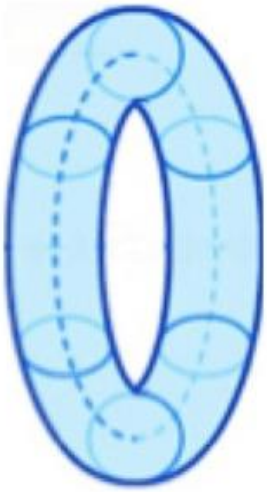
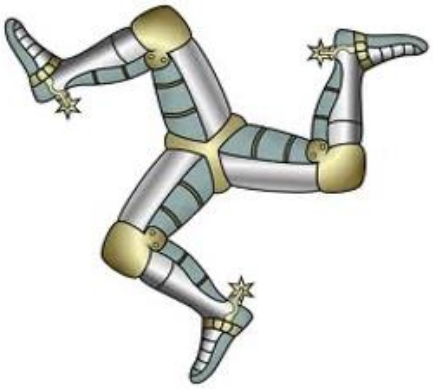
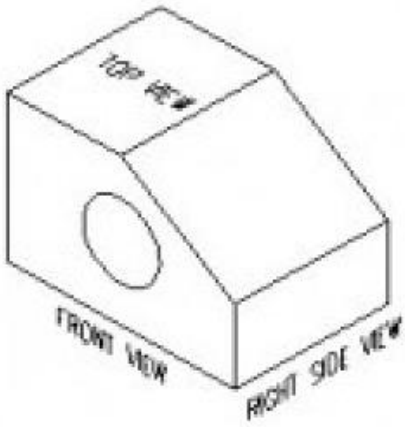
# DRAW AND TALK GAME CARDS

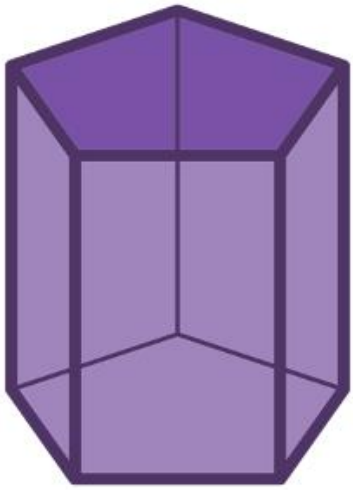
Any number of players.

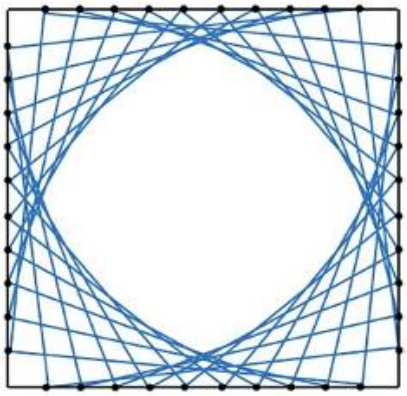
Larger images of all the cards. To be printed with information on reverse side.

