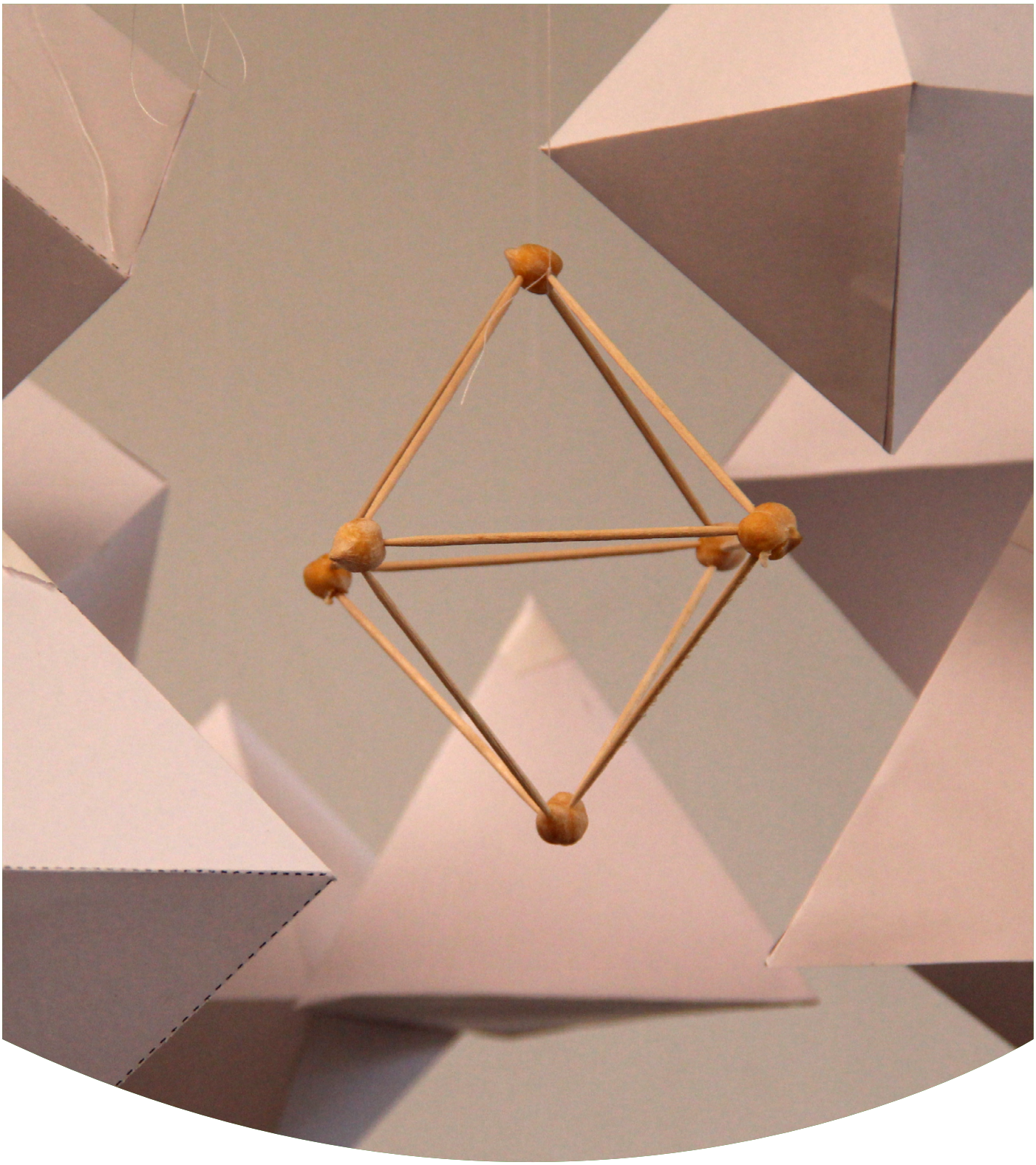


What can we learn from the Ancient Greeks about the order of Nature?

Geometry teaching pack

The Harmony Project

GEOMETRY ACTIVITIES

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

The six activities in this geometry pack have been developed to explore with students some of the discoveries the Ancient Greeks made about geometry and shape. They can be used to support learning about 3D shapes in maths, to enrich an exploration of Ancient Greek civilisation or to teach geometry as a standalone activity. They could also be used to introduce students to the principle of Geometry. You can find out more about Nature's principles of Harmony on The Harmony Project website.

In each activity, students focus on constructing a different 3D shape. Step-by-step text instructions are provided as a guide for teachers, with accompanying diagrams and lists of the resources students will need to complete each activity. There are also photocopiable templates to support the activities.

At the end of each activity, students could be encouraged to count how many faces, edges and vertices each of the shapes they have constructed has, and fill in this information in the table on page 3.

CONTENTS

WHY GEOMETRY?

Learning the geometry of Nature provides students with a new way of looking at the world. The observational skills and careful drawings that are required to recreate this geometry can have a powerful impact on students' understanding of Nature and their place in it. If we are to create a sustainable future, we need to see the world through a different lens, to understand that the patterns of life that exist around us also exist in us. This way of seeing the world means we view everything from a place of connection, rather than separation. This sense of connection is an essential part of learning to live sustainably. After all, the word 'Harmony' means joined or connected.

COMPASSES

The activities in this pack can be adapted so that there is no need to use a compass to complete them by using the templates provided at the end of each activity. However, if you would like your students to engage in more of the geometric construction, Jakar compasses will help ensure accuracy and are easy to use. The can be purchased at a discount through The Harmony Project website.

PLATO AND POLYHEDRA

Plato was a philosopher who lived in Ancient Greece. He was born around 427BC and is famous for his ideas and teachings. He wrote many books in which he shared his thoughts and philosophy.

One of the things Plato talked about was something called the 'Platonic solids'. There are only five Platonic solids: the tetrahedron, the cube, the octahedron, the dodecahedron and the icosahedron. Each of these shapes has all its sides and angles equal, making them symmetrical. A platonic solid will look the same from every corner, or vertex.

Scientists and mathematicians find the Platonic solids fascinating because they appear in many places in Nature, from the structure of crystals to the arrangement of atoms. They are like building blocks of the universe.

As you learn more about these regular 3D shapes, collect information about them and record it in the table below as you go. Can you see any patterns?

Solid	Number of faces	Number of faces that meet at a vertex	Sum of angles
Tetrahedron			
Cube			
Octahedron			
Icosahedron			
Dodecahedron			
Truncated tetrahedron			

GEOMETRY ACTIVITY 1

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

LEARNING QUESTION How do I build a tetrahedron?

The tetrahedron is one of the five Platonic solids. Platonic solids are special 3D shapes that share certain features: all the faces are identical regular polygons; exactly the same same number of faces meet at each vertex; and every edge is the same length.

The other Platonic solids are the cube (with six square faces), octahedron (eight triangular faces), icosahedron (20 triangular faces) and dodecahedron (12 pentagonal faces).

The tetrahedron has four faces, all of which are identical equilateral triangles, and it has six straight edges and four vertices. The tetrahedron is a symmetrical shape. This means that if you rotate or flip it, it will still look the same.

In Nature, the tetrahedron can be found in the form of crystals and minerals, molecules, viruses and bacteria.

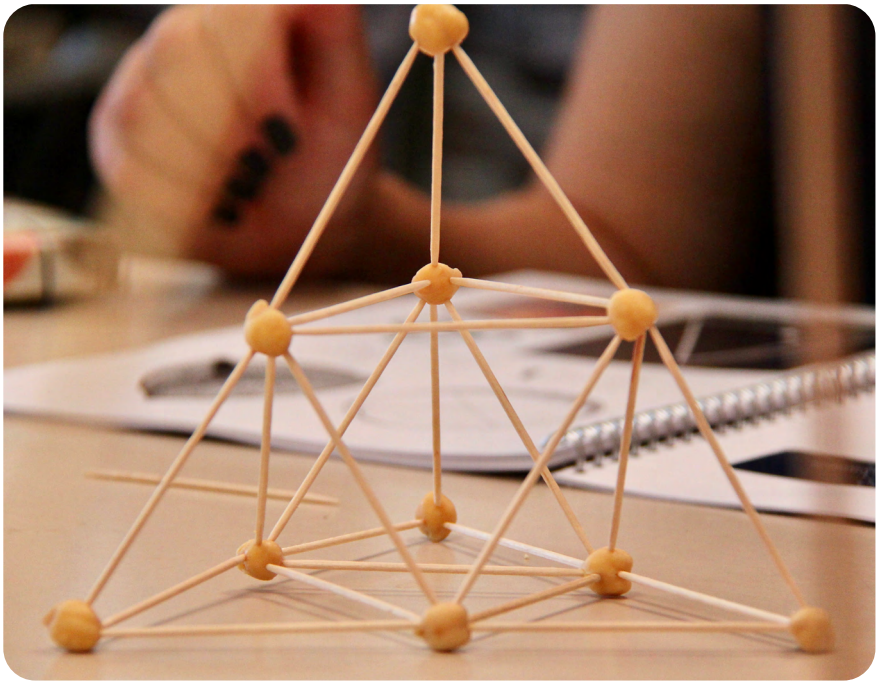
YOU WILL NEED

Ruler
HB pencil
Compass
Good-quality eraser
Scissors
Glue
Optional copies of Resource 1A or 1B

DID YOU KNOW?

The word 'polyhedra' comes from the Greek language. In Greek, 'poly' means many and 'hedra' means flat surfaces, or faces. So, when we combine the two, 'polyhedra' means many faces. It's a term used in geometry to describe 3D shapes with flat surfaces, edges and corners.

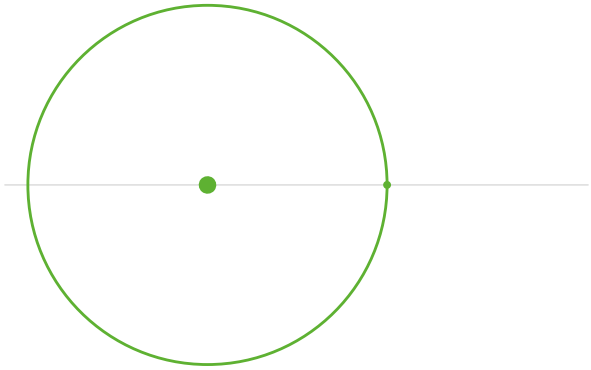
Tetrahedron model made by Year 5 students using chickpeas and toothpicks



ACTIVITY 1

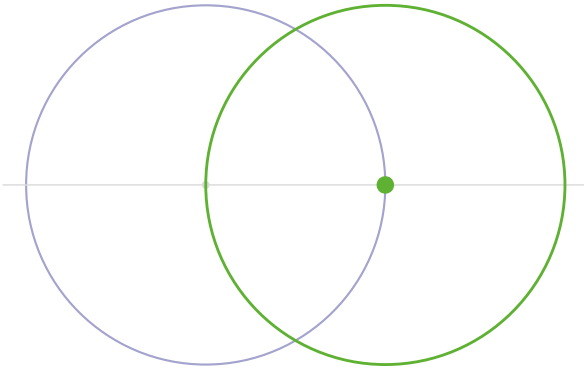
STEP 1 Draw a circle

Use a ruler to draw a horizontal line on your page. With the compass radius set to 5cm, place the compass needle on the line slightly to the left of the centre, as shown below in green, and draw a circle. Alternatively, use Resource 1A and start from Step 4, or use Resource 1B and start from Step 7.



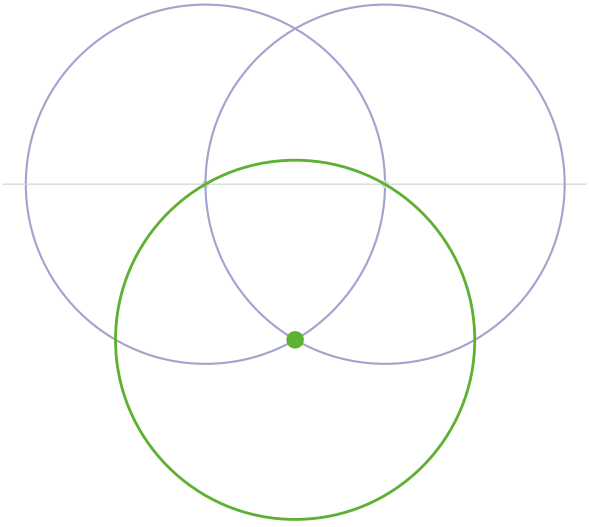
STEP 2 Draw a second circle

Mark the point shown below in green where the horizontal line intersects the circumference of the first circle on the right-hand side. With the compass radius still set to 5cm, place the compass needle on this dot and draw a second circle.



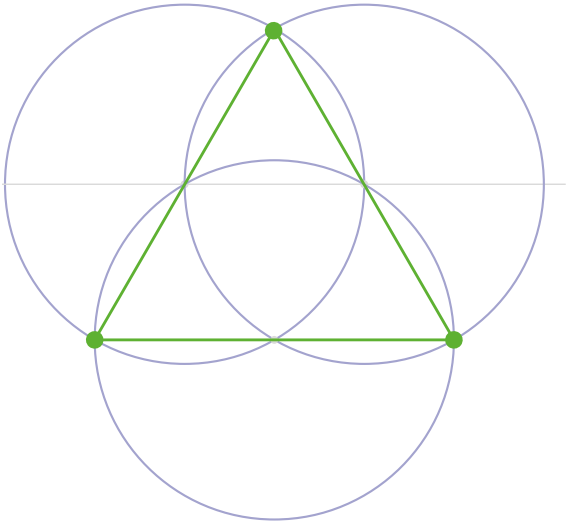
STEP 3 Draw a third circle

Mark the point shown below in green where the two circles intersect in the lower half of the page. With the compass radius still set to 5cm, place the compass needle on this dot and draw a third circle.



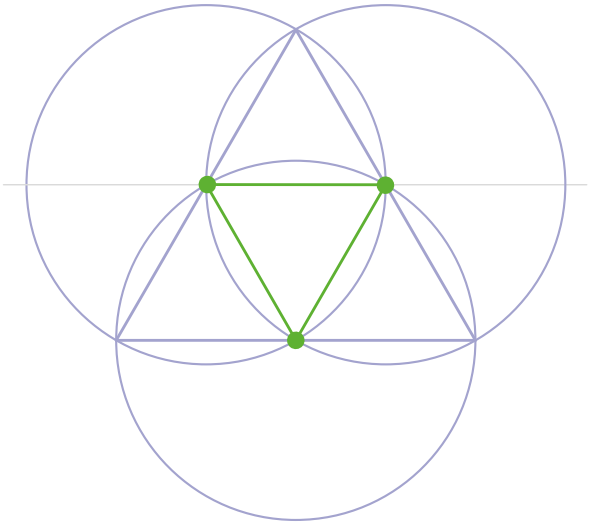
STEP 4 Draw a triangle

Use a ruler to draw three lines connecting the points marked below in green. This creates the outline of a triangle.



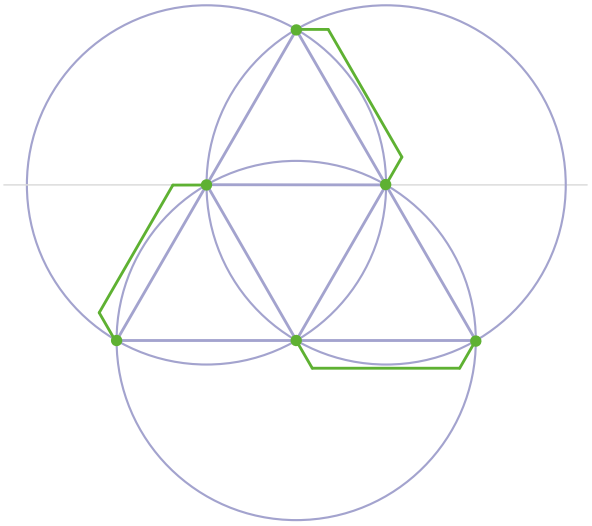
STEP 5 Draw a smaller triangle

Divide this triangle into four smaller triangles by drawing three lines connecting the three points shown below. The four triangles will be the faces of the tetrahedron net.



