Dancing to Nature's Geometrical Tune

Laurie SMITH

HISTORICBUILDINGGEOMETRY

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This eDITION 2016

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Text Geometry Photographs Design
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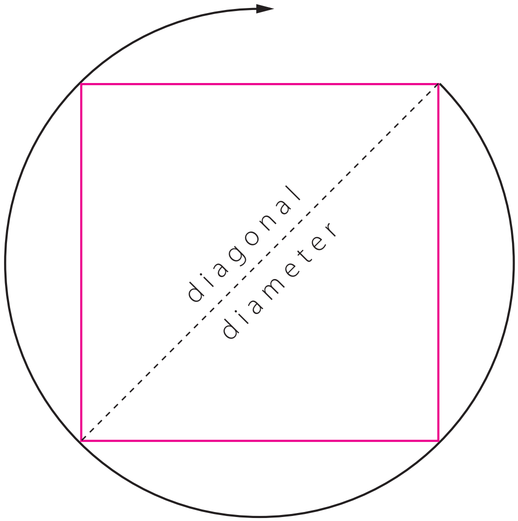
INTRODUCTION

The idea for this article arose during a visit to the Eden Project in Cornwall.

The photograph shows the perfect internal spiral structure of the Nautilus shell which is found in the waters of the Mediterranean. In 500 BC, Greek geometers first recognised the perfection of the shell's spiral and then discovered how to construct it's curvature as a geometrical drawing. Their discovery translated the natural evolution of the shell's growth into a proportional diagram that could be used in the design of buildings that are still regarded, over 2,500 years later, as some of the world's most aesthetically perfect man made structures. Today, the exquisite beauty of the shell's spiral and the geometrical proportions embodied within it continue to inspire architects. Spiral proportions can also be found in the form of plants and flowers, the pine cone's double interlacing spirals providing the visual stimulus and design code for the Eden Project's Core building.

It is one of life's miracles that our eyes are identical in form to the planet that we live on and that we can walk the spherical surface of the Earth and observe its wonders through our spherical eyes. This book is about the invisible geometry that gives the Nautilus shell, the Earth and the eye their perfect form, how we have learned about geometry through visual observation of the natural world and



how we have applied nature's geometries to the design of architecture.

Geometry is both extraordinarily simple and deeply profound. The planet Earth, our home, has an equatorial circumference of 24,900 miles and, if we stand on the equator, we are travelling at 1000 miles per hour, twice the speed of a jet airliner, as the Earth spins on its axis. It also orbits the sun at 66,600 miles per hour, following its elliptical path for 365¼ days until it returns to its starting point in space. Maybe a celestial chequered flag should wave as the Earth crosses the line each year but it never does. The statistics are hard to grasp.

But the Earth's form can be drawn with a compass by a child and when I showed my young grandson Harris how to draw his first circle his eyes lit up as the compass revolved and the line followed its pre-ordained track around the paper. *It's dancing!* he shouted in delight. And so the compass was, in a graceful and geometrically perfect pirouette.

Looking further into geometry it becomes apparent that not only is the compass dancing along curved lines but that pens and pencils are gliding along the straight edges of rulers and that the two kinds of line, straight and curved, are the male and female elements of geometrical drawing. If we draw four straight lines at right angles to form a square and then draw a circle through its corners we have two different routes between four equidistant points. One route is masculine and angular and involves precision changes of direction, the other is feminine, orbital and fluid, flowing along a constant path. Despite the difference between the routes they have a harmonic relationship because the diagonal of the square is simultaneously the diameter of the circle. The harmonic symmetry that exists between the circle and square is unchanging and eternal and is a fundamental law governing the nature of space. So geometry is not only dancing but is choreographing the dance, playing the tune and painting the scenery, determining the aesthetic characteristics of three dimensional natural forms and their two dimensional surface patterns. Of course, the geometrical purity of forms and patterns are subject to processes of growth and erosion through the passage of time so that the perfection of the bird's egg is destroyed by the birth of the chick that it protects. But the bird retains geometrical purity in the spheres of its eyes, its most critical faculty, while its body and wings adapt to the forces of nature around it. Eventually the bird mates and, carrying nature's blueprint, lays another geometrically perfect egg. Our own blueprint, in the geometrical double helix of DNA, is another example. We carry it within us invisibly until it blossoms in the miracle of conception, birth and growth, each new generation passing it on into the future. Plants carry their own blueprints and often grow in geometrical ways. Inanimate crystals form into geometrical structures. None of this is conscious. The bird, the person, the plant and the crystal are only obeying orders, following pre-ordained patterns of growth that are fundamental to the nature of the universe that we all exist in. We are all playing the game of life by the rules and dancing to nature's geometrical tune.