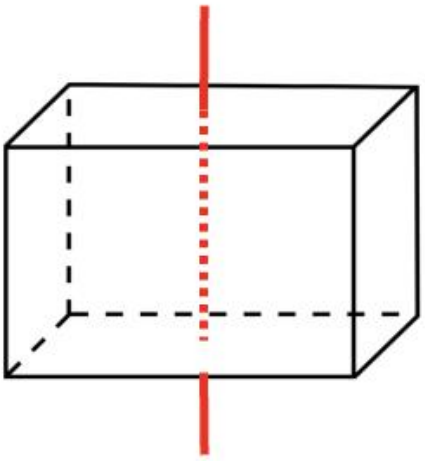


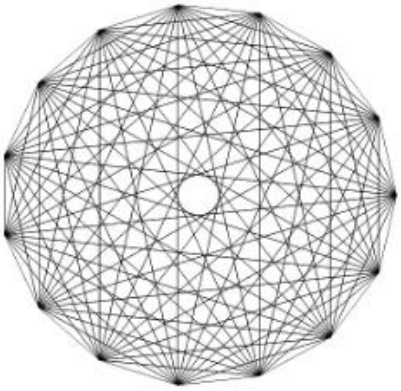


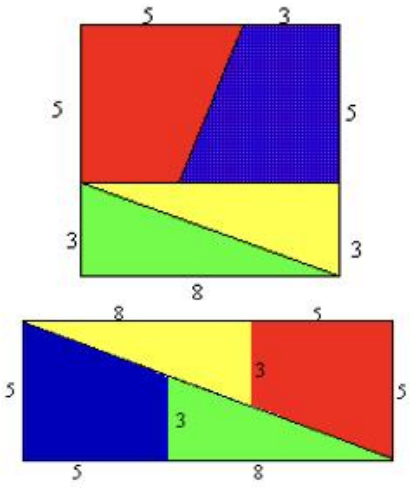










**PLAN AND ELEVATION**

Engineering and architectural drawings consist of separate views from 3 perpendicular directions:
(1) PLAN OR TOP VIEW a bird's eye view looking vertically down,
(2) FRONT ELEVATION representing the front view
(3) SIDE ELEVATION showing a side view.

**3 LEGS OF MAN**

This symbol on the coat of arms of the Isle of Man, (a small island off the coast of England) represents the perseverance, strength, and independence of its people. The Tynwald, the Isle of Man's parliament, set up by the Vikings in the 9th Century is the oldest continuous parliament in the world.

**TORUS**

A cup is topologically equivalent to a torus. Circles are the straight lines on the surface. One type of path goes through the hole, another goes around the hole and neither can be shrunk to a point. Small circles do not go around or through the hole and it can be shrunk to a point.

**ROTATIONAL SYMMETRY**

The picture shows a rectangular cuboid and one of the 3 axes of rotational symmetry. It can be rotated by 180° about this axis to fill the same space. A rectangular cuboid has 3 axes of rotational symmetry and 3 planes of reflection symmetry.

**ENVELOPE**

This picture is made up of straight lines and you can see curves, called envelopes, to which all the lines are tangent. In the plane an envelope is a curve that is tangent to a family of other curves. In 3D an envelope is tangent to each of a family of surfaces.

**PENTAGONAL PRISM**

The cross section of this prism is a regular pentagon. It is shown standing on a pentagonal face. The vertical faces are rectangles. It has 7 faces, 10 vertices and 15 edges. Faces 7 + Vertices 10 = Edges 15 + 2 satisfying Euler's formula.

**MAGIC OR AN ILLUSION?**

The rectangle and the square are made from the same 4 pieces of the jigsaw, but they have different areas, and that is not possible. Can you explain the trick?

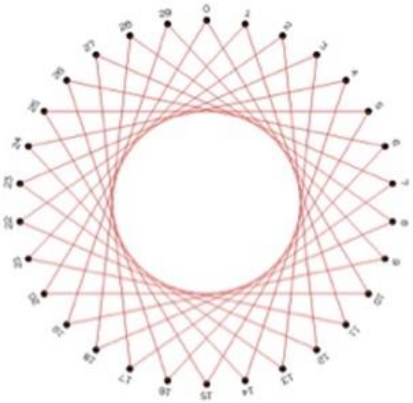
**ODD MYSTIC ROSE**

To draw this pattern, mark 15 points equally spaced around a circle and join each point to every other point by a straight line. The lines envelope a small circle at the centre. In Mystic Rose patterns with an even number of points all the lines are diameters going through the centre.

**BUCKY BALL**

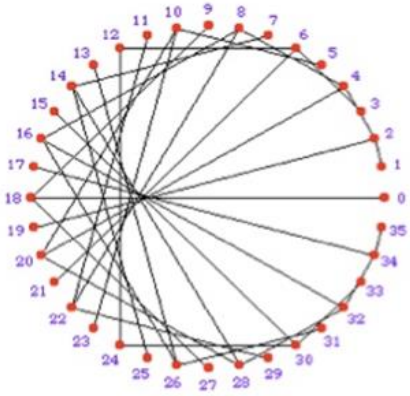
This football is made from 20 hexagons and 12 pentagons. Can you imagine making this shape by slicing off a pentagonal pyramid at each vertex of an icosahedron? The carbon molecule called a buckminster fullerene (found in soot) is like Fuller's geodesic dome structures.