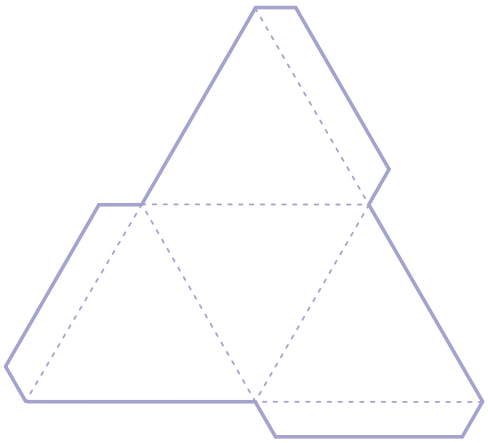
STEP 6 Add tabs

To make it possible to construct the net, add three tabs, as shown below in green.

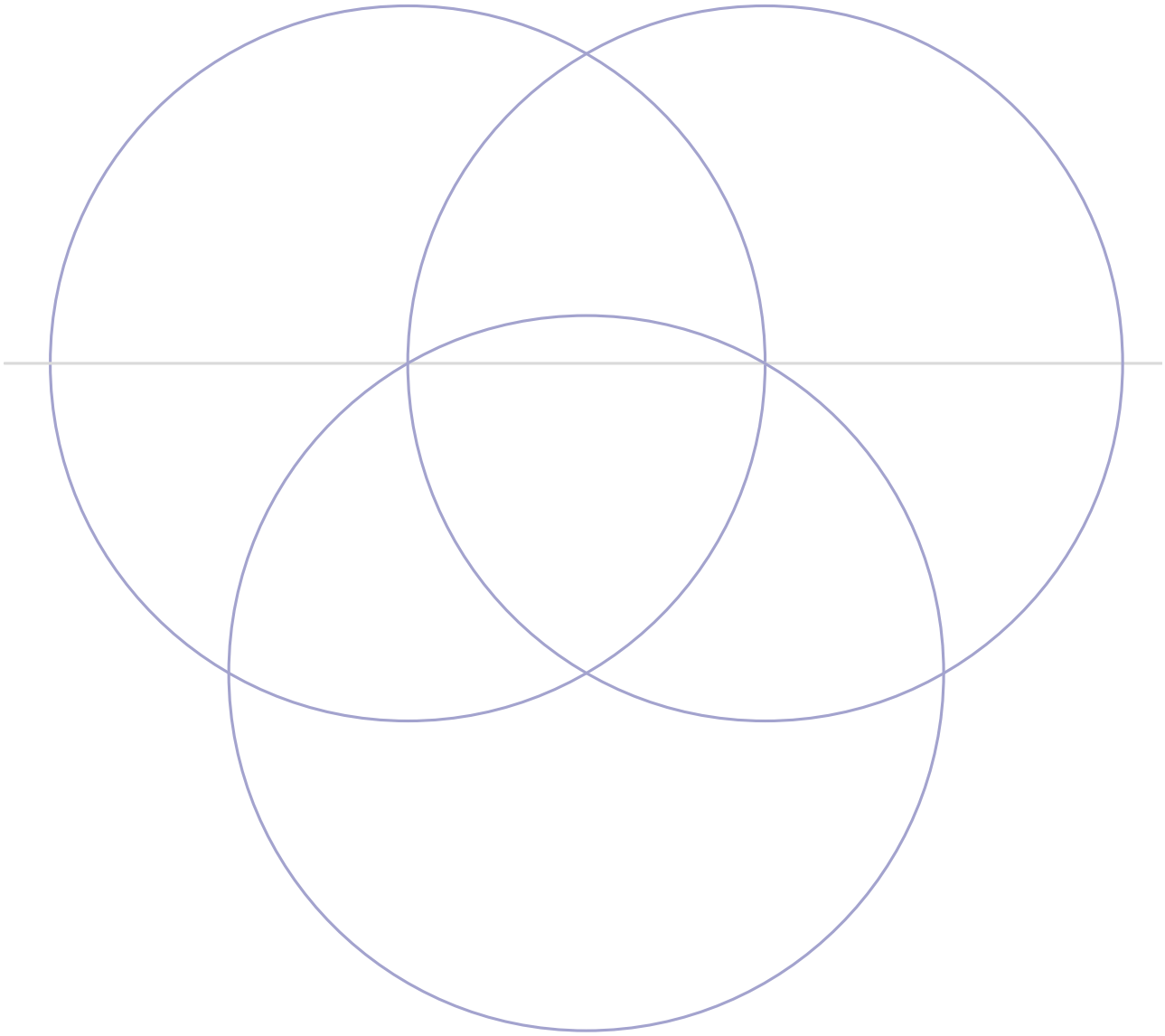


STEP 7 Build the tetrahedron

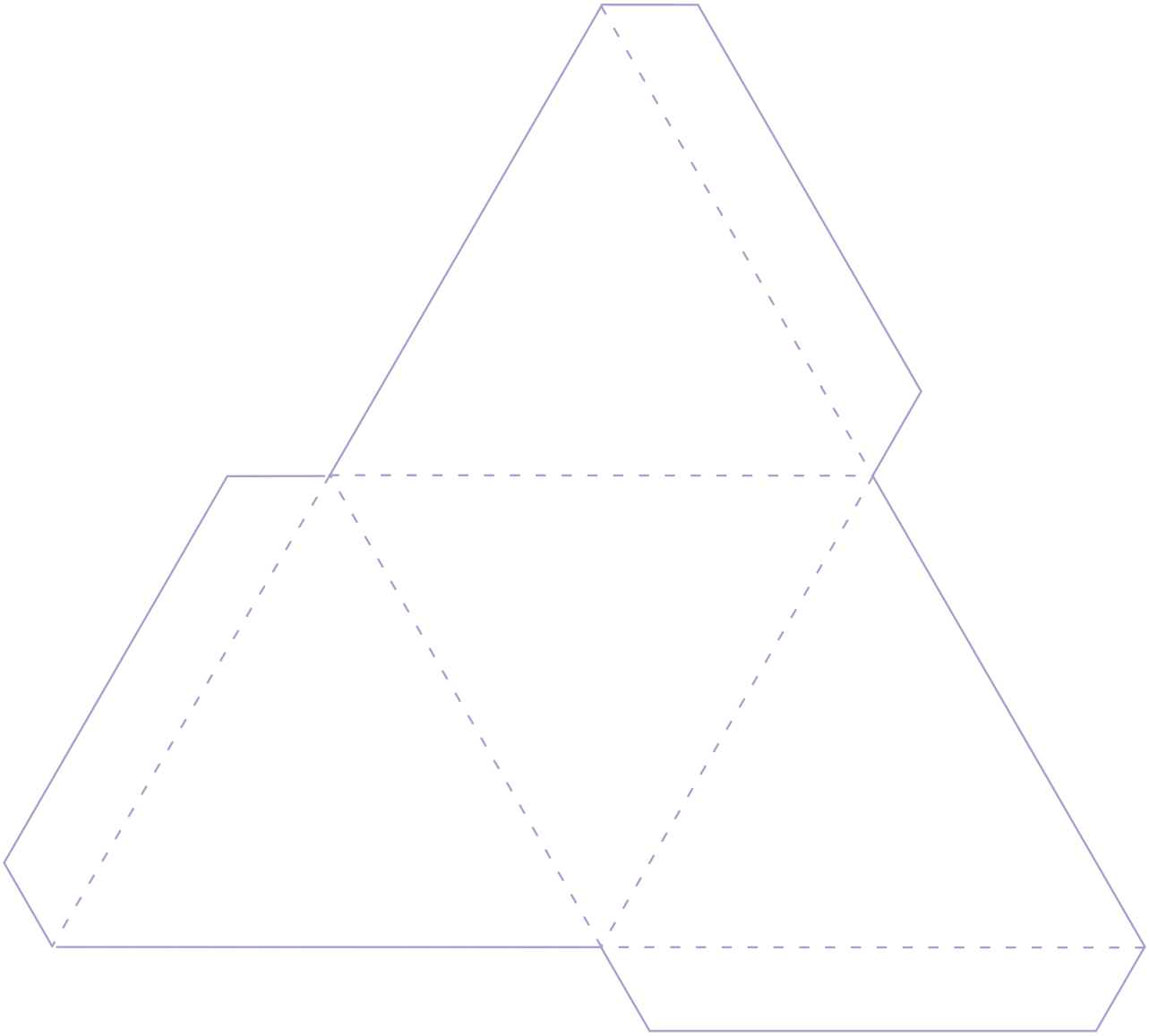
Cut out the net carefully, taking care to cut around the outer edge of each tab. Fold along the dotted lines, then use glue to stick the tabs in place.



PHOTOCOPIABLE RESOURCE 1A



PHOTOCOPIABLE RESOURCE 1B



GEOMETRY ACTIVITY 2

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

LEARNING QUESTION How do I build a cube?

The cube is one of the five Platonic solids. Platonic solids are special 3D shapes that share certain features: all the faces are identical regular polygons; exactly the same number of faces meet at each vertex; and every edge is the same length.

The cube is a special type of shape called a regular polyhedron. It has six square faces, 12 edges (the lines along which the faces meet) and eight vertices (corners) where three edges come together. The cube is a symmetrical shape. This means that no matter how you turn or flip it, it will always look the same. It has multiple lines of symmetry that divide it into equal parts.

Ancient civilizations such as the Egyptians and Greeks used cubes in their architecture and maths, and the cube was considered an important shape by philosophers including Plato. Cubes are all around us, from dice to sugar cubes, building blocks or even a Rubik's Cube! They are used in building and in many games and puzzles.

YOU WILL NEED

Copies of Resource 2A
Ruler
HB pencil
Good-quality eraser
Coloured pencils
Scissors
Glue
Optional copies of Resource 2B

DID YOU KNOW?

The other name for a cube is a hexahedron. A hexahedron is another word for a shape that has six faces. In the case of a cube, all six of its faces are squares. So, a cube is a special type of hexahedron. The word 'hexahedron' is made up of two parts: 'hexa' and 'hedron'. Hexa, meaning six, is found in words such as hexagon (a shape with six sides) and hexapod (an insect with six legs). The word 'hedron' means a flat surface or face. So, when we put them together, 'hexahedron' means a shape with six faces.

Cube pyrite crystal

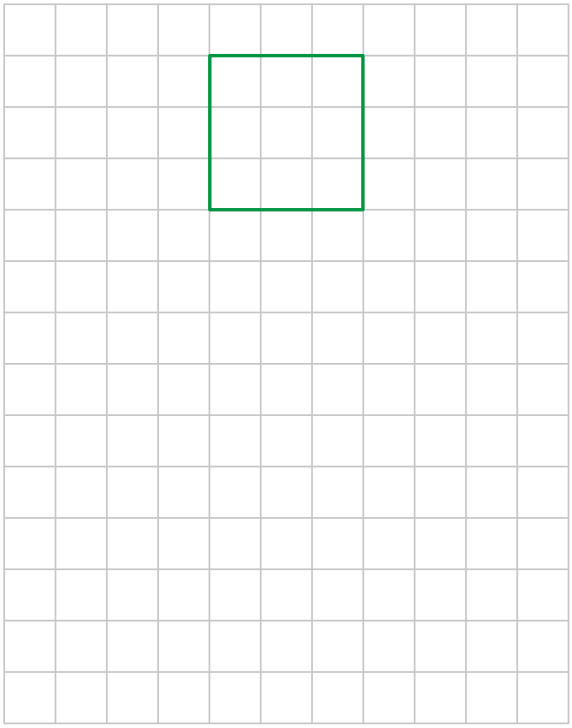
TEACHER TIP

This activity provides a fantastic jumping off point for exploring the different nets that can be drawn to create a cube. You could even challenge students who are more confident with shape to try to find them all. There are 11 possible nets in total.

ACTIVITY 2

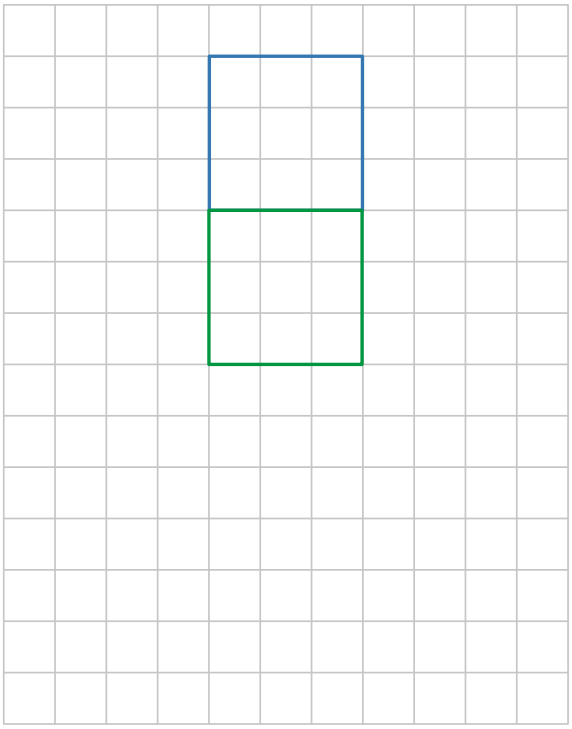
STEP 1 Draw a square

Start with a printout of Resource 2A. Use a ruler to draw a square that is 3 x 3 small squares, one square down from the top of the grid in the centre, as shown below in green. Alternatively, use a printout of Resource 2B and start from Step 8.



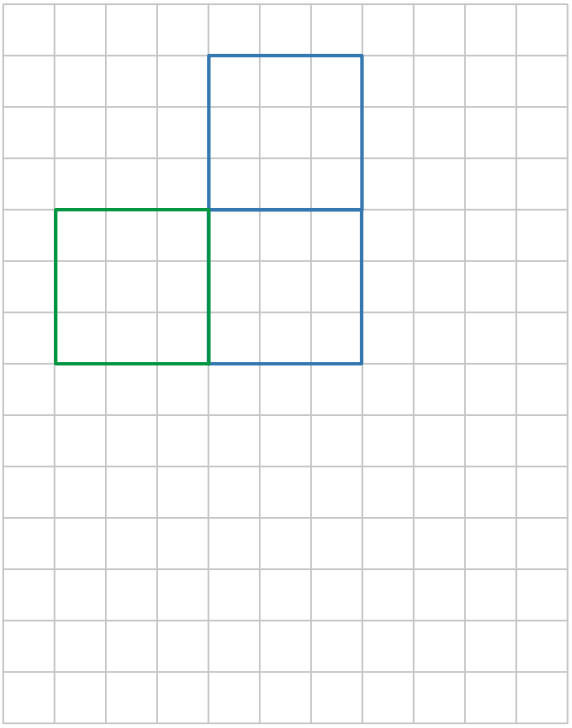
STEP 2 Draw a second square

Use a ruler to draw a second 3 x 3 square that sits directly below the first, as shown below in green.