Clay has been an influence in my life. As a small boy in Essex I dug pits in the garden and made models from the clay. My parents praised the models but grumbled about the pits. Years later, after the pivotal experience of a visit to the Leach Pottery in Saint Ives, I studied ceramics and subsequently taught the subject for twenty years. So china clay from Cornwall was one of the raw materials that I was familiar with as a constituent of bone china products exported throughout the world. It is humbling, on a visit the Eden Project biomes, to contemplate the phenomenal volume of clay removed from Bodelva, its metamorphosis into tableware and its use on millions of international tables. Stacking dinner plates in just one biome is an overwhelming thought.

Thinking of clay brings other memories to mind. As a student at the Central School of Art in London I was fortunate to be in the Ceramics Department for, as well as the obvious study of ceramics, it had a long reputation for encouraging students to draw. The philosophy was simple: *observe, record, analyse, understand*. Our tutor, South African Bonnie van de Wettering, collected flowers and vegetables from Covent Garden, shellfish, crustaceans and fish from Billingsgate, skulls and bones from Smithfield. We bisected, magnified and disected plants, fruits and seeds, halved cauliflowers and revealed their mirror symmetry, recorded the pattern of fish scales, mapped the curvatures of a crab or lobster carapace, probed a spherical eye socket. At the end of each drawing day we took our work home for our evening meal so that drawing first enriched our minds and then sustained our bodies.

We were also taken on architectural visits, climbing spiral stairs between the inner and outer domes at Saint Paul's Cathedral, looking down through space from the whispering gallery and out into space across London from beneath the golden ball. And we were taken to pottery factories in Stoke on Trent to learn industrial production techniques. This is where geometry appeared, for setting out the models from which production moulds would be made. And these moulds would transform Bodelva clay into functional tableware for hotels, restaurants and homes.

Leaving the biomes behind and walking upwards through the open space where the clay used to be, back to Bodelva's rim, the spirit is lifted on the breeze. And the thought arises that it would be good, having learned so much from this place, to give form to some of my own knowledge and to make it available to others. And so this small book came into mind, written and designed in response to the Eden Project and its inspirational educational vision, its creative reclamation of an exhausted industrial clay pit and its metamorphosis into a magnetic and spiritually stimulating environment that points the way towards an intelligent and viable future.
The book is in two sections. Section 1 explores the relationship between nature and geometry and Section 2 gives examples of geometrical building design. Inevitably, because the subjects are so inextricably interwoven, there are some places where the two sections overlap.

New places and sights often seem more stimulating than the places we know and some examples are shown from the southern hemisphere. But revelations are often found within common, everyday objects or places that, because we are familiar with them, we often take for granted and overlook. Almost all of the examples of natural geometry in leaves, flowers or butterflies were found in my own small garden at Gwernfyda in Wales. All I had to do was observe, record and analyse.

Laurie Smith
Gwernfyda 2009
Sutcombe 2016

SECTION 1
NATURE • GEOMETRY

SECTION 2
GEOMETRY • ARCHITECTURE

NOTE The numbers above refer to individual texts.
Illustrations are not individually numbered but are described within the texts.

