

HISTORY

The platonic solids have been around for more than 10,000 years, dating back to the Neolithic period with the carving of stone balls in Scotland. They came to real prominence, however, in Ancient Greece as a result of the work of the philosopher Plato, after whom they are named. Some historical sources claim that Pythagoras may have discovered the solids, though others believe he was only aware of the tetrahedron, cube and dodecahedron. In any case, it is Theaetetus who gave the first mathematical definition of all five solids and likely published the first proof that only five such shapes can exist.

For a three-dimensional shape to be classified as a platonic solid it must satisfy two simple rules:

1. Each face must be the same regular polygon: a two-dimensional shape with all angles and sides of equal length.
2. At each vertex (corner) the same number of faces must join together.

QUIZ: The five shapes are displayed below, match the shape to its name.

HINT: The shapes are named by the number of sides that they have. Use the names of the 2D shapes that you are familiar with to help you.

ELEMENTS

Plato wrote about the platonic solids in his work *Timaeus* published in 360 BC. The Ancient Greeks believed that the universe was made up of the four classical elements: earth, air, fire and water. The philosopher Aristotle extended the definition further in his text *On Generation and Corruption* by assigning each element to two of the four sensible properties: hot, cold, dry and wet.

Aristotle also added a fifth element called 'aether' which related to the constellations and the heavens. His reasoning was that the stars could not be made of any of the four classical elements and must instead be made of a different, unchangeable, heavenly substance.

A later Greek philosopher, Proclus, believed that the four classical elements each had three properties and were joined together as follows:

Fire	Sharp	Subtle	Mobile
Air	Blunt	Subtle	Mobile
Water	Blunt	Dense	Mobile
Earth	Blunt	Dense	Immobile

Plato was a firm believer in the classical element theory (which we now know to be untrue) and he associated each solid with one of the four classical elements: earth, air, fire and water and the fifth with the heavens and constellations (similar to Aristotle's aether).

QUIZ: Can you match each platonic solid with the corresponding element chosen by Plato?

HINT: Use Proclus' properties of the elements to help you to think about each substance and which shape best demonstrates the same properties.

PLANETS

The platonic solids have been the subject of study by many famous mathematicians throughout history. The thirteenth book of Euclid's *Elements* describes their mathematics completely, from how they are constructed, to the ratio of the diameter of the sphere inscribed inside each shape to the length of a side of that shape. Euclid's *Elements* remained the key textbook on geometry for over 2000 years.

In the 16th century the German astronomer Johannes Kepler attempted to relate the known planets of the solar system to each of the platonic solids. In his text *Mysterium Cosmographicum* he outlined his idea that each solid corresponded to the distance between the known planets Mercury, Venus, Earth, Mars, Jupiter and Saturn (Uranus and Neptune were discovered in the 18th and 19th centuries respectively). He began by enclosing each platonic solid in a sphere and then fitting the five spheres one inside the other. Finally, they were enclosed in one giant sphere, which represented the orbit of Saturn. The ordering of the solids and the spacing between them gave the distance relationships between the planets. We of course now know this to be untrue, but the idea was revolutionary at the time and ultimately led to Kepler's discovery of elliptical orbits.

American physicist and chemist Robert Moon created an electron shell model based on the platonic solids in the 20th century. It was similar to the theory of Kepler, with each solid being inscribed inside one another to describe the geometric ordering of the protons and neutrons inside the nucleus of an atom.

QUIZ: Can you match each platonic solid to the planet Kepler thought it represented in the solar system?

HINT: Think about the distances between the planets to help you (displayed in the table below). 1 AU (Astronomical Unit) is the distance from the Sun to the Earth.

Mercury	0.39
Venus	0.72
Earth	1.0
Mars	1.5
Jupiter	5.2
Saturn	9.5

NATURE

The Platonic Solids are seen by many as the most beautiful and symmetrical shapes in mathematics, but they also appear everywhere in the natural world. The fact that they are so symmetrical means that they fit together very well and thus provide the perfect building blocks for nature.

They have particular prominence in chemistry where the shapes of molecules and the structure of crystals make use of their naturally occurring symmetries. A molecule may require its atoms to be spread out as much as possible, whilst a crystal needs a strong and stable structure that can be easily replicated.

Many viruses have evolved to take the form of a Platonic Solid as they allow them to fit together in neat bundles, thus making them more difficult to destroy. A recent theory even hypothesises that the shape of the universe may be a Platonic Solid.

QUIZ: Can you match the Platonic Solid to its appearance in nature?

HINT: Use what you know about the natural object to help you to pick the correct shape. For example, what is the chemical formula of methane? And what are the main properties of diamond?

MAN-MADE

Having discovered the Platonic Solids and the many ways in which they are used by nature, it was only a matter of time before we humans began to use them.

The symmetry of the shapes combined with their regular structure, makes them particularly useful in the world of engineering. The American inventor Buckminster Fuller was particularly fond of the Platonic Solids and they can be seen in many of his most famous inventions and designs, including his 'Fuller Projection' of the world map from a sphere onto a flat surface which has a maximum distortion of only 2%.

We also tend to enjoy presenting many of our foodstuffs as regular Platonic Solid shaped objects – ice and sugar perhaps being the most common examples.

The recent advances made in photography and video capturing technology have led to the world's first 360°, full motion camera that is able to capture high-resolution video from every direction simultaneously at more than 100 million pixels per second. Its design is based on a Platonic Solid.

Finally, weather vanes which are used to tell the direction of the wind, have a special form in the shape of a Platonic Solid that is used in airfields. The design will always point into the wind and they are often built large enough to be seen from the air by pilots.

QUIZ: Which Platonic Solid matches up with the man-made use described above?

HINT: Think about what properties are required for each of the man-made uses and which shape would best fit their needs.