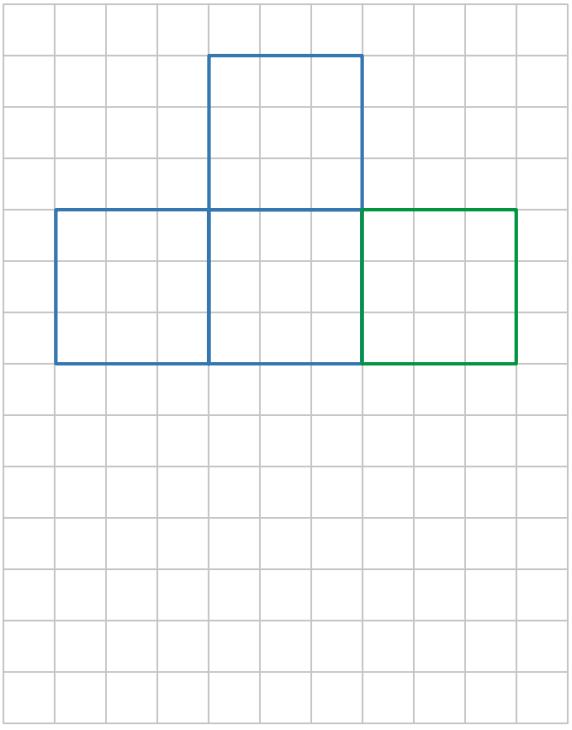
STEP 3 Draw a third square

Draw another 3 x 3 square to the left of the second square, as shown below in green.



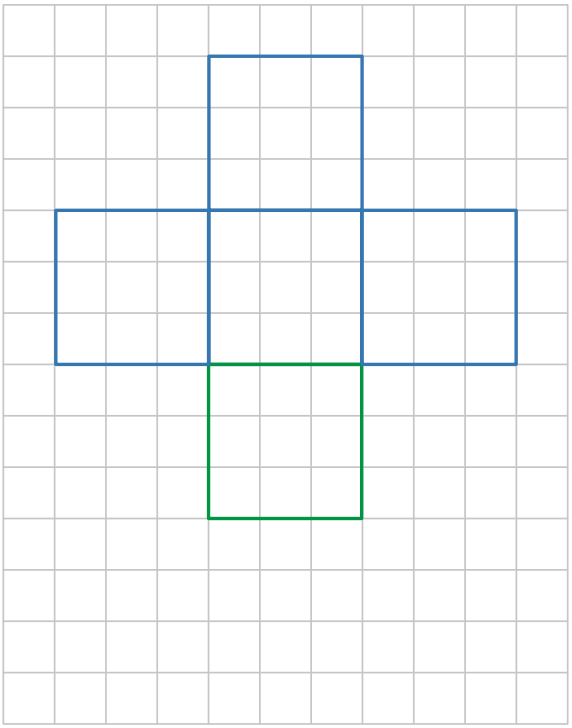
STEP 4 Draw a fourth square

Draw a fourth 3 x 3 square to the right of the second square, as shown below in green.



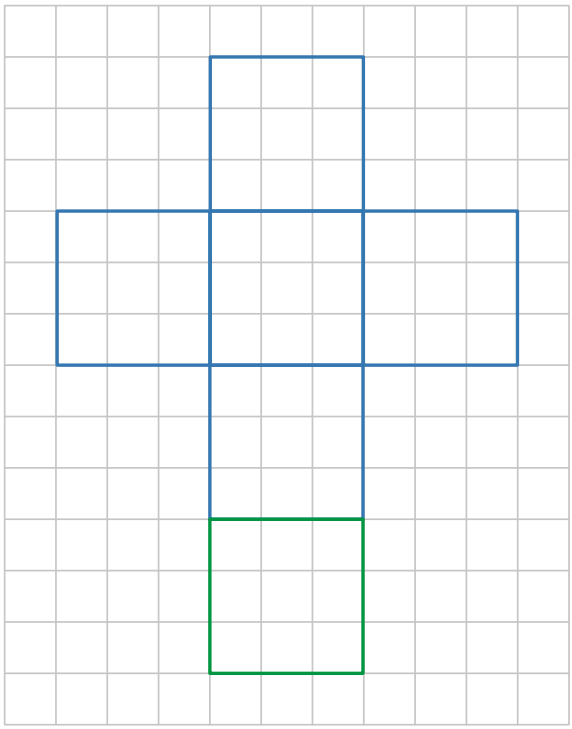
STEP 5 Draw a fifth square

Draw a fifth 3 x 3 square directly below the second square, as shown below in green.



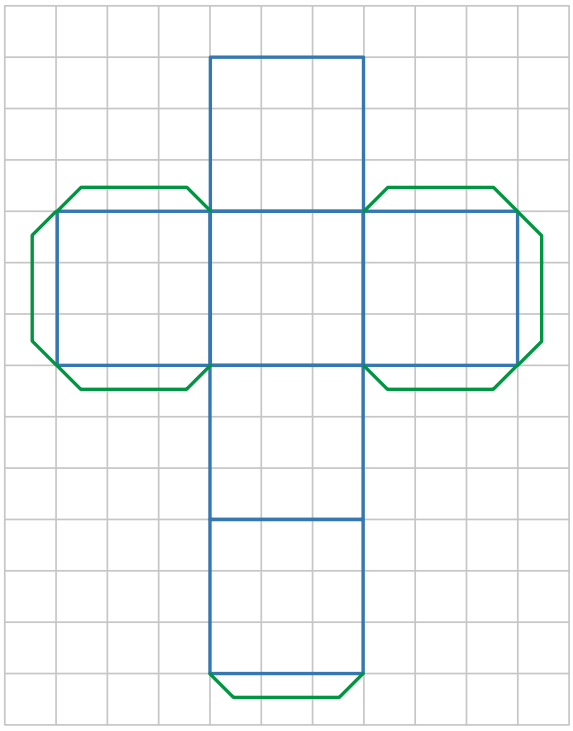
STEP 6 Draw a sixth square

Draw a sixth and final 3 x 3 square directly below the fifth square, as shown below in green.



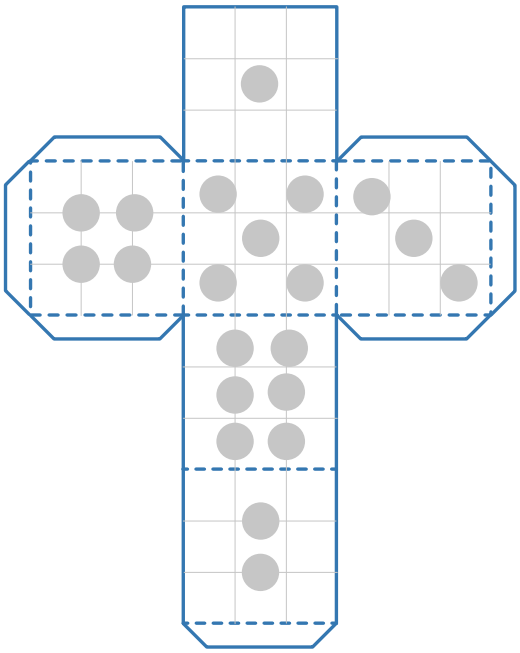
STEP 7 Add tabs

Draw seven tabs, as shown below in green, to complete the net.

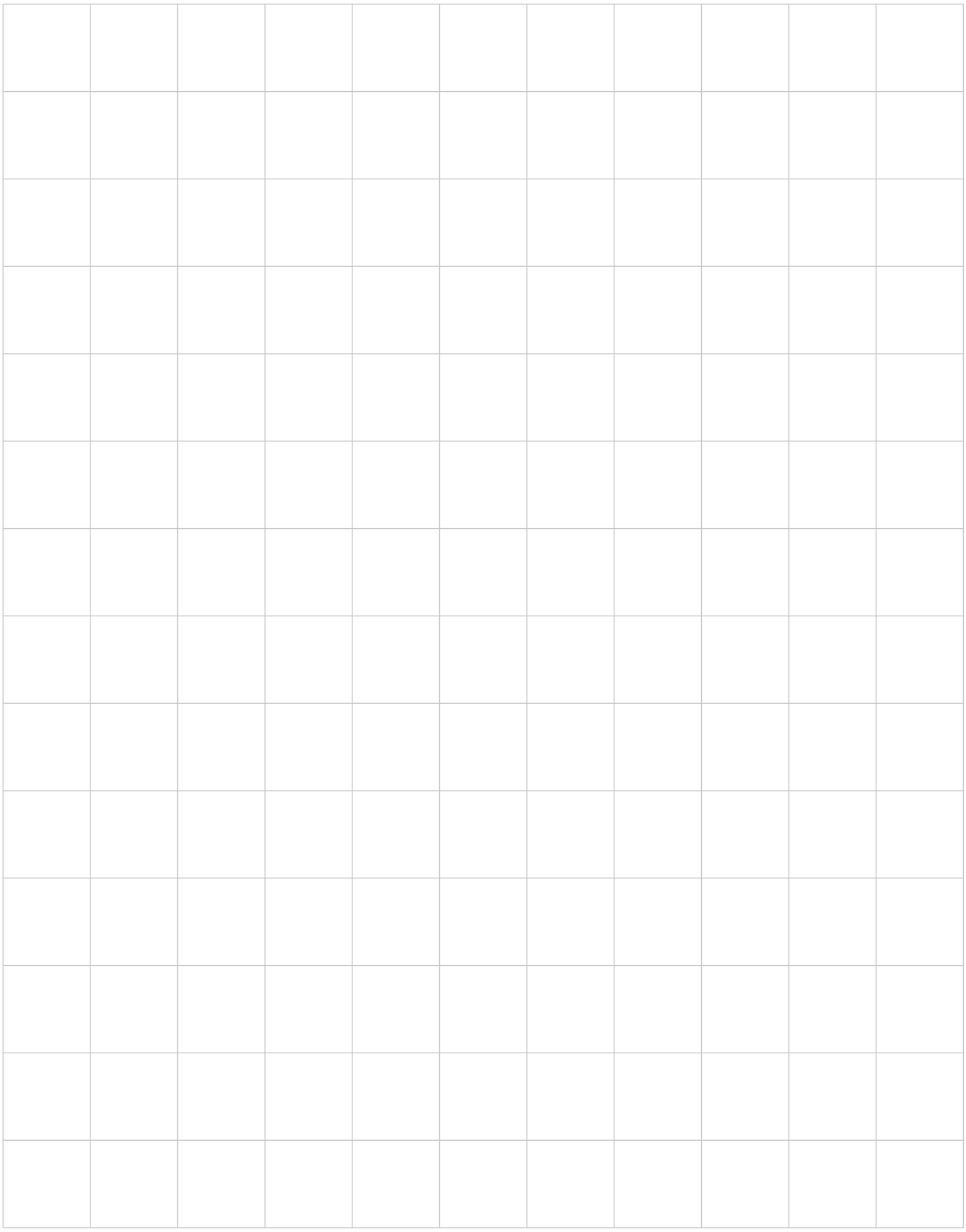


STEP 8 Assemble the cube

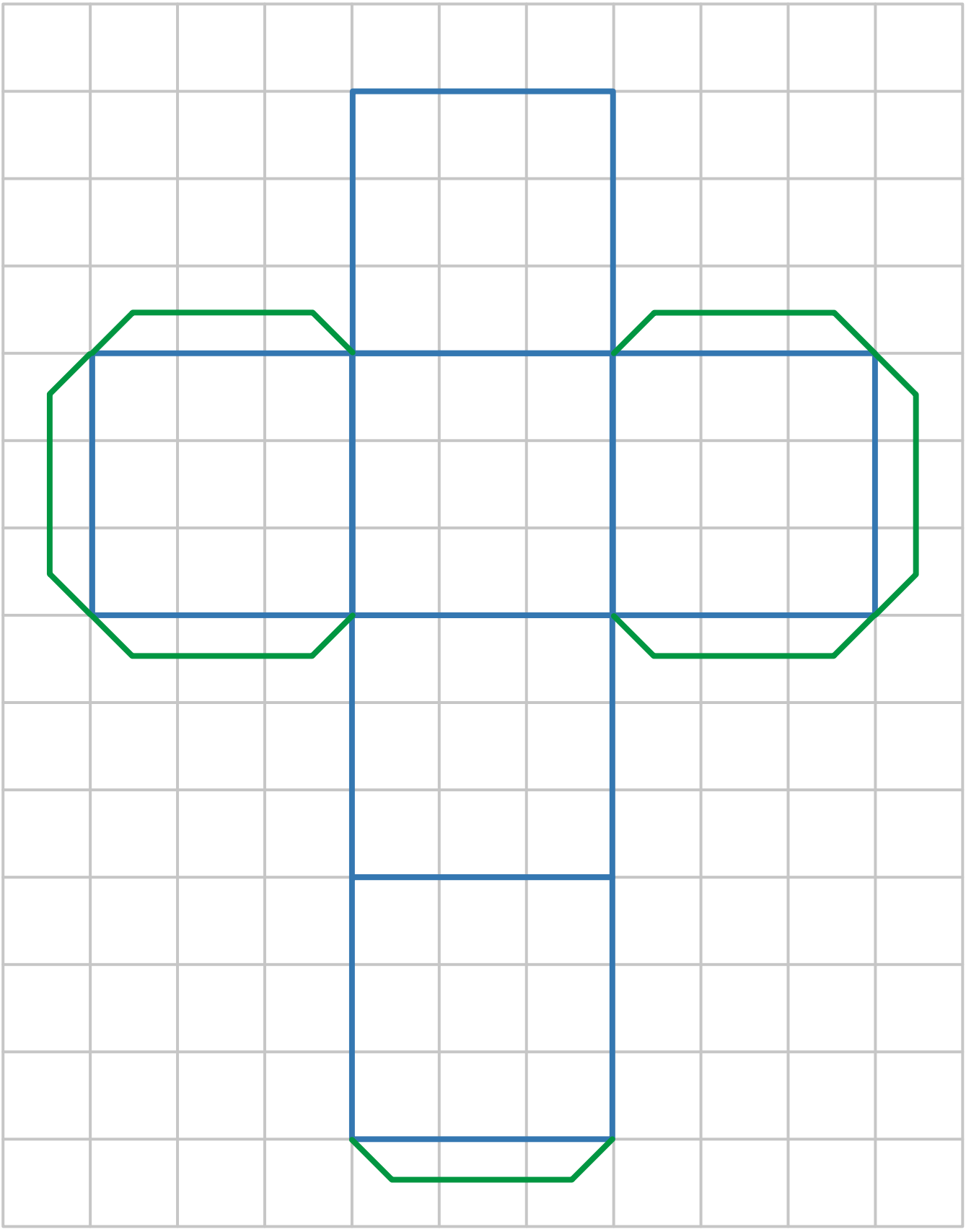
Cut out the net carefully, taking care to cut around the outer edge of each tab. At this stage, the cube can be turned into a dice by adding dots, as shown below (remember: the dots on the opposite faces of a dice should always add up to seven). Fold along the dotted lines, then use glue to stick the tabs in place.



PHOTOCOPIABLE RESOURCE 2A



PHOTOCOPIABLE RESOURCE 2B



GEOMETRY ACTIVITY 3

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

LEARNING QUESTION How do I build an octahedron?

The octahedron is one of the five Platonic solids. Platonic solids are special 3D shapes that share certain features: all the faces are identical regular polygons; exactly the same number of faces meet at each vertex; and every edge is the same length.

The octahedron has eight faces, all of which are identical triangles, and it looks like two pyramids stuck together at their bases. An octahedron has 12 edges, which are the lines along which two faces meet. It also has six vertices, which are the points at which four edges meet. The octahedron is a symmetrical shape. This means that if you rotate or flip it, it will still look the same.

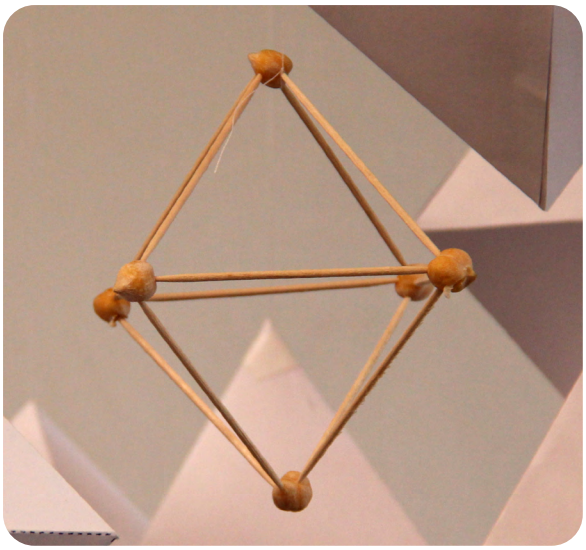
Although you might not come across octahedra very often in everyday life, they can be found in various fields. For example, some crystals and minerals naturally form octahedral shapes. The octahedron is a stable and strong shape. Its triangular faces share forces evenly, making it a good structure for building.