## CIRCLE



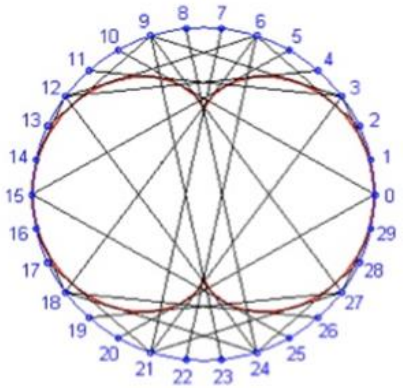
N=30 $n \to n + 10$

## CARDIOD

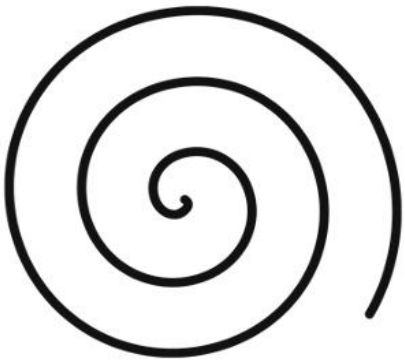


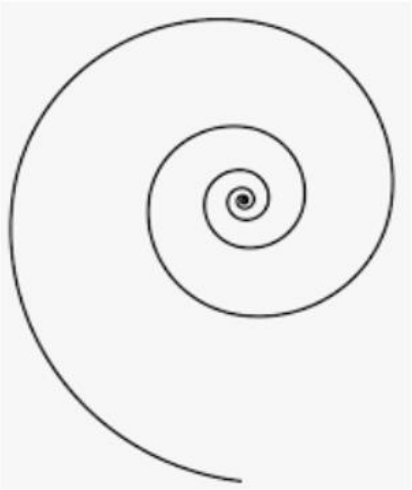
N = 36 $n \to 2n$

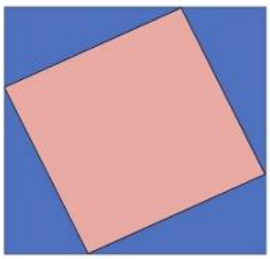
## NEPHROID

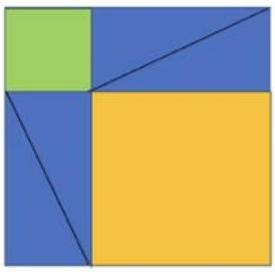


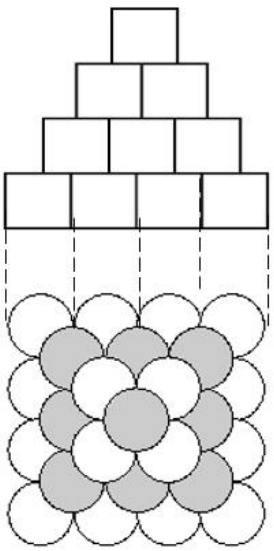
N = 30 $n \to 3n$











## NEPHROID

To draw this pattern mark 30 points equally spaced around a circle.
Number the points 1 to 30 and join points 1 to 3, 2 to 6, 3 to 9 and each point n to the point numbered 3n (n→3n).
This forms the envelope of a nephroid to which all the lines are tangents.

## CARDIOID

To draw this pattern mark 36 points equally spaced around a circle.
Number the points 1 to 36 and join points 1 to 2, 2 to 4, 3 to 6 and each point n to the point numbered 2n (n→2n).
This forms the envelope of a cardioid to which all the lines are tangents.