SECTION 1
NATURE • GEOMETRY

Eight-petalled Clematis photographed at Plas yn Rhiw on the Lleyn Peninsula, North Wales.

INVISIBLE ENERGIES

As human beings we are constantly aware of the material world. We buy, prepare, cook and eat food, wear clothes, drive vehicles and live in houses. We read books, magazines or papers and watch televisions. We travel on trains and buses, sail in ships and fly in aircraft. We experience all of these things as real and solid. But our senses record the world around us in scents, sounds, flavours, images and sensations and, although these are also real, they are far from solid. If we smell a scent, say cut grass in a park, we can see and walk, despite the keep off sign, on the freshly mown grass but where and what exactly is the scent? Aromas attract our interest but are as elusive as shadows in the dark. Our other senses are the same. If we try to define a flavour, a sound or an image there is nothing solid that we can get a grip on. Our sensory experience is elusive and, on a grander scale, life itself is elusive. Yesterday is a memory, today is passing as we live it, the here and now an ever shifting moment of reality and tomorrow is imaginary. If we try to find the foundations upon which our experience is built we are hard pressed to locate any and the deeper we dig the more elusive they become. At least, this is the case if we think in only material terms. If we face the opposite way we can see that the material world, like a great tree grown from a miniature seed, is the result of many influences and energies and that these are also elusive. As the tree takes time to grow and it's evolving form occupies an enlarging space, it manufactures energy from light. Time, space and light are invisible energies.

All the energies that influence the behaviour and form of matter are invisible and though we can see the products of each force we are blind to the force itself. So we can see the flash of lightning but not electricity. We can attract iron filings with a magnet but cannot see magnetism. We can tune in to radio programmes in the northern hemisphere and hear voices from the southern hemisphere but we cannot see radio waves. We can feel the pain of a broken bone and can observe an xray of it but we cannot see or feel radiation. We can join Isaac Newtown and watch apples descending from trees but we cannot see gravity. We can speak to each other and whisper or sing but cannot see the sound waves. We can observe ice melt to water and boiling water turn to steam but cannot see the transfer of energy. We can watch the sun rise and fall or the moon wax and wane, observe the changes of the seasons and the temperature changes that come with them but the force that regulates the sun's spherical form and our elliptical orbit around it remains invisible. Time, which is eternal, and space, which is infinite, are also invisible. In fact we live in a paradoxical world where the controlling energies that maintain our lives and drive us on towards the future are all invisible. Our own driving force, our will to live, our spirit, is invisible. Our thoughts and ideas are invisible. Except on frosty winter mornings even the air we breathe is invisible. Yet beneath this veil of invisibility there is order, for each of the invisible energies exercises power over its own domain.

Geometry itself has invisible characteristics. On a human scale, for example, when we use a compass to draw a circle, it's axis, radius and diameter are invisible and, similarly, a square's diagonals and centre point are invisible. On nature's scale we can see evidence of geometry in the circularity of grass stems or tree trunks and in the curvature of branches. Flowers present radial arrays of petals. Birds weave hemispherical nests and lay ovoid eggs. Woodlice and hedgehogs curl into defensive spheres when threatened. Water at rest has, on the grand scale, a spherical surface curvature like the Earth. Frozen, on a small scale, water appears as flat sheets of ice. Mineral crystals form cubic, triangular, hexagonal and other geometrical configurations. Yet the geometrical force that regulates their forms remains invisible.

The winds blowing rain clouds across the sky are invisible.