YOU WILL NEED

Ruler
HB pencil
Compass
Good-quality eraser
Scissors
Glue
Optional copies of Resource 3A, 3B and 3C

DID YOU KNOW?

The octahedron is a shape that can be found in crystals. Crystals are solid materials with a repeating pattern of atoms or molecules. Some crystals, such as fluorite and diamond, naturally form shapes that look like octahedrons. This means that the atoms in these crystals are arranged as octahedrons. This symmetry helps give crystals their unique shapes and structures. So, when you see an octahedral crystal, you can appreciate its beautiful and organised arrangement of atoms.

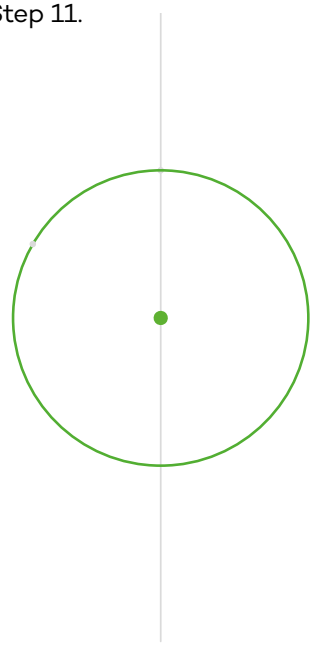


Octahedron model made by Year 5 students using chickpeas and toothpicks

ACTIVITY 3

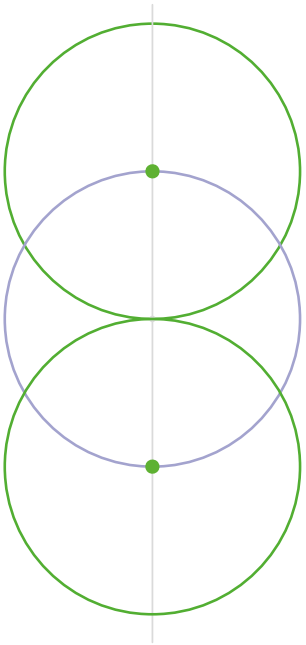
STEP 1 Draw a circle

Draw a vertical line down the centre of the page. With the compass radius set to 5cm, place the compass needle somewhere near the middle of this line and draw a circle. Alternatively, use Resource 3A and start from Step 2; use Resource 3B and start from Step 5; or use Resource 3C and start from Step 11.



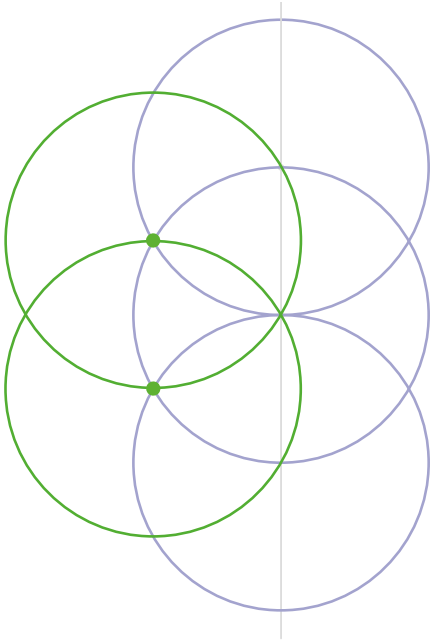
STEP 2 Draw a second and third circle

Mark the two points shown below in green where the first circle intersects the vertical line. With the compass still set to 5cm, place the compass needle on each of these dots in turn and draw two more circles above and below the first one.



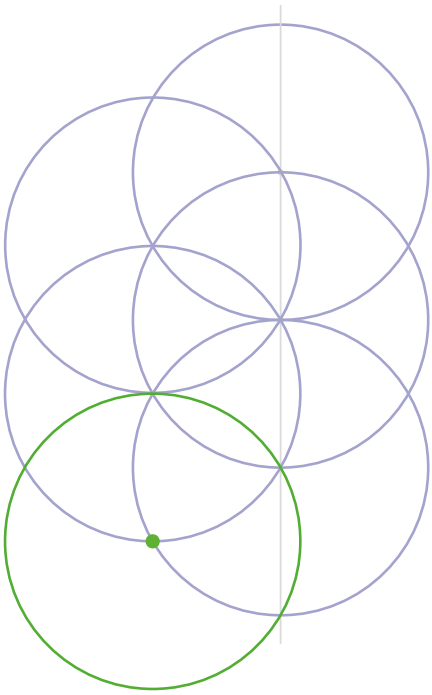
STEP 3 Draw a fourth and fifth circle

On the left-hand side, mark the two points shown below in green where the circumference of the first circle intersects the second and third circles. With the compass still set to 5cm, place the compass needle on each of these dots in turn and draw two more circles, as shown below.



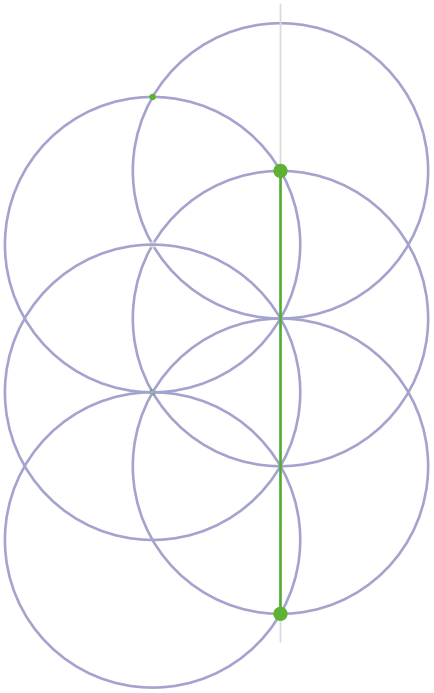
STEP 4 Draw a final circle

Mark the point shown below in green where the circumference of the fifth circle intersects with that of the third. With the compass still set to 5cm, place the compass needle on the dot and draw a sixth and final circle, as shown below.



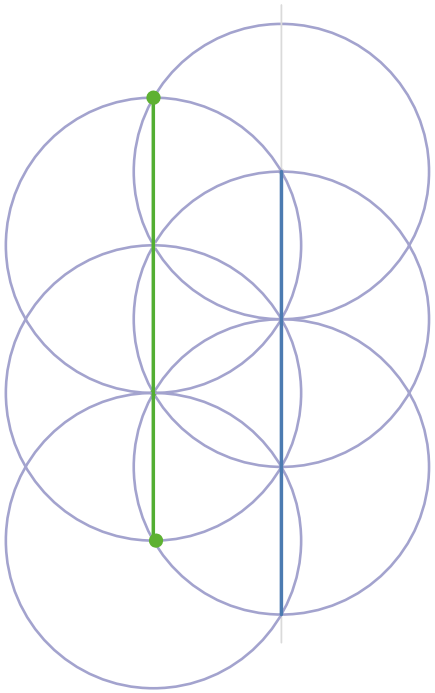
STEP 5 Draw a vertical line

Mark the points shown below in green from the centre of the second circle down to the bottom of the third. Use a ruler to line up these dots and draw a straight vertical line.



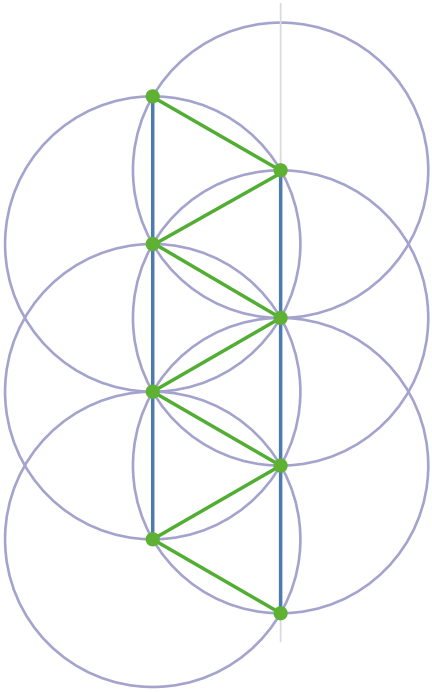
STEP 6 Draw a second line

Mark the points shown below in green from the centre of the sixth circle up to the top of the fourth. Use a ruler to line up these dots and draw a straight vertical line.



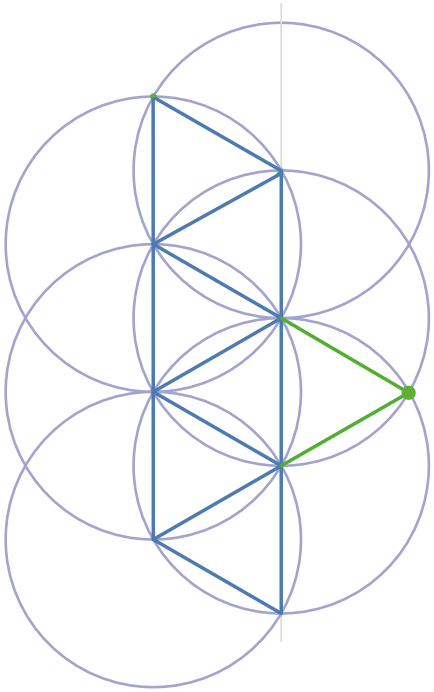
STEP 7 Draw six triangles

Mark the points shown below in green on the two vertical lines and use a ruler to draw seven diagonal lines as shown below. This will create six triangles.



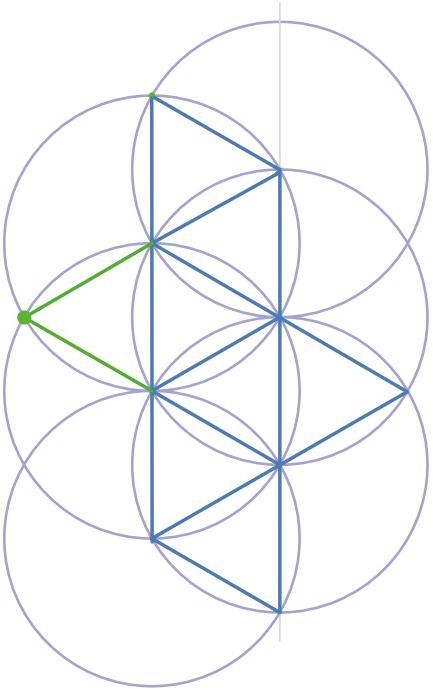
STEP 8 Draw a seventh triangle

To the right of the fourth triangle from the top, draw two more lines to create a seventh triangle, as shown below in green.



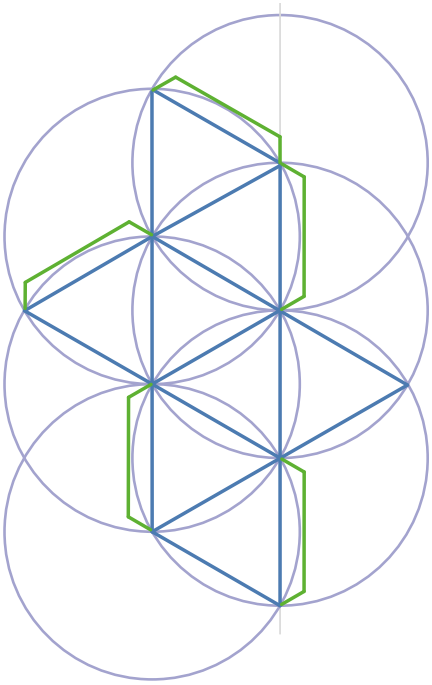
STEP 9 Draw an eighth triangle

To the left of the third triangle from the top, draw two more lines to create an eighth triangle, as shown below in green.



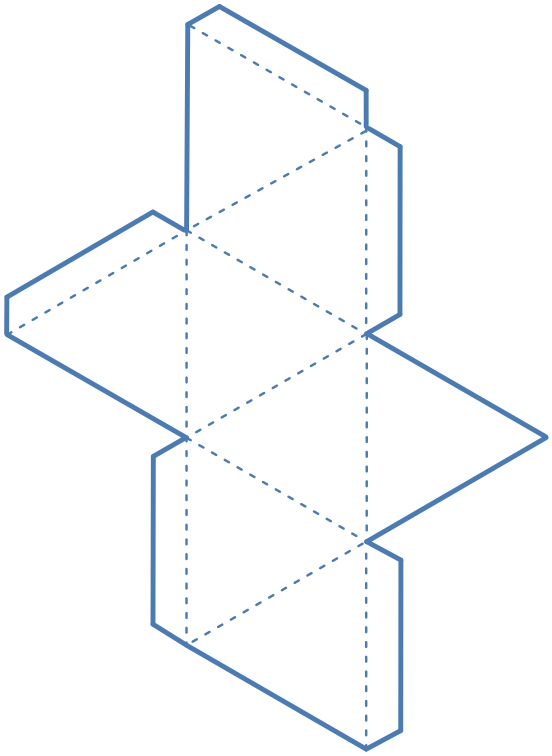
STEP 10 Add tabs

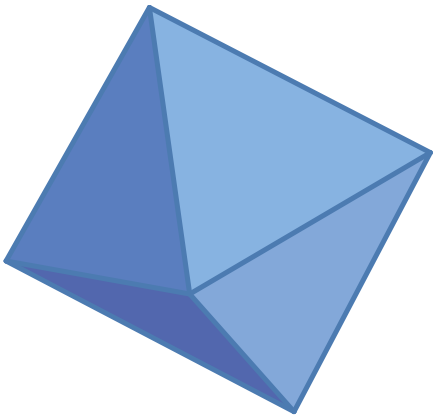
To make it possible to construct the net, add five tabs, as shown below in green.