## CIRCLE ENVELOPE

To draw this pattern mark 30 points equally spaced around a circle and join each point to the point 10 spaces round the circle (n→n+10).
This forms the envelope of an inner circle to which all the lines are tangents.
Try drawing patterns using different numbers

## NAUTILUS SHELL

The animal can withdraw into its shell and close the opening. The interior of the shell divides into chambers. As the nautilus matures, it creates new, larger chambers, and moves its growing body into the larger space, sealing off the empty chambers so that it can always float vertically.

## LOGARITHMIC SPIRAL

This spiral, described by Albrecht Durer in 1525, has been called an eternal line, a marvellous spiral, a growth spiral and an equiangular spiral. It is a self-similar spiral curve often found in nature.
The distance between loops increases as a geometric series.

## ARCHIMEDEAN SPIRAL

This spiral is named after the 3rd century BCE Greek mathematician Archimedes and it is like a coiled rope lying on a flat surface.
It is the locus of a point moving away from a fixed point with a constant speed along a line that rotates with constant angular velocity. The radial distance between loops is constant.

## STACKING IN PYRAMIDS

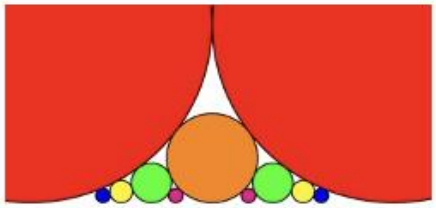
Fruit, or cans on a market stall or in a supermarket, are often stacked in pyramids.
The picture shows a stack in the form of a square based pyramid with 16 in the bottom layer, then 9, then 4 and 1 on top.
Four layers stacked in a triangular pyramid would have 10, 6, 3 and 1 objects in the 4 layers.

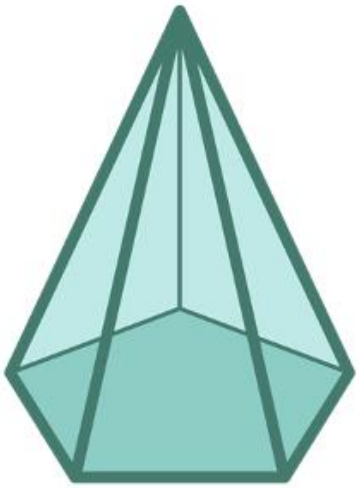
## SPIRALS IN PINECONES

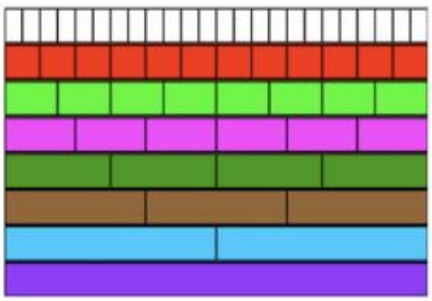
Pinecones commonly have 3 steep and 5 gradual spirals (5/8, or 8/13). This arrangement is called phyllotaxis. Leaves on a stem often form a spiral pattern called a phyllotactic spiral. A similar form of spiralling occurs in the outer petals of artichokes and other flower buds.

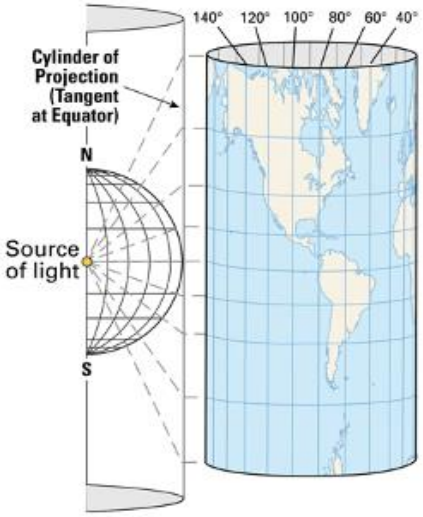
## PROOF OF PYTHAGORAS

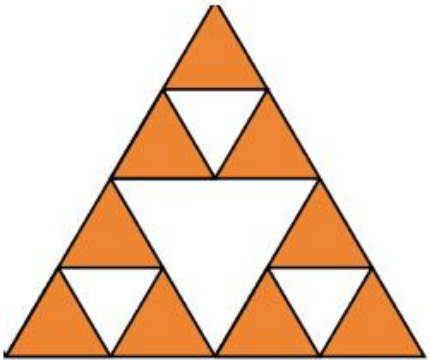
Another proof in a picture!
Focus on areas and take away the 4 congruent triangles in each frame.
The remaining areas must be the same.