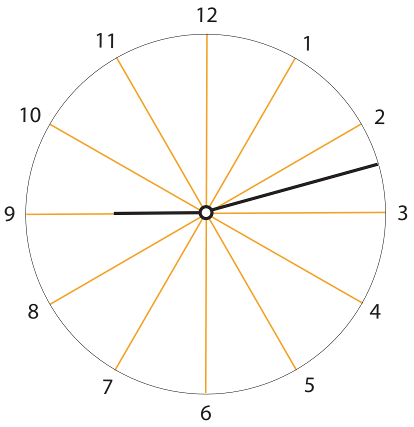
TIME

In some ways we are very familiar with time. The rhythms of our wakefulness and sleep synchronise our lives to the rotation, orbit and seasons of the Earth. Our language is littered with references to time. Time for a change, tea time, bed time, summer time, all in good time, big time, small time, time scale, time zone, time warp, time is running out and that chilling modern phrase, killing time. Yet time is enigmatic, something not fully understood. Although certain scientists present the big bang as the start of the universe and the origin of time it is obvious that the theory merely moves the unanswerable question further back. What was there before the big bang? Something or nothing? Perhaps a previous period of time. Or layered sediments of ancient eras with fossil times embedded deep within them. On any ordinary day, time seems to be eternal and we find it impossible to imagine either its beginning or its end. However, there is one thing about time that we can be certain of. Time is fundamental to life. For it is self evident that without time no living creature could be conceived or live a lifespan to its natural conclusion. Time, which allows evolution to take place, is the first requirement for life.

Our day is determined by the Earth's revolution on its axis and our year by the Earth's annual orbit through space around the sun. Interestingly, the geometry that gives us the twelve equal 15° divisions of a circle that we recognise as a clock is also a diagram of orbits rotating around the circumference of a central circle. Alone among the living creatures on Earth, we construct geometrical diagrams of time.

Division of the circle into twelve equal sectors can be done in two ways. First, if six circles are drawn around the circumference of an initial circle, so that each passes through the axis of its neighbour, it generates the six slender symmetrical petals within the central circle (known as the daisy wheel) and six larger petals that reach beyond the central circle's boundary. Bisection of all the slender and larger petals divides the central circle into twelve equal 15˚ sectors, the basis of the twelve hour clock face, left. Alternatively, the daisy wheel can be duplicated so that it has either a north south axis or an east west axis, like the petals of the daffodils. If both wheels are overlapped, they divide the circle's circumference into the twelve sectors necessary for recording time, right.

In the way that the sundial and candle were superceded by the geometrical precision of clockwork, clockwork has itself given way to the metronomic pulse of the quartz crystal. Time marches on and evolution keeps it company.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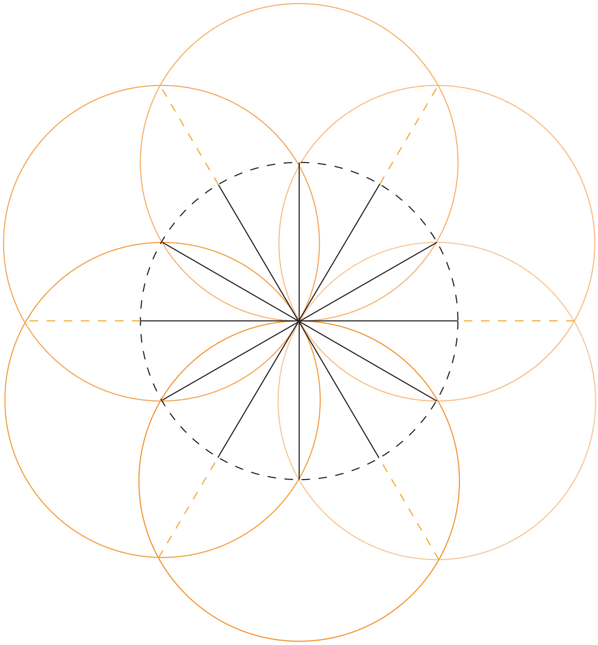