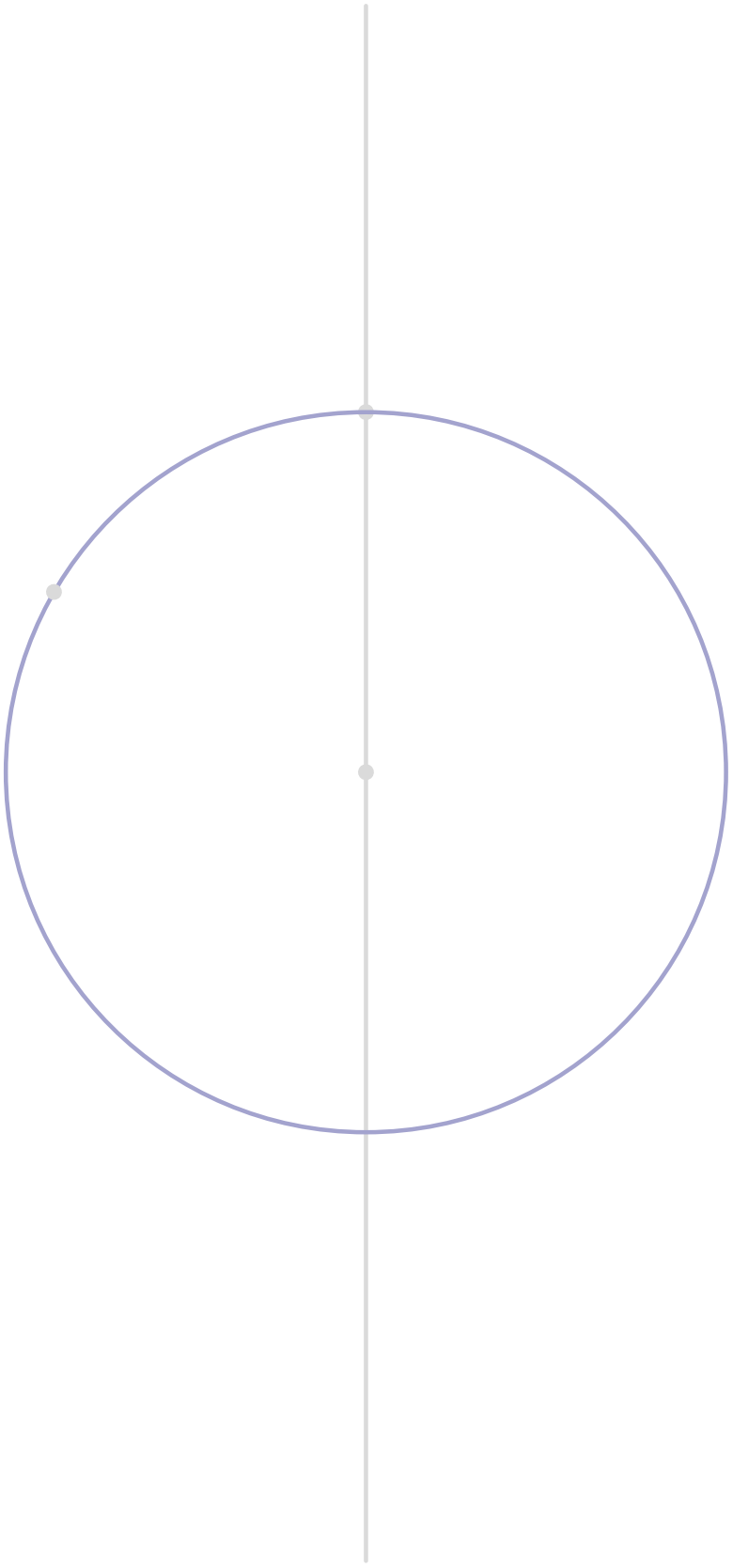
STEP 11 Build the tetrahedron

Cut out the net carefully, taking care to cut around the outer edge of each tab. Fold along the dotted lines, then use glue to stick the tabs in place.

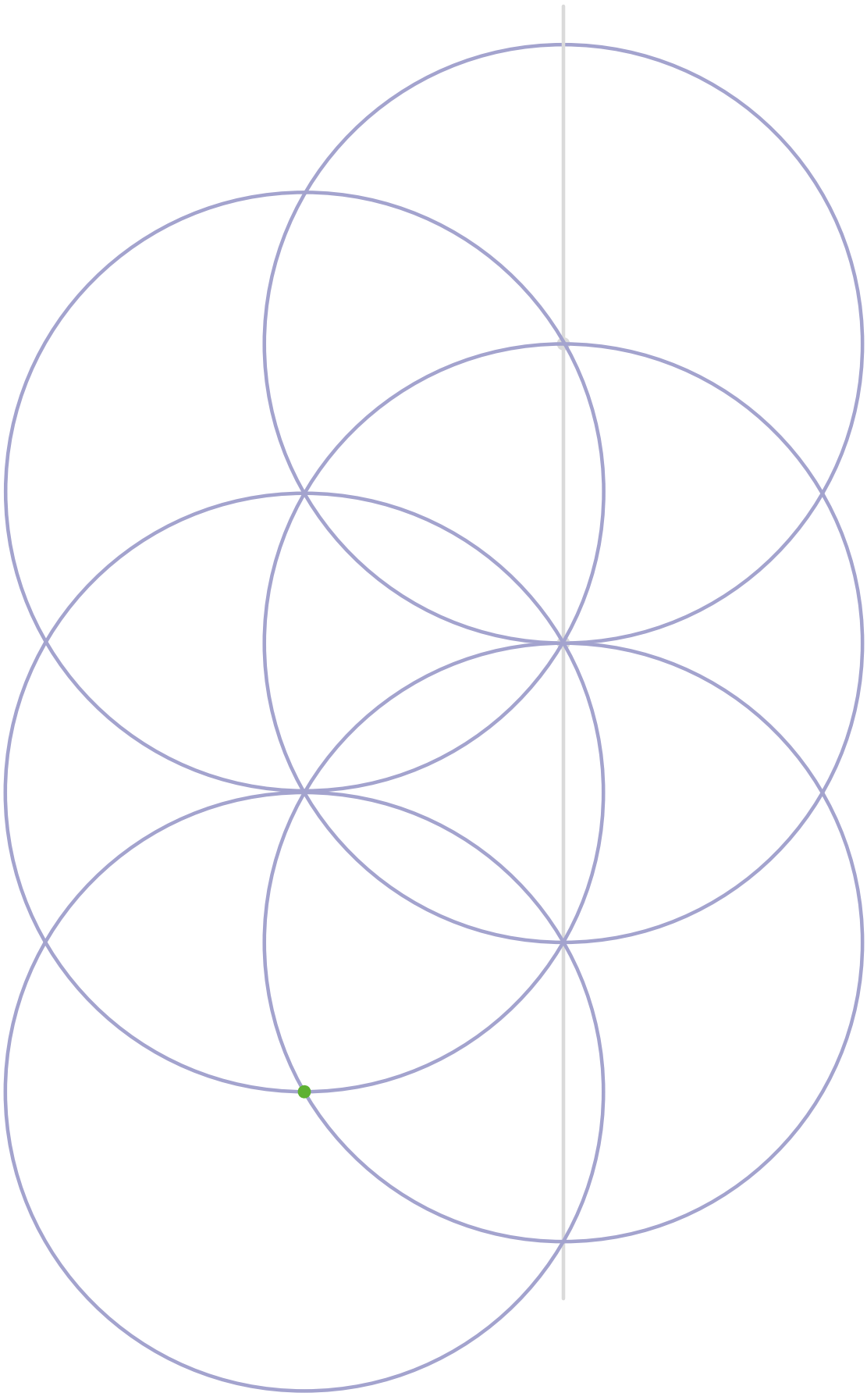




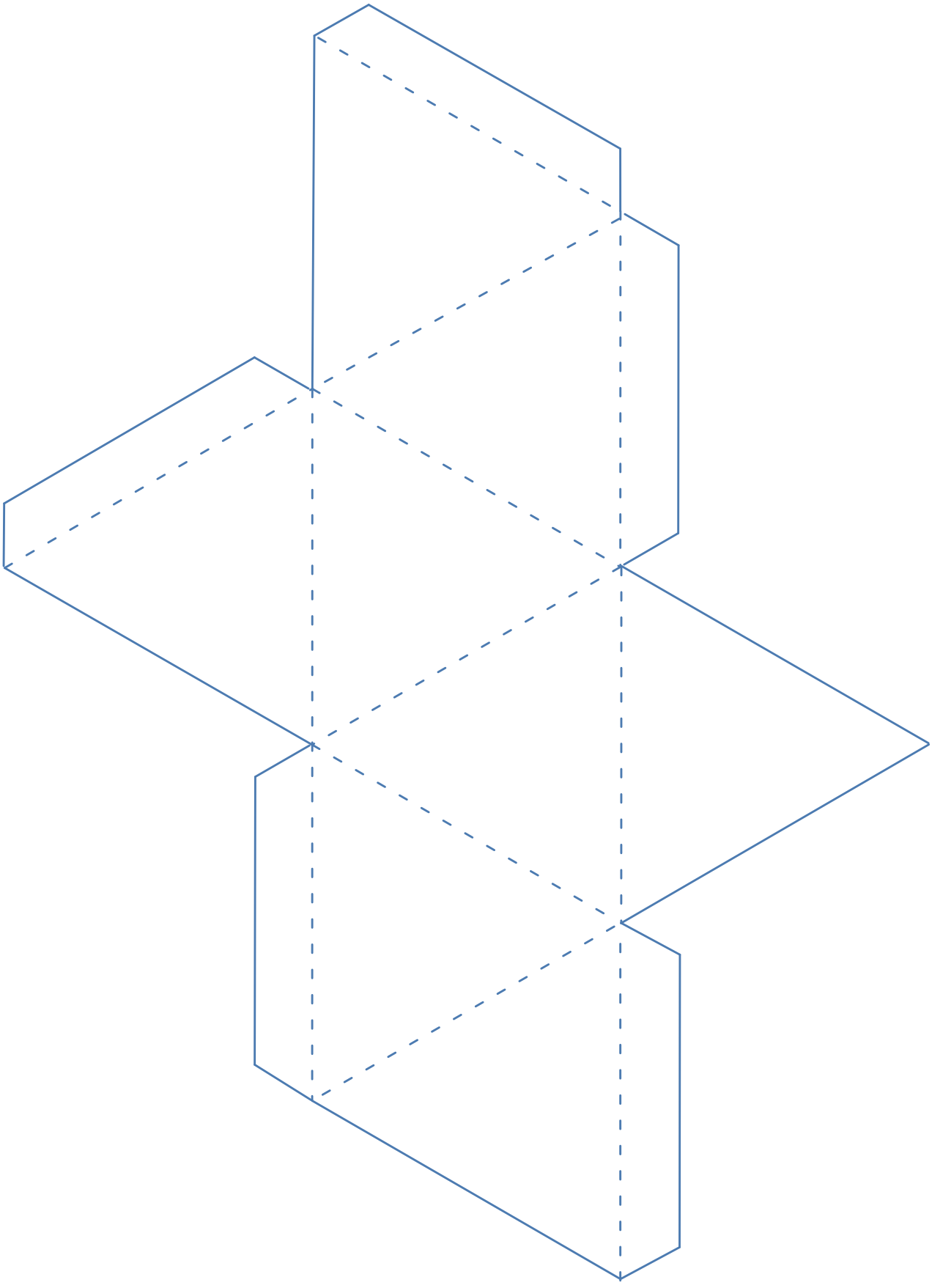
PHOTOCOPIABLE RESOURCE 3A



PHOTOCOPIABLE RESOURCE 3B



PHOTOCOPIABLE RESOURCE 3C



GEOMETRY ACTIVITY 4

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

LEARNING QUESTION How do I build an icosahedron?

The icosahedron is one of the five Platonic solids. Platonic solids are special 3D shapes that share certain features: all the faces are identical regular polygons; exactly the same number of faces meet at each vertex; and every edge is the same length.

An icosahedron has 30 edges (the lines where faces meet) and 12 vertices (the points where three or more edges come together). Each of its 20 faces is an equilateral triangle. The icosahedron is symmetrical; it looks the same no matter how you rotate or flip it.

The icosahedron is an interesting geometric shape because it has a large number of faces. This gives it a more spherical appearance compared with some other polyhedra – footballs and certain dome structures, for example, are based on the icosahedron. Icosahedra can also be found in Nature: under a microscope, certain viruses have an icosahedral shape.

YOU WILL NEED
Copies of Resource 4A
Dried chickpeas, soaked overnight (or plasticine)
Toothpicks

Polyhedron inscribed with letters of the Greek alphabet, 2nd-3rd century, The Met museum, New York

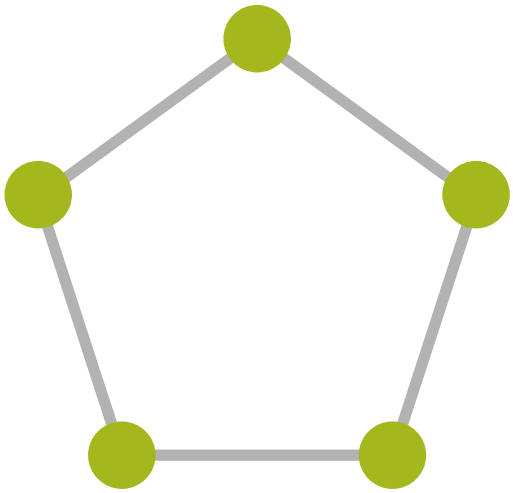
ACTIVITY 4

TEACHER TIP

This activity requires overnight preparation. For a class of 30, soak 500g dried chickpeas overnight and have 1,000 toothpicks ready to begin the activity. Alternatively, use plasticine balls instead of chickpeas.

STEP 1 Build a pentagon

Using five soaked chickpeas and five toothpicks, build a pentagon, as shown below. Pay attention to where you place the tip of the toothpick to leave room for others – each chickpea will need to hold five toothpicks.

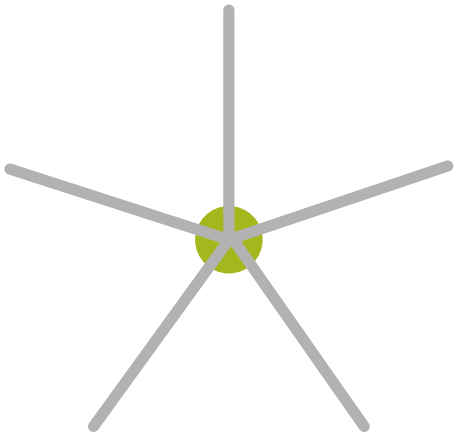


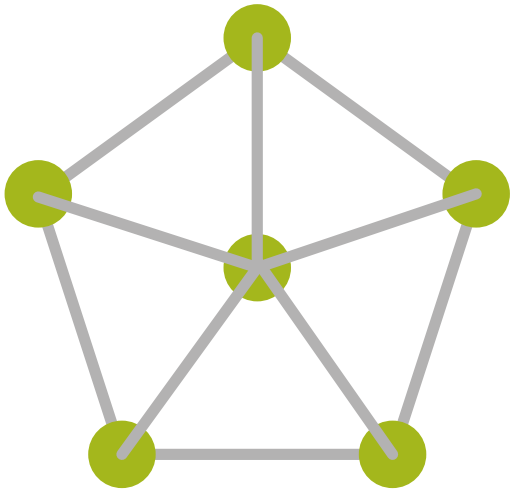
STEP 2 Build a star

Take one chickpea and assemble a five-pointed star, with all the toothpicks coming out from the central chickpea at a slight angle, as shown below. The ends of the arms should line up with the vertices of the pentagon you created in Step 1.

STEP 3 Build a pyramid

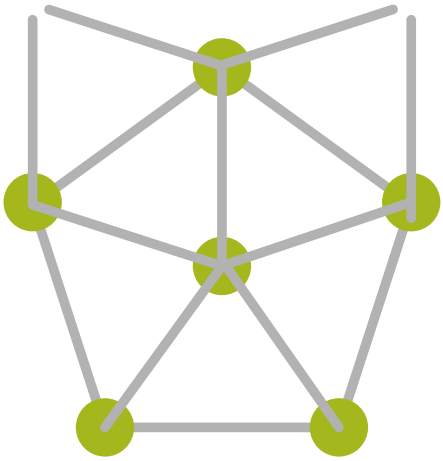
Combine the two shapes you made in Steps 1 and 2 to create a pentagonal-based pyramid, as shown below. You may need to angle the toothpicks on the star shape a little to achieve this. Turn the pyramid over so the concave side is facing upwards.



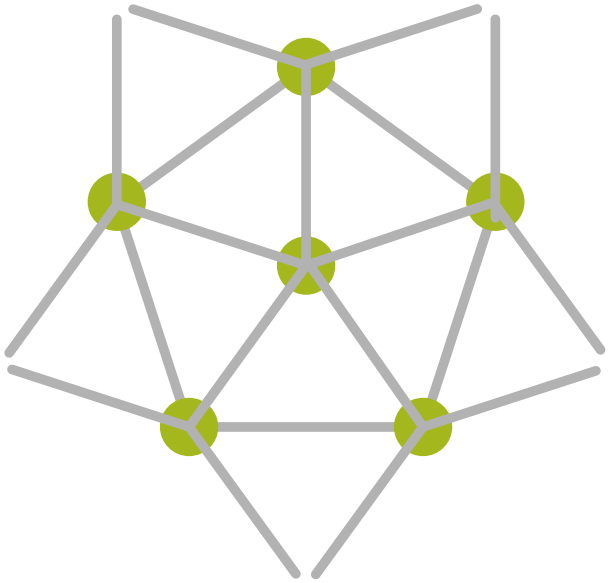


STEP 4 Build up from the pyramid

Using two toothpicks at a time, build up from the base of the pentagonal-based pyramid to create the middle section of the icosahedron. The placement of the toothpicks is shown below in 2D as a guide, and again on the template on Resource 4A, but you will need to angle the toothpicks at roughly 90º from the base of the pyramid. The picture on page 22 will help you.