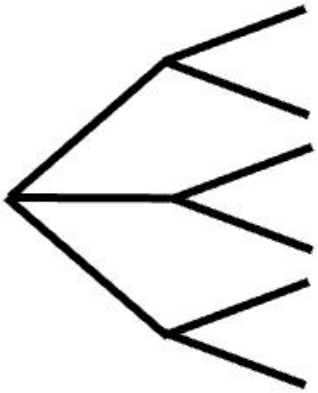


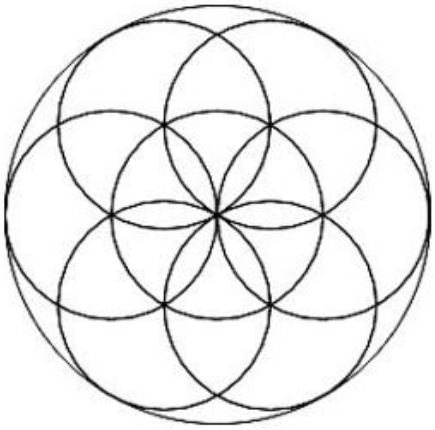


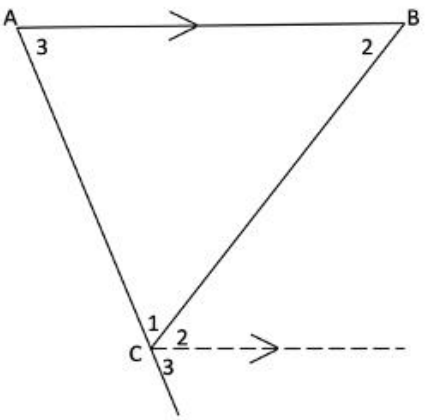



140° 120° 100° 80° 60° 40°
Cylinder of Projection (Tangent at Equator)
N
Source of light
S








A
B
3
2
1
2
C
3

**PYTHAGOREAN TREE**

This is a fractal tree made up of copies of the same image of 3 squares on the edges of a right-angled triangle, at smaller and smaller scales. It can be continued indefinitely with the 'branches' getting smaller and smaller. What if the triangle is isosceles?

**PENTAGONAL PYRAMID**

The base of this pyramid is a regular pentagon and the sloping faces are isosceles triangles. The vertex is vertically above the centre of the base. It has 6 faces, 6 vertices and 10 edges. Faces 6 + Vertices 6 = Edges 10 + 2 satisfying Euler's formula.

**FAMILY OF FORD CIRCLES**

These circles touch their neighbours. They all touch the horizontal axis (an infinite circle) at rational points: red circles at integer points, orange circles at $\frac{1}{2}$, green circles at $\frac{1}{3}$ and $\frac{2}{3}$, yellow circles at $\frac{1}{4}$ and $\frac{3}{4}$ etc.

**SIERPINSKI TRIANGLE**

This is stage 2 of a repeating (iterative) process that replaces the image at each stage by 3 smaller copies of itself, reduced in edge length by scale factor $\frac{1}{2}$. The Sierpinski Triangle fractal is formed by repeating this process infinitely often.

**MERCATOR PROJECTION**

In this projection, invented by Mercator in 1569, the surface of the earth is projected onto a cylinder preserving directions but distorting distances. Surprisingly it preserves areas. It is the standard map projection for atlases and navigation at sea but no use for flight paths.

**FRACTION WALL**

The base of the fraction wall is one unit in length and each layer of the wall shows smaller and smaller fractions. You can easily compare different fractions using this picture. What fractions are shown in each of the levels? Can you build it any higher?