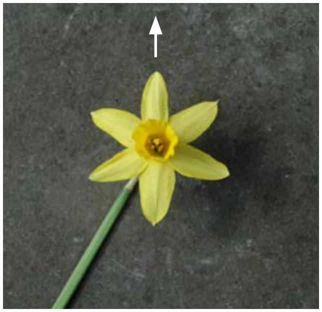

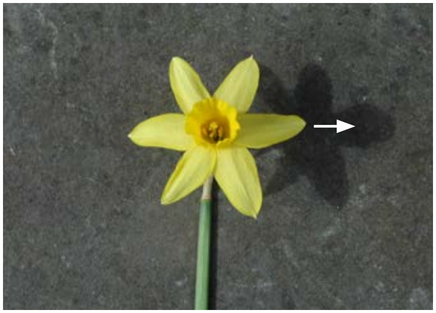

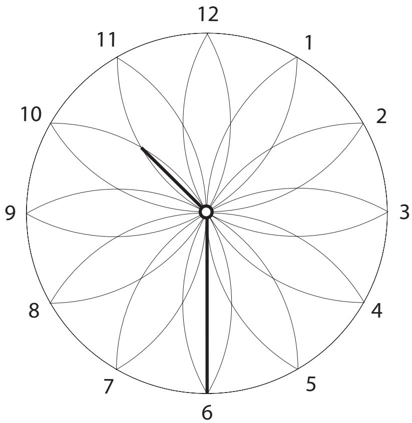
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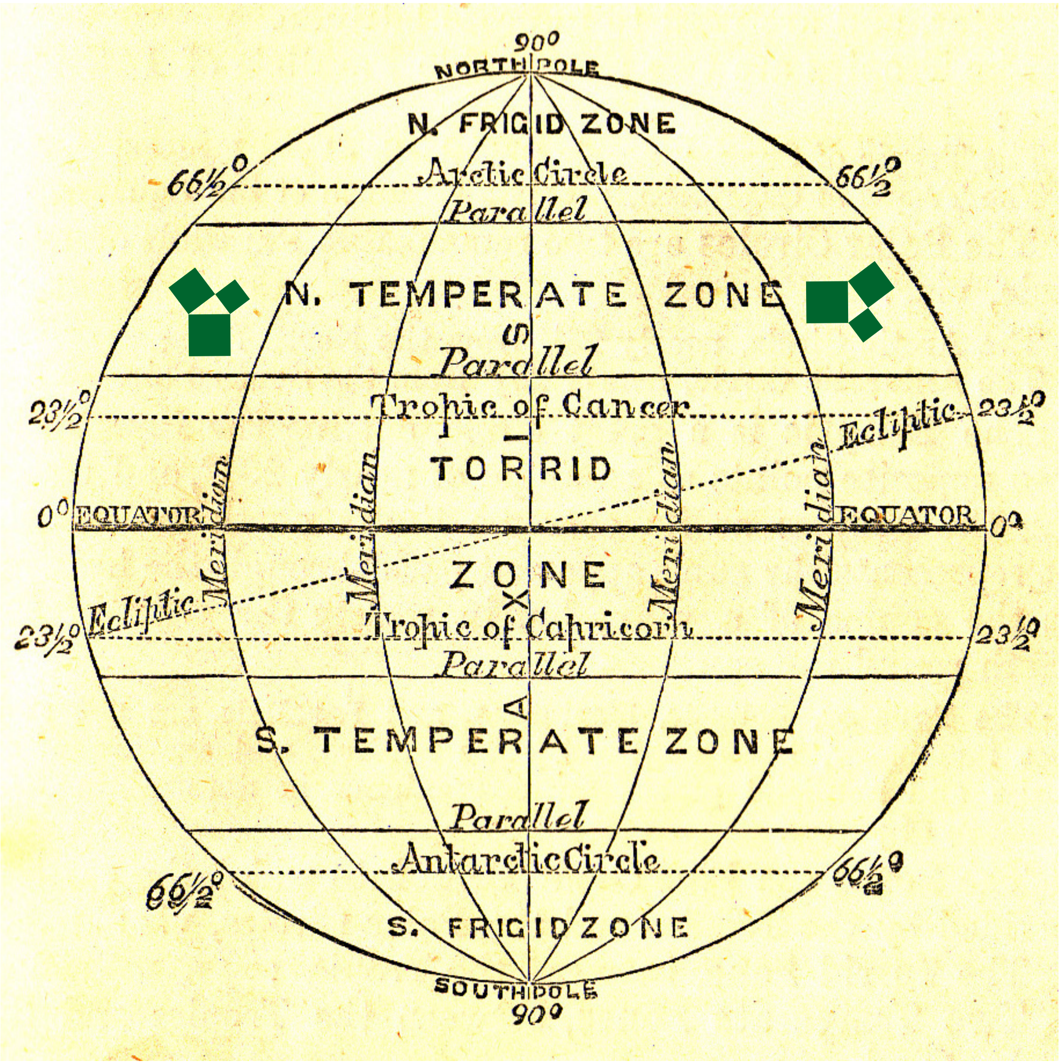
SPACE