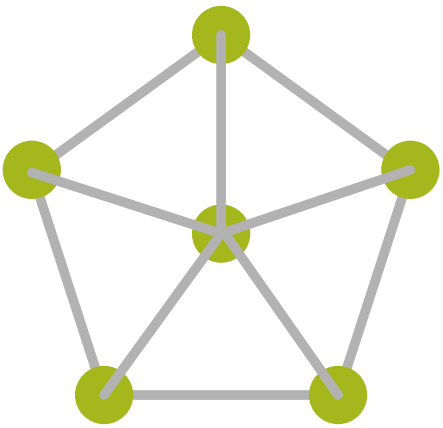


The finished star should look like a 3D version of the shape shown below.



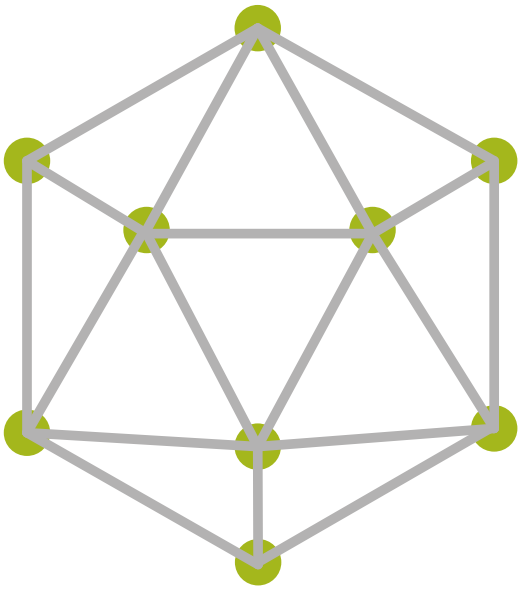
STEP 5 Build a second pyramid

Repeat Steps 1 to 3 to build another pentagonal-based pyramid.

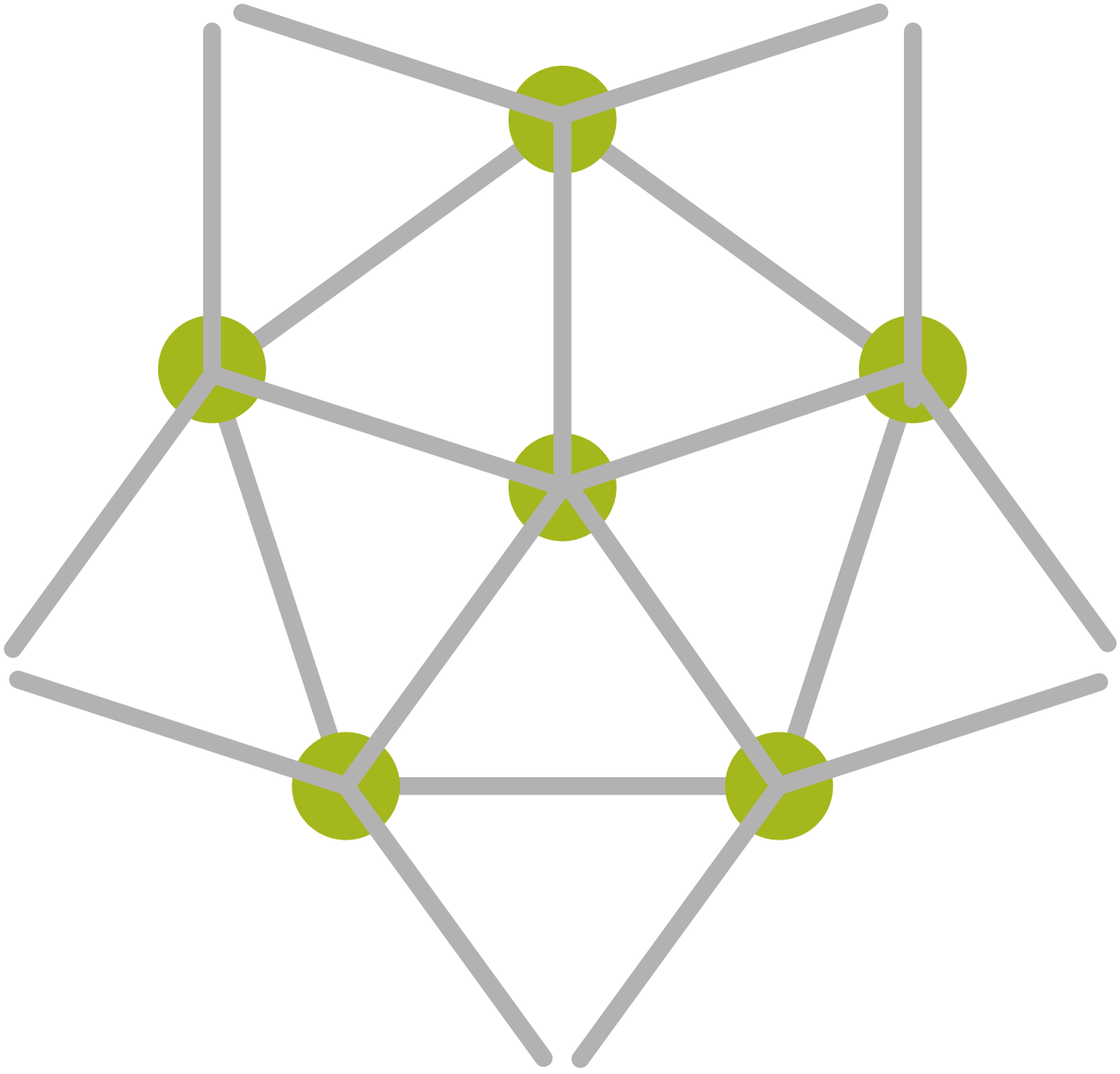


STEP 6 Combine the two shapes

Lift up the first structure you built in Steps 1 to 4 and join the toothpicks added in Step 4 to the base of the second pyramid, to create an icosahedron. You may need to angle the toothpicks a little to achieve this. Again, look at the picture on page 22 as a guide to help you. You might find it easier to work with a partner to complete this step.



PHOTOCOPIABLE RESOURCE 4A



GEOMETRY ACTIVITY 5

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

LEARNING QUESTION How do I build a dodecahedron?

The dodecahedron is one of the five Platonic solids. Platonic solids are special 3D shapes that share certain features: all the faces are identical regular polygons; exactly the same number of faces meet at each vertex; and every edge is the same length.

In the case of the dodecahedron, each of its 12 faces is a regular pentagon. It has 30 edges (the lines where faces meet) and 20 vertices (the points where three edges come together). The dodecahedron is a symmetrical shape. It looks the same no matter how you rotate or flip it. It has multiple lines of symmetry that divide it into equal parts.

Dodecahedra are not common but they do appear in Nature. Crystals sometimes have a dodecahedron shape, as do some tiny sea creatures called diatoms.

YOU WILL NEED

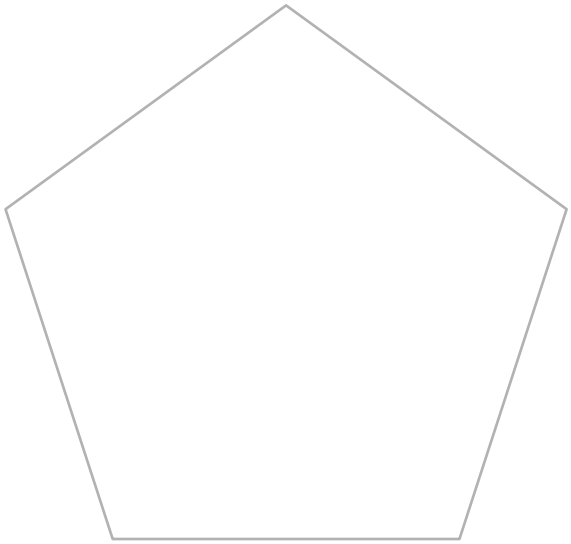
Copies of Resource 5A
Ruler
HB pencil
Good-quality eraser
Felt tip pen
Scissors
Glue
Optional copies of Resource 5B

Dodecahedral pyrite crystal

ACTIVITY 5

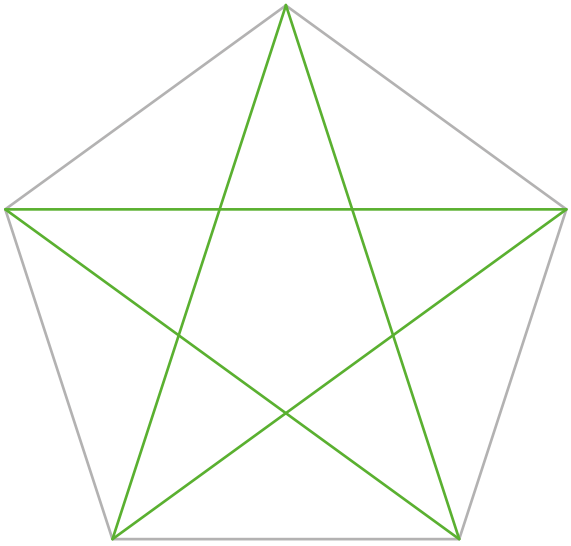
TEACHER TIP

Pentagons are tricky to construct with a compass, so use the pentagon template provided on Resource 5A. The dodecahedron will be easier to construct if Resource 5A is printed out on A3 paper. Alternatively, use Resource 5B and start from Step 9.



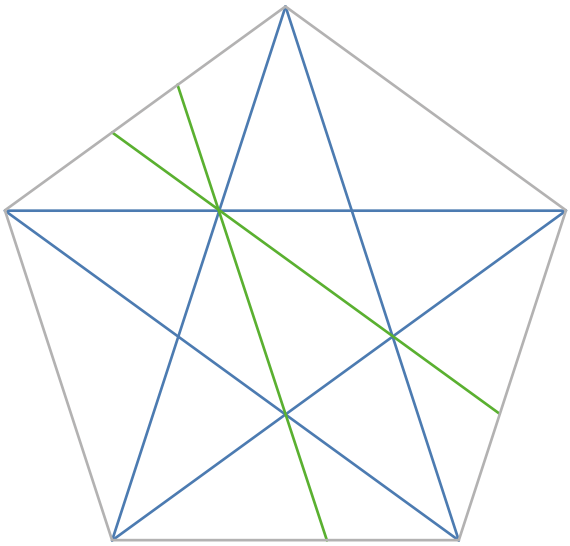
STEP 1 Draw a star

Start with a printout of Resource 5A. Draw a star inside the pentagon by using a ruler to connect almost-opposite vertices, as shown below.



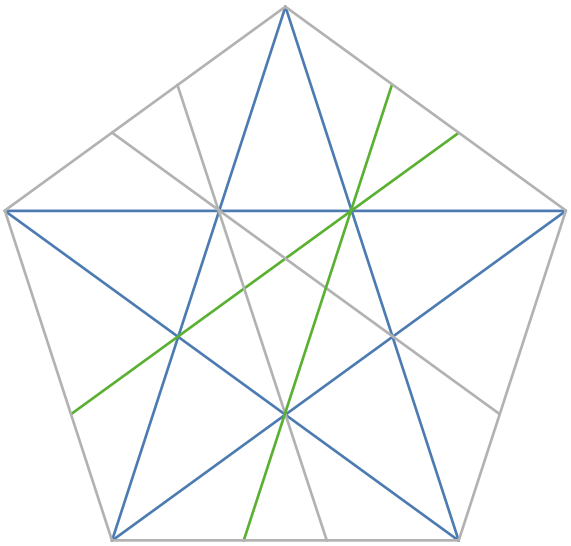
STEP 2 Draw a pair of lines

The star created inside the pentagon has a smaller pentagon at its centre, pointing downwards. Draw a pair of lines as shown below in green. The first intersects the top left and bottom vertices of the small central pentagon. The second line intersects the top left and bottom right vertices. Make sure each line extends right to the sides of the larger pentagon.



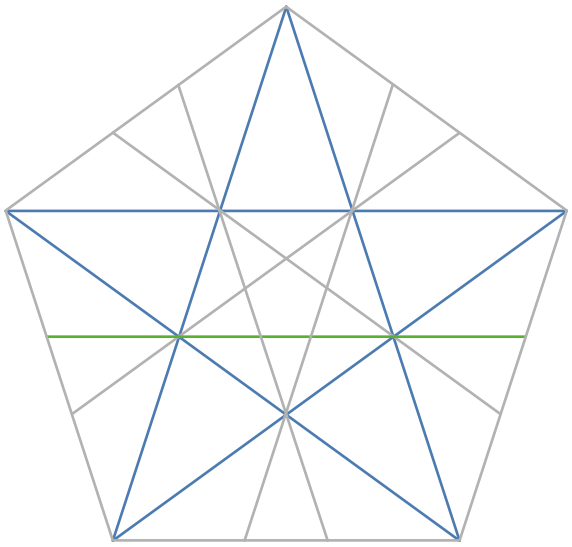
STEP 3 Draw another pair of lines

Repeat Step 3 to draw a pair of lines as shown below in green. The first intersects the top right and bottom vertices of the small central pentagon. The second line intersects the top right and bottom left vertices. Make sure each line extends right to the sides of the larger pentagon.



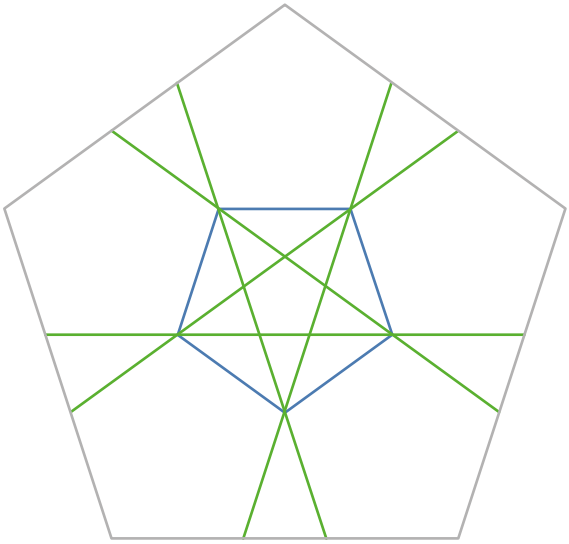
STEP 4 Draw a final line

Use a ruler to line up the bottom left and bottom right vertices of the smaller pentagon and draw a horizontal line that runs through both and extends to the sides of the larger pentagon, as shown below.



STEP 5 Outline six pentagons

There should now be six smaller pentagons visible within the larger one, as shown below. Use a felt tip pen to mark these clearly. You can now rub out the construction lines inside the small central pentagon if you wish, working very carefully.