**PICTURE STORY**

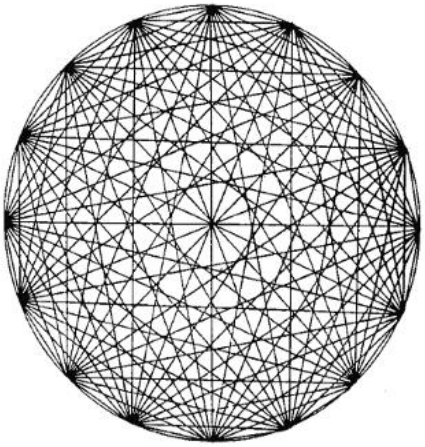
A picture can give a proof without words. The parallel lines show that the exterior angle of a triangle is equal to the sum of the interior opposite angles. The theorem that the angles of a triangle add up to 180° follows because the angles on a straight line add up to 180°.

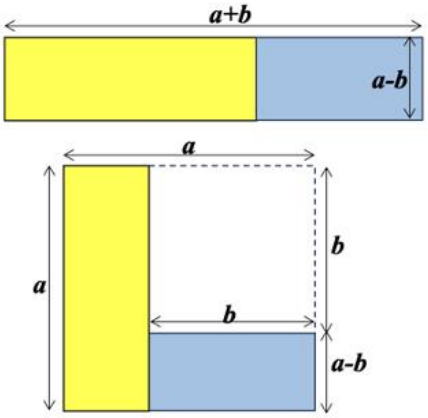
**FLOWER OF LIFE**

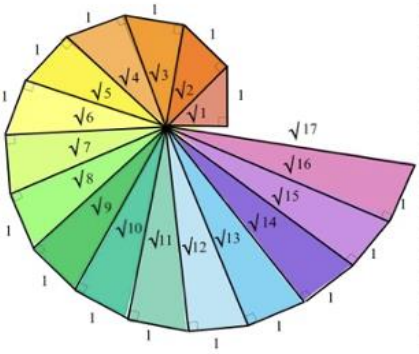
The flower of life is a geometric shape recognised as sacred by many cultures throughout history including Egyptian, Buddhist, Hindu, Christian and Muslim. It is seen to represent the cycles of life, death and re-birth, the unity of all life and the interconnectedness of all beings.

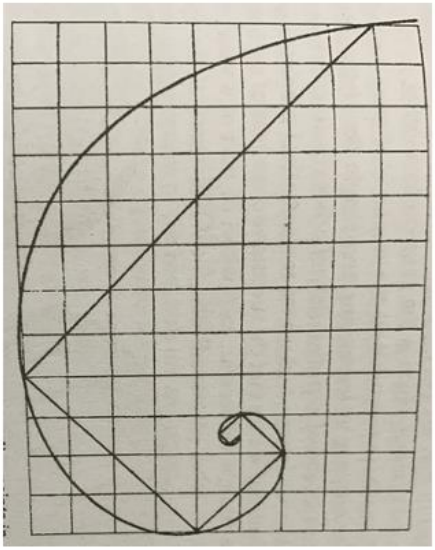
**TREE DIAGRAM**

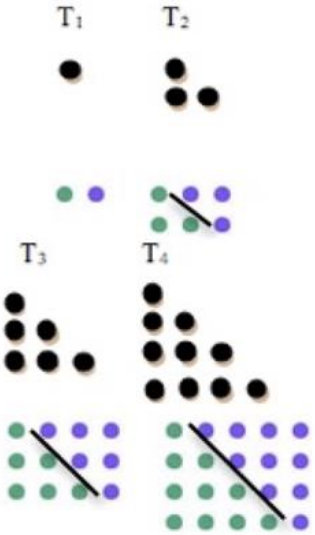
Tree diagrams use networks to show all possible outcomes of a series of events, for analysing probabilities and games. In this diagram the 1st event can have 3 outcomes and the 2nd event 2 outcomes so the combined events have 6 possible outcomes.

