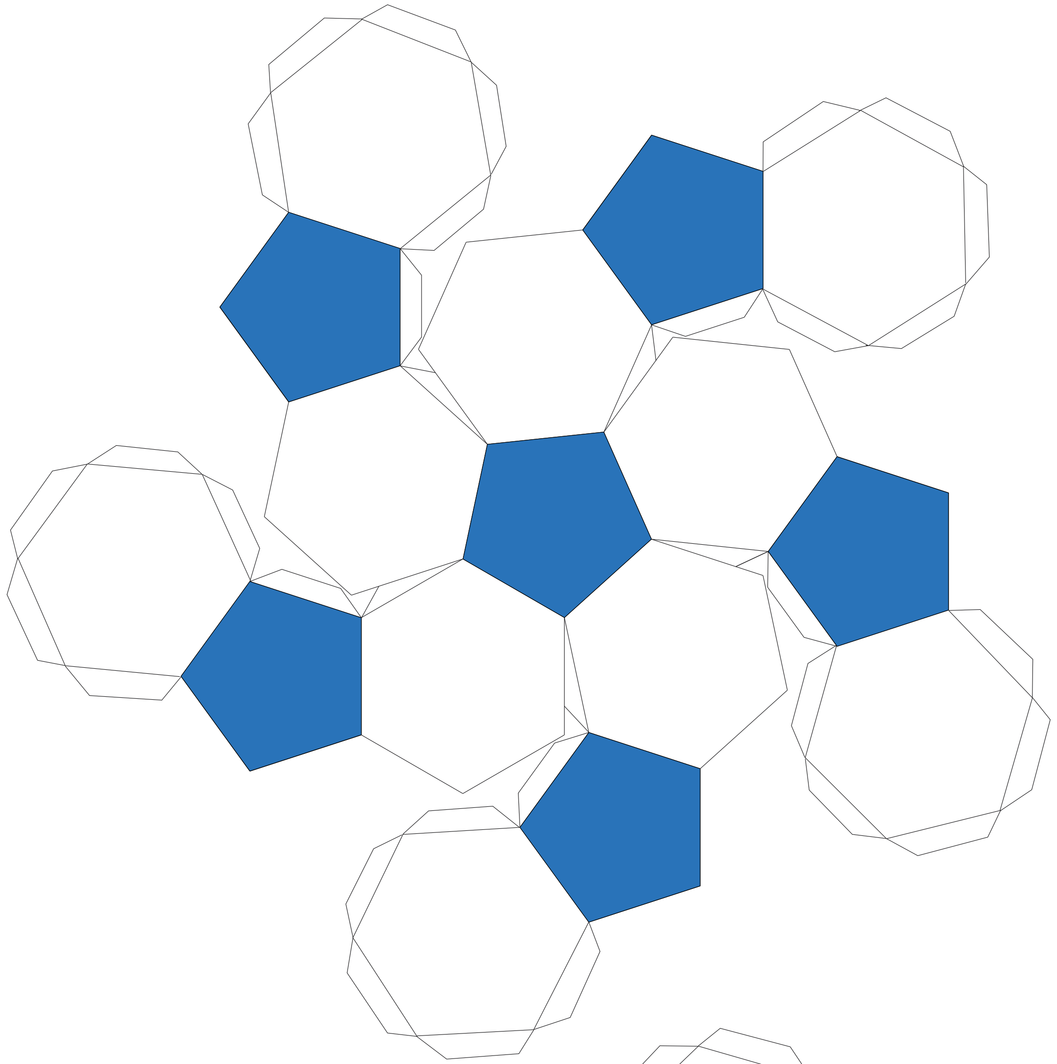

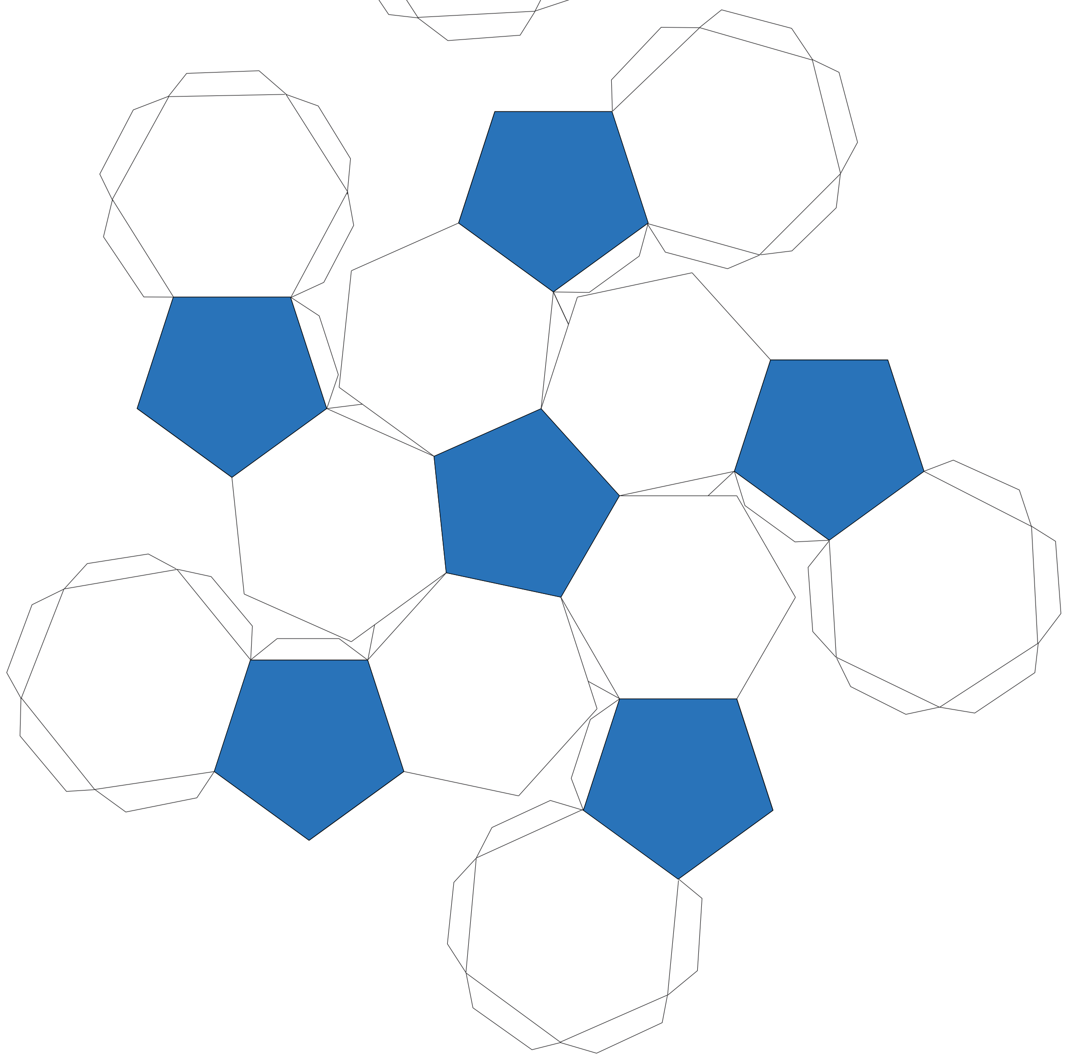

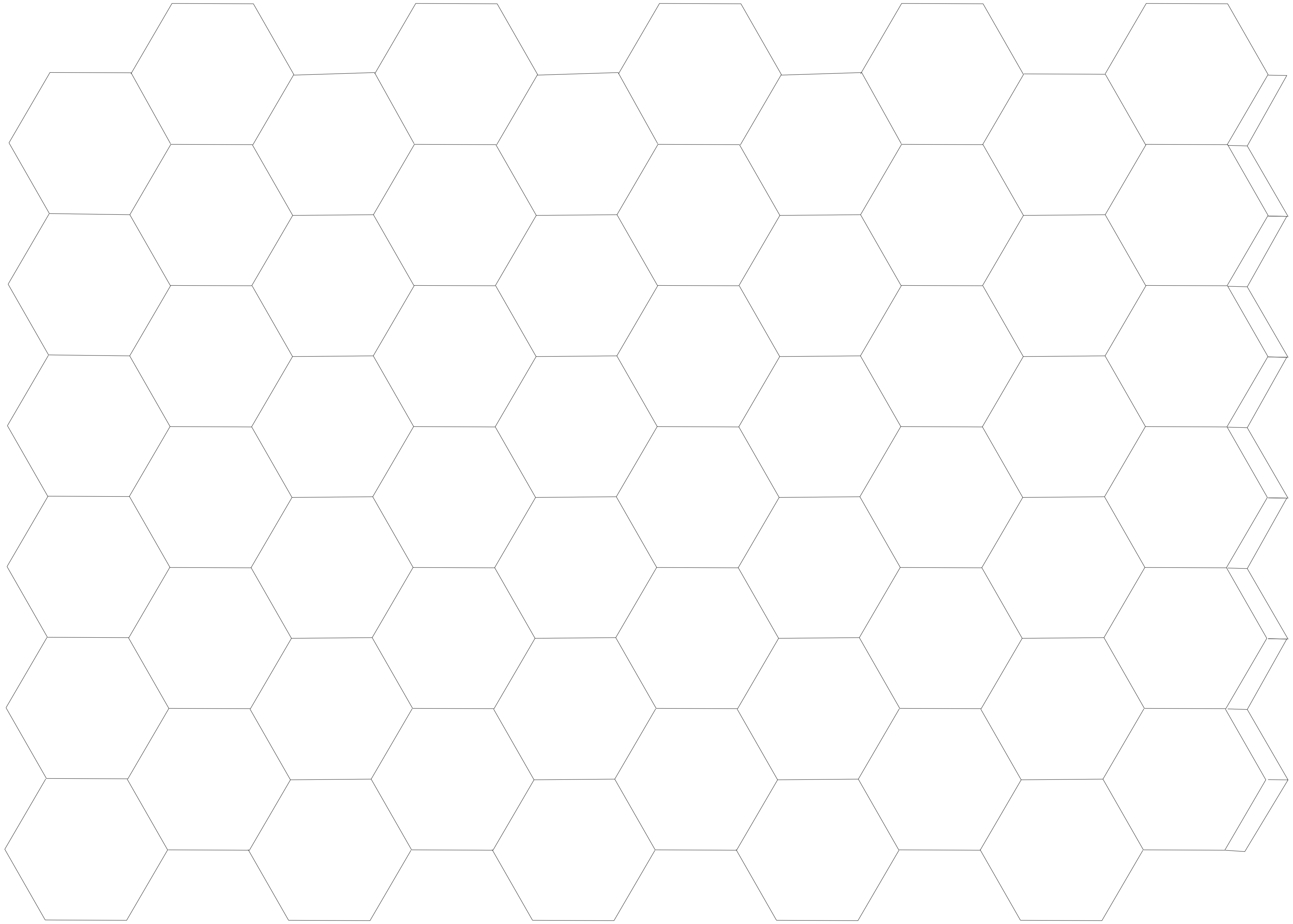

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2 FOLD

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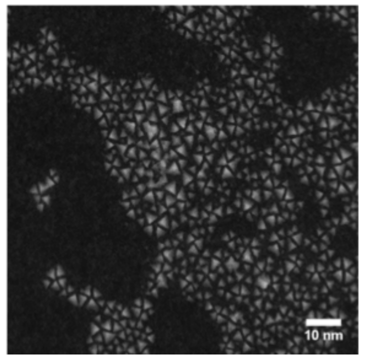
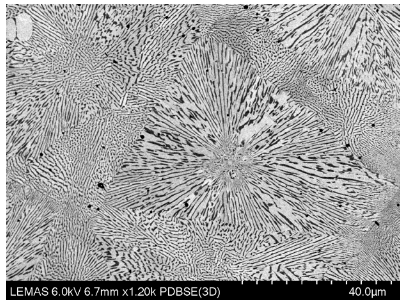
Did you know (Emergent/Divergent)?