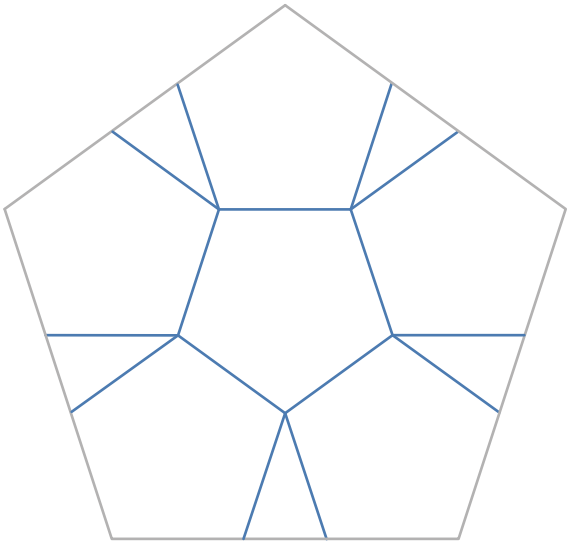


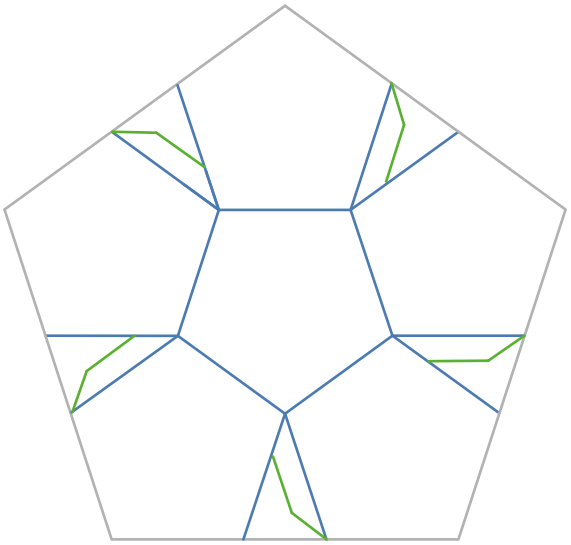
TEACHER TIP

To construct a dodecahedron, students will have to work with a partner from this point onwards and stick the nets they have each created together. One student in each pair will need to follow the instructions for Side A to draw tabs; the other will need to follow the instructions for Side B.

STEP 6 Add five tabs to Side A

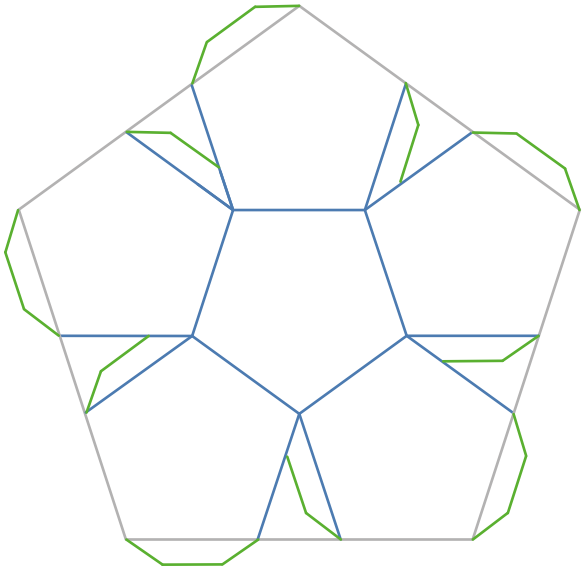
Working clockwise around the diagram, draw five tabs on the right-hand side of each outer pentagon, as shown below in green. These tabs will hold this half of the dodecahedron together.





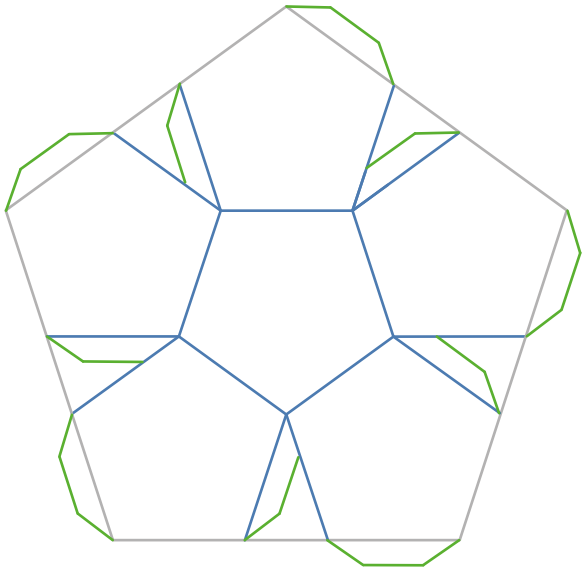
STEP 7 Add five more tabs to Side A

Draw five more tabs, shown below in green, on the outside of the large pentagon template. There should now be 10 tabs in total.



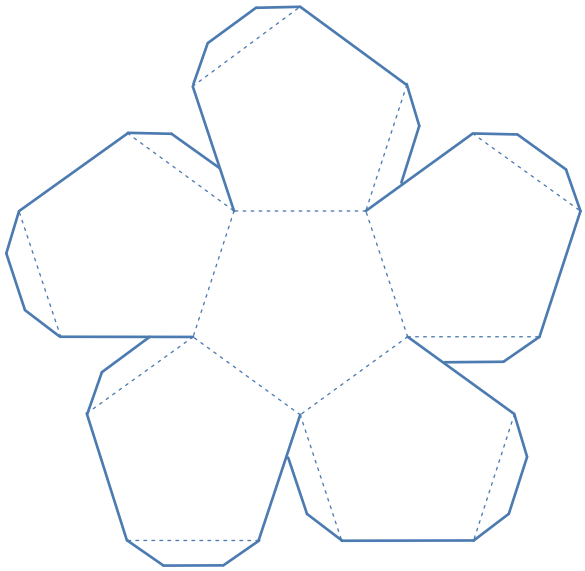
STEP 8 Add 10 tabs to Side B

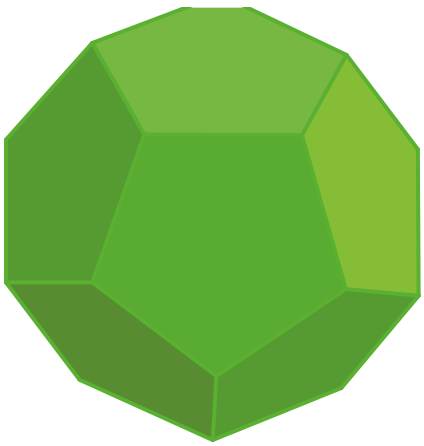
Draw 10 tabs as shown below in green on the second student's net – these are reversed when compared with side A.



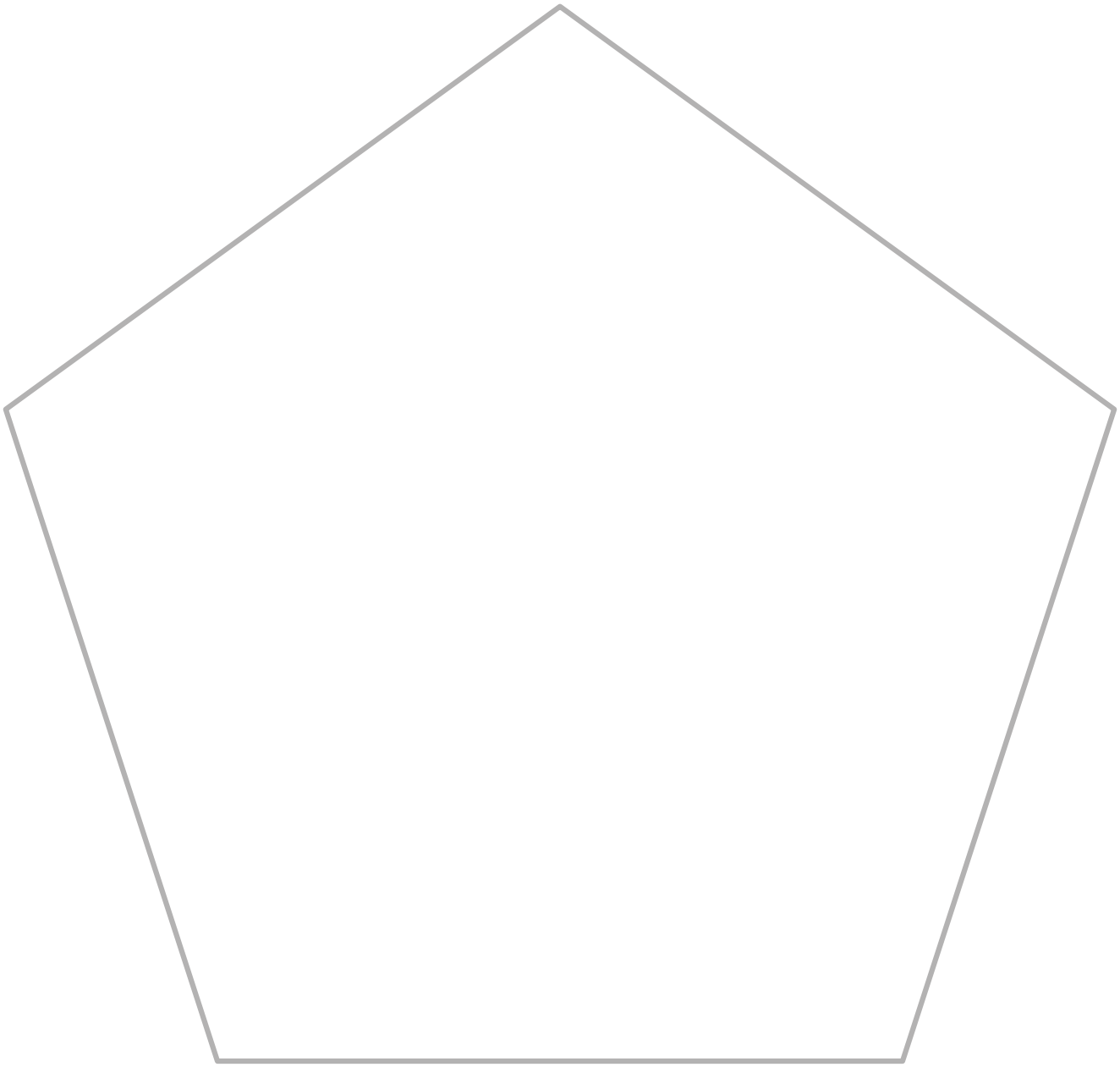
STEP 9 Build the dodecahedron

Cut out each net carefully, taking care to cut around the outer edge of each tab. Fold along the dotted lines, then use glue to stick the tabs in place. Stick the nets together to complete the dodecahedron.

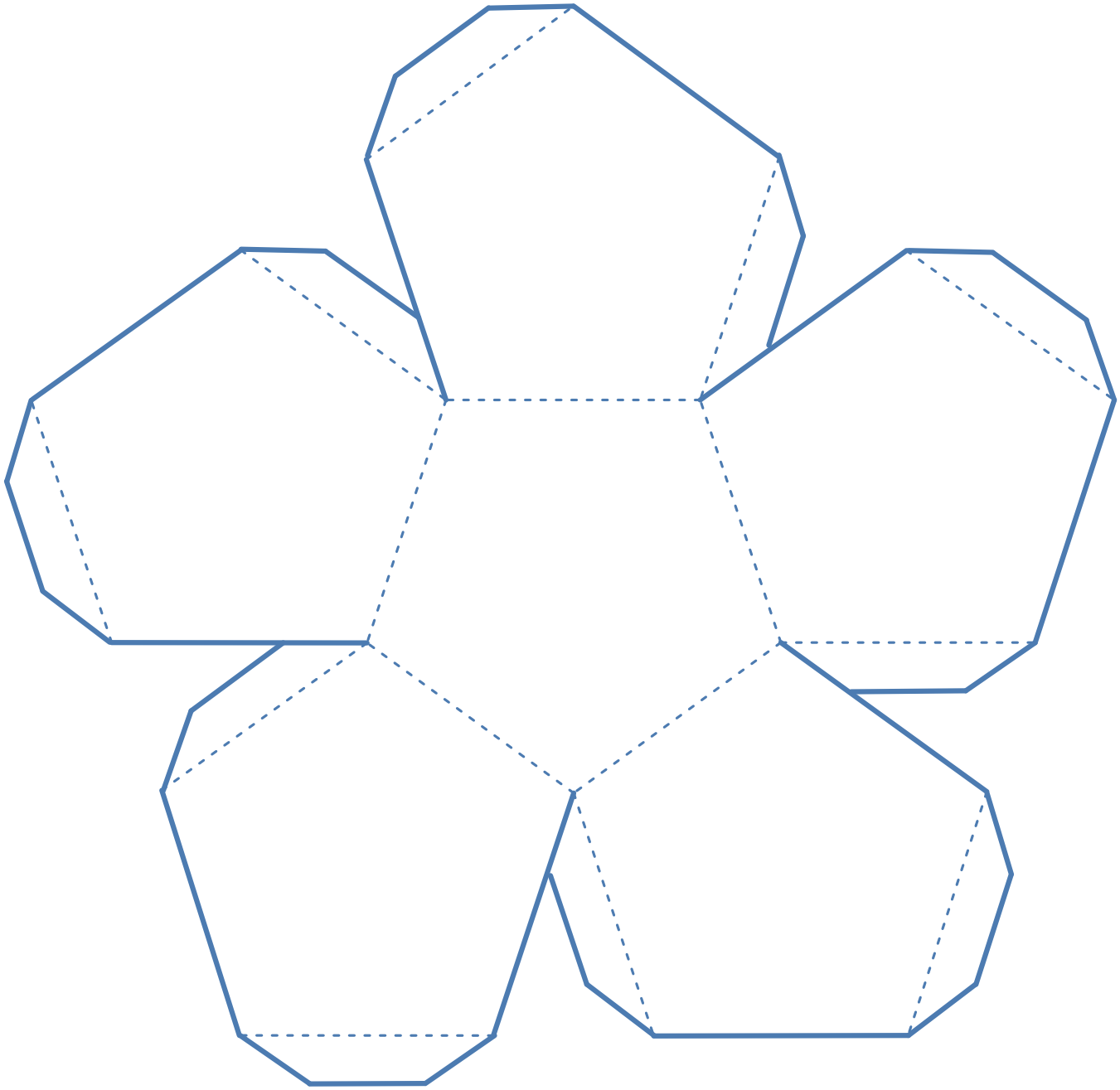




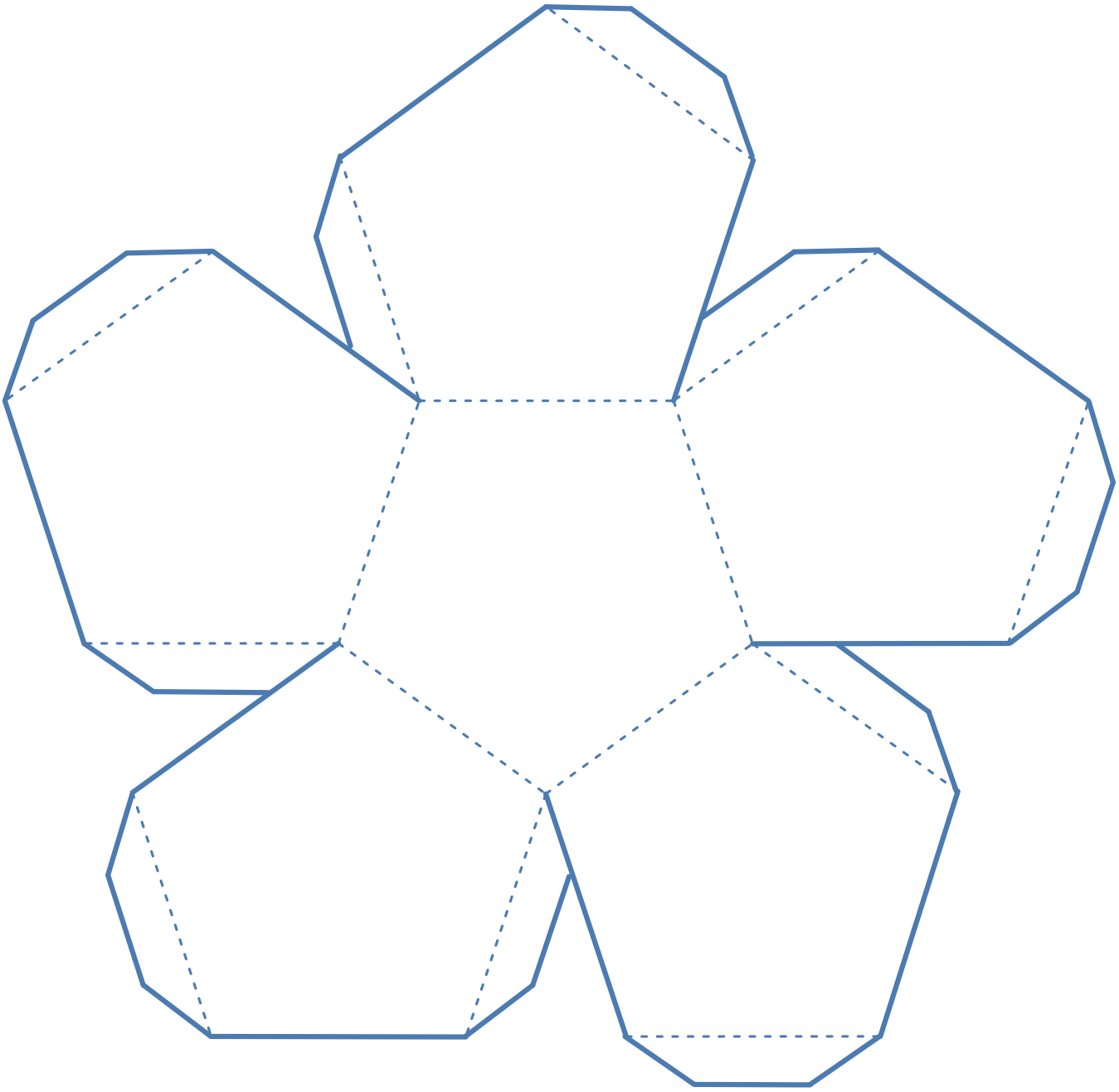
PHOTOCOPIABLE RESOURCE 5A



PHOTOCOPIABLE RESOURCE 5B Side A



PHOTOCOPIABLE RESOURCE 5B Side B



GEOMETRY ACTIVITY 6

ENQUIRY OF LEARNING What can we learn from the Ancient Greeks about the order of Nature?