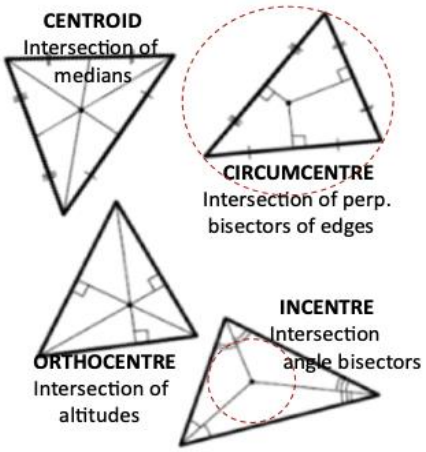


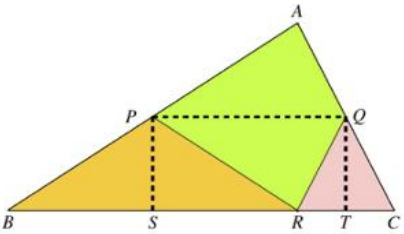

a+b
a-b
a
b
a
b
a-b


1
√1
√2
√3
√4
√5
√6
√7
√8
√9
√10
√11
√12
√13
√14
√15
√16
√17




T1
T2
T3
T4


CENTROID
Intersection of medians
CIRCUMCENTRE
Intersection of perp. bisectors of edges
ORTHOCENTRE
Intersection of altitudes
INCENTRE
Intersection angle bisectors


A
P
Q
B
S
R
T
C

## SPIRAL OF THEODORUS

The Greek mathematician. Theodorus lived in the 5th century BCE.

This spiral is built from a sequence of right-angled triangles. The triangle at the centre has edges 1, 1, and √2. The hypotenuse of each triangle in the sequence forms one of the legs of the next triangle, with the other leg one unit in length.

## DIFFERENCE OF 2 SQUARES

A proof without words!

For all values of $a$ and $b$, $a^2 - b^2 = (a - b)(a + b)$.

Whatever the values of $a$ and $b$, take a square of edge length $a$, and cut away a square of edge $b$. The yellow and blue rectangles formed together make a rectangle with edges (a – b) and (a +b).

## EVEN MYSTIC ROSE

To draw this pattern, mark 16 points equally spaced around a circle and join each point to every other point by a straight line.

All the lines are diameters going through the centre.

With an odd number of points the lines envelope a small circle at the centre.

## SUNFLOWER

The seeds in a sunflower form equiangular spiral patterns. Each spiral makes a different angle with the radii. For each angle the number of spirals in the sunflower is a Fibonacci number. The numbers of spirals with the same angle, winding clockwise and anti-clockwise, are successive Fibonacci numbers.

## 'STRAIGHT LINE' SPIRALS

This logarithmic spiral is constructed by drawing straight line segments and arcs on a grid. The radii of the arcs double in length. The Fibonacci spiral is constructed similarly with the lengths of the radii of the arcs increasing as a Fibonacci sequence 1, 1, 2, 3, 5, 8...

## SPIRAL STAIRCASE

The treads of the staircase shown in this picture are attached to, and wind around, a central pole.

Staircases can also take the form of a helix, or of a double helix, in which case they wind around a void.

They are helical but are often mistakenly called spiral.

## TRIFOLD

Proof by paper folding!

P and Q are midpoints of edges AB and AC. By folding along the dotted lines you can show that the angles of a triangle add up to 180° and the area of the triangle is $\frac{1}{2}$ **base × height**

## CENTRES OF A TRIANGLE

(1) The centroid is the intersection of the medians.

(2) The orthocentre is the intersection of the altitudes.

(3) The centre of the circumscribed circle is the intersection of the angle bisectors.

(4) The centre of the inscribed circle is the intersection of the perpendicular bisectors of the edges.

## TRIANGLE NUMBERS

The triangle numbers are the sums 1, 1+2, 1+2+3, 1+2+3+4 etc. which can be represented by triangular arrays of dots. Two copies of a triangle made of n dots form an n by (n+1) rectangle showing that the sum of the natural numbers from 1 to n is $\frac{1}{2}n(n+1)$.

Consecutive triangles form a square.