Once a substance is smaller than around 100 nanometres and becomes a nanomaterial, quantum phenomena become important and new functionalities are observed which are size-dependent within the nanoscale. Thus properties emerge or diverge as a function of system size
Divergent behaviour is where properties diverge (change) as the system gets smaller. A good example of this is quantised behaviour where properties become dependent on size – this could be colour (light absorption), (metal nanoparticles in stained glass/ cancer therapy, quantum dots for imaging), electrical conductivity, hardness, chemical reactivity, magnetism. This arises because the energy levels for electrons in a material depend sensitively on system size, it is the energy of these electrons that either directly or indirectly give rise to the properties.

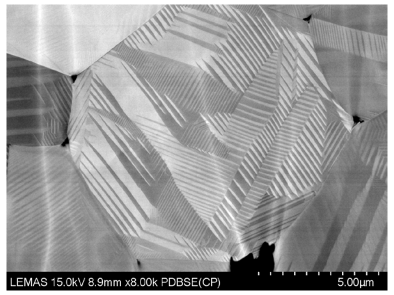
The converse of this is emergent behaviour where properties emerge as the system get bigger. This is due to collective effects whereby the interactions between nano-objects (e.g. particles) give rise to new phenomena. An example might be a photonic crystal where a collection of voids (or different materials) arranged periodically in 2 or 3 dimensions cause waves to be diffracted (e.g. light) giving rise to colour (e.g. butterfly wing). Another example are larger scale molecular structures formed from self-organised molecules – e.g. membranes. These larger scale structures have distinct properties from their individual components (e.g. liquid crystals).



Quantum dots – the quantum confinement effect allows the dots to filter light to produce intense colours



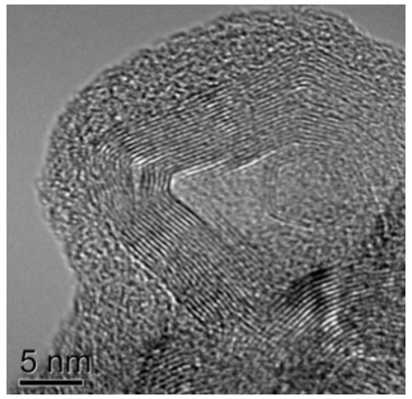
There is growing concern regarding the toxicity in lead-containing devices driven by more stringent hazardous substances directive regulations. To address this concern, there has been a resurgence in the compositional development of lead-free piezoelectric materials. The composition and structure of the ceramics must be tightly controlled and the materials can be examined through high resolution microscopy.



Graphene is a two-dimensional atomic crystal made up of carbon atoms arranged in a hexagonal lattice and can form a mesh which is impermeable to larger atoms and molecules. It is the thinnest material known to man being one carbon atom thick (a million times thinner than a human hair), optically transparent; exceptionally strong (around 100-300 times stronger than steel) and the lightest material known (1m2 weighs less than1 milligram).

The type of bonding (carbon-carbon sp2) means that it is also very flexible. Similarly to the nanotubes, it is extremely electrically and thermally conductive, properties which can be adjusted through chemical modification.

While production of graphene has proven difficult, great advances have been made in this, and as it is essentially a very large molecule of carbon, the raw material is extremely cheap and freely available. In time it is likely to find uses in many areas such as energy generation & storage, polymer composites, membranes and electronics. Graphene is considered so important to the future that the EU have made it the focus of one of very few of their flagship projects
http://graphene-flagship.eu/project



Graphite – the individual layers (when viewed from above in this example) are graphene sheets. These can slide freely over each other due to weak bonds between sheets, however the bonds within the sheets are very strong and chemically stable.