LEARNING QUESTION How do I build an Archimedean solid?

An Archimedean solid is a special kind of 3D shape that has faces that are different regular polygons, such as triangles, squares or hexagons. As the sides of these shapes are all the same length, they fit together perfectly. All the vertices of an Archimedean solid look the same because the same number of edges meet at each vertex.

There are 13 different Archimedean solids and they have been studied by mathematicians for a long time. They are named after the Ancient Greek mathematician Archimedes because he studied and described them in detail. He discovered that these solids have special properties and their faces are made up of different regular polygons.

The truncated tetrahedron is one of the Archimedian solids. It is a geometric shape that is made by cutting off the corners of a regular tetrahedron. It has four faces that are equilateral triangles and four hexagonal faces. It has a total of 12 edges and eight vertices (corners) where three faces meet.

YOU WILL NEED

Copies of Resource 6A
HB pencil
Coloured pencils
Good-quality eraser
Ruler
Scissors
Glue
Optional copies of Resource 6B

Truncated tetrahedron dice

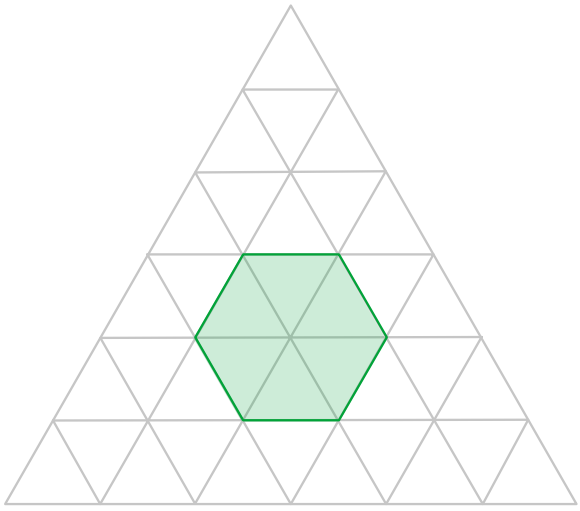
DID YOU KNOW?

'Truncated' means cut off or with part of something removed. The word comes from the Latin word 'truncatus', which means 'cut off' or 'shortened'. In geometry, when we talk about a truncated shape, it means that some of its corners or edges have been removed to create a new shape. For example, a truncated tetrahedron is made by cutting off the corners of a regular tetrahedron.

ACTIVITY 6

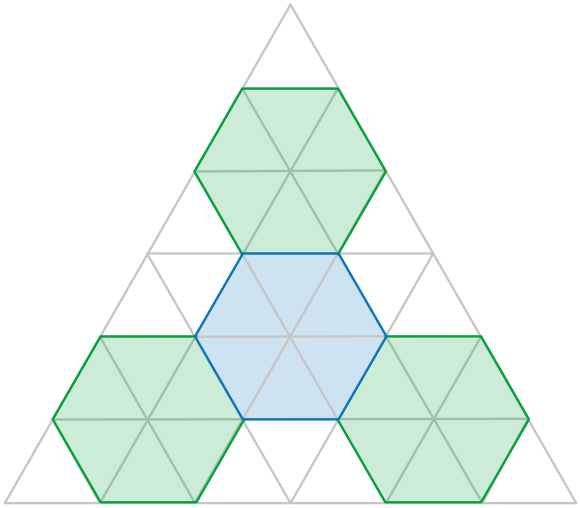
STEP 1 Draw a hexagon

Start with a printout of Resource 6A. Use a ruler to outline the hexagon at the centre of the grid of triangles, as shown below in green. Alternatively, use Resource 6B and start from Step 6.



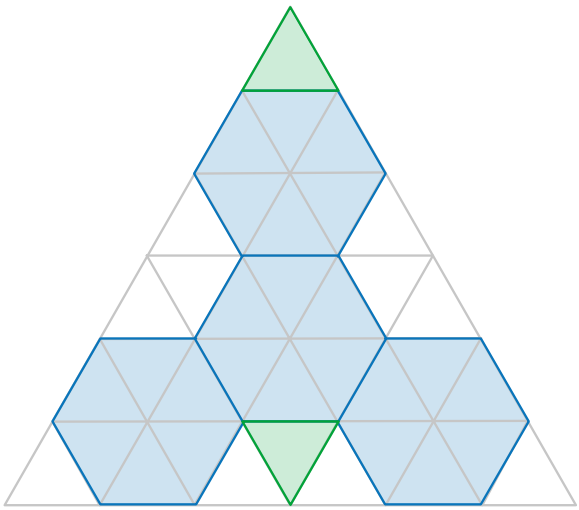
STEP 2 Draw three more hexagons

Draw three more hexagons adjoining the first, as shown below in green.



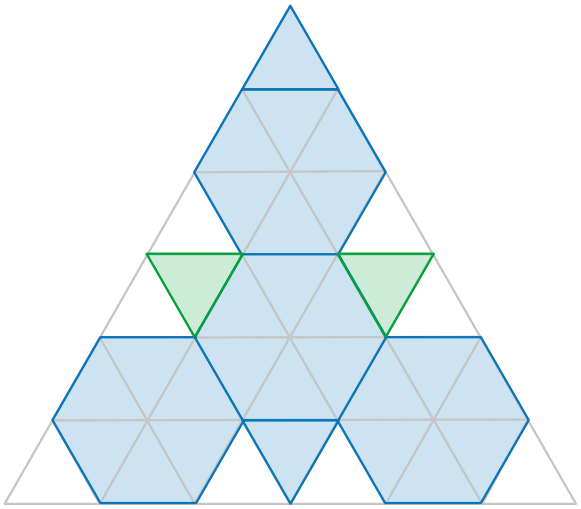
STEP 3 Draw two triangles

Draw two triangles, one at the top of the grid and one at the bottom, as shown below in green.



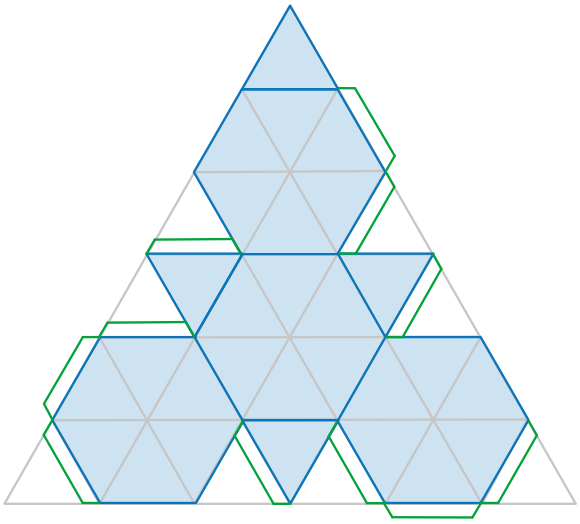
STEP 4 Draw two more triangles

Draw two more triangles on the left- and right-hand sides of the central hexagon, as shown below in green.



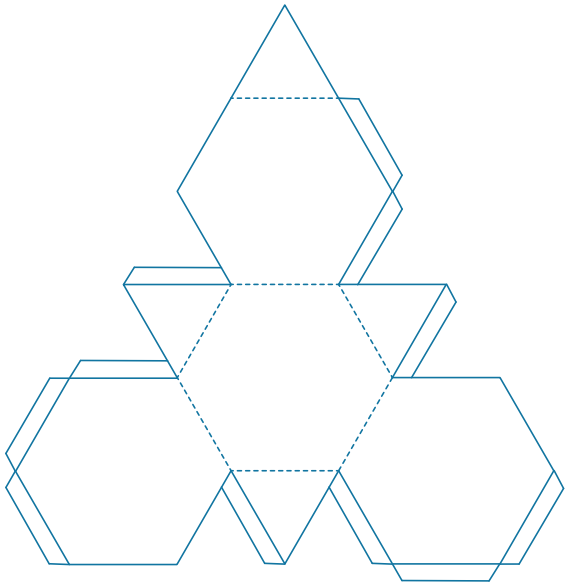
STEP 5 Add tabs

To make it possible to construct the net, add 11 tabs, as shown below in green.



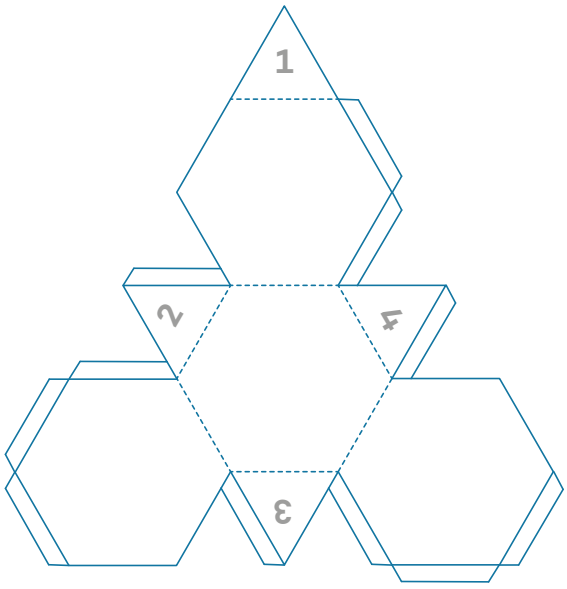
STEP 6 Cut out the net

Cut out the net carefully, taking care to cut around the outer edge of each tab, and fold along the dotted lines.



STEP 7 Build the truncated tetrahedron

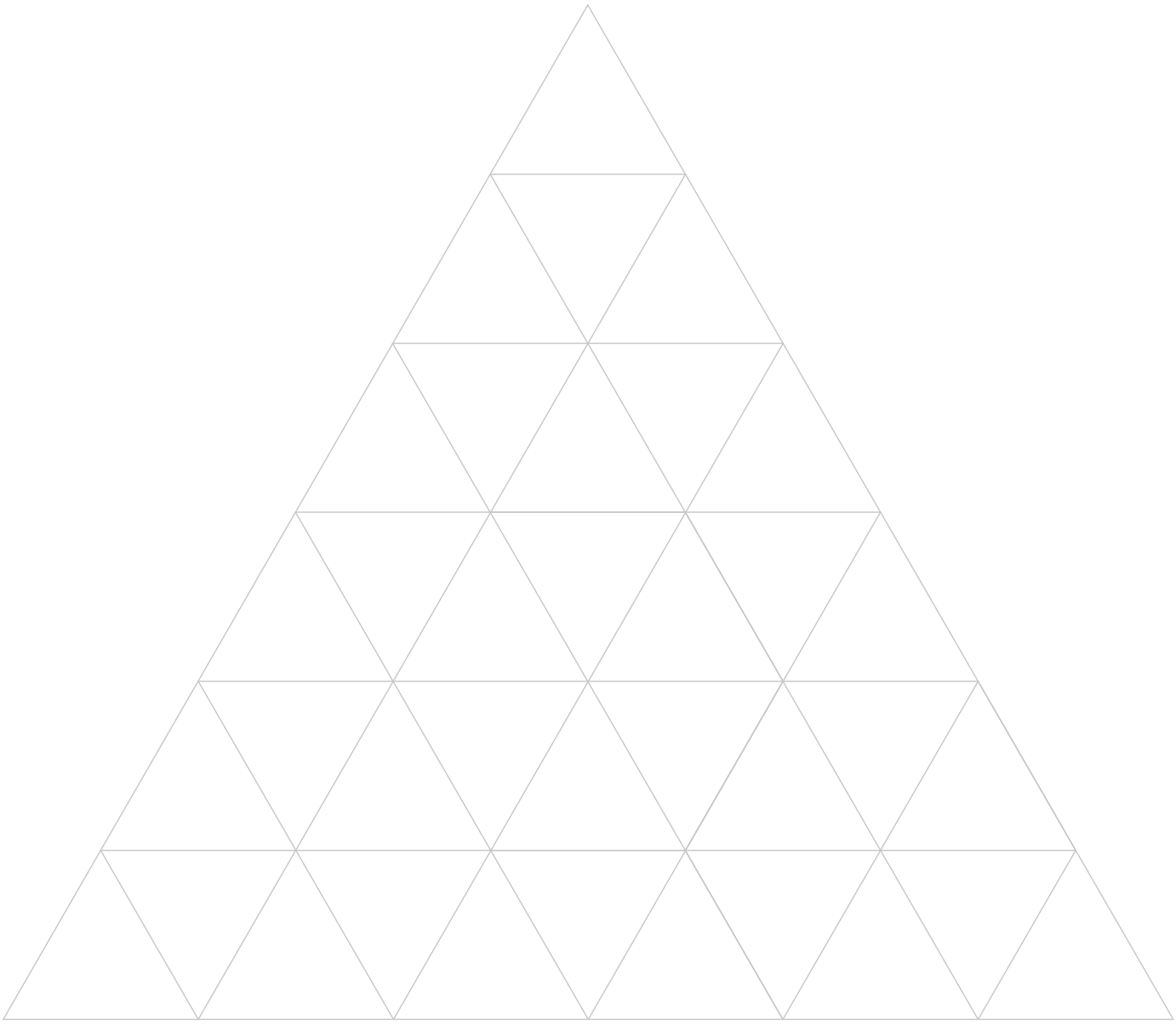
At this stage, four numbers could be added to the triangular faces, as shown below, to make a four-sided dice for games. Use glue to stick the tabs in place.



TEACHER TIP

Once students have constructed all six different 3D shapes associated with the Ancient Greeks, check that they have used them to record their properties in the table on page 4. Encourage them to compare what they have found with a partner. Discuss their findings as a class, including any patterns they have found in the numbers, and tackle any misconceptions.

PHOTOCOPIABLE RESOURCE 6A



PHOTOCOPIABLE RESOURCE 6B