The difficulties of understanding time are paralleled by those of understanding space. But we are familiar with space and, as with our ability to measure the flow of time, we also have ways of measuring space. We define space by linear distance, area and volume and it is easy to record the distances between places, the area of a room, field, or county or the volume of a kettle, hot air balloon or reservoir. But these are all examples of space at close quarters. When we consider space in its entirety it stretches our credulity and becomes infinite. We are hard pressed to imagine any boundary to space. If it had a boundary what would lie beyond it? Yet if it had no boundary then how do we comprehend the fact? We have less words for space than for time. Spaceman, spaceship and outer space record our modern advances into space and on Earth we talk of spatial relationships. When overtired, confused or elated we are spaced out. But, once again, there is something that we can be certain about with space. Space is fundamental to the existence of all things, whether bright and beautiful, living or inanimate, from microscopic microbes to human beings, from plants to planets and upwards in scale to galaxies. Anything that moves, whether by its own volition or by the propulsion of some external energy, can only exist and move in space. Space is the second requirement for life.

One aspect of the human consideration of space is the question of whether there is life elsewhere in the universe. Since space flight began we have been throwing metaphorical messages in bottles into space to reveal our presence to other potential civilisations. Perhaps the most comical example, and a geometrical one, dates from 1830 when the German mathematician Carl Freidrich Gauss suggested planting vast forests based on Pythagoras' theorem to indicate the existence of intelligent life on Earth to hitch-hikers on a guided tour of the galaxy. An 1875 book on Physical Geography shows the geometrical mapping of the Earth's spherical surface with giant Pythagorean forest indicated in the northern temperate zone.

In general we give more credence to matter than to space and perceive the Earth's surface as the outer boundary of our solid planet. But we could, alternately, think of it as the edge of solidity and the beginning of space. Similarly, we tend to think of buildings as solid structures rather than enclosures of space. The translucent boundaries of the Eden biomes make us think again by disguising the transitions between interior, structure and exterior that are simultaneously enclosing, occupying and resisting space.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NORTH POLE
N. FRIGID ZONE
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N. TEMPERATE ZONE
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Tropic of Cancer
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Ecliptic
TORRID
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Meridian
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AXIS
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Tropic of Capricorn
23½°
23½°
Parallel
S. TEMPERATE ZONE
Parallel
Antarctic Circle
66½°
66½°
S. FRIGID ZONE
SOUTH POLE
90°

LIGHT

We have a greater understanding of light than we do of time or space and recognise that the constant thermo-nuclear reactions of our sun are a source of both light and heat. The constant rotation of the Earth upon its axis brings us face to face with the sun during the day and turns our back on the sun at night. Strangely, daylight's brilliant illumination restricts our perception to the luminous sphere of the Earth's atmosphere while night's lack of light reveals uninterrupted views over unspoilt galaxies. It is a paradox of light and space that, kept in the dark, the naked eye can see further into the limitless depths of the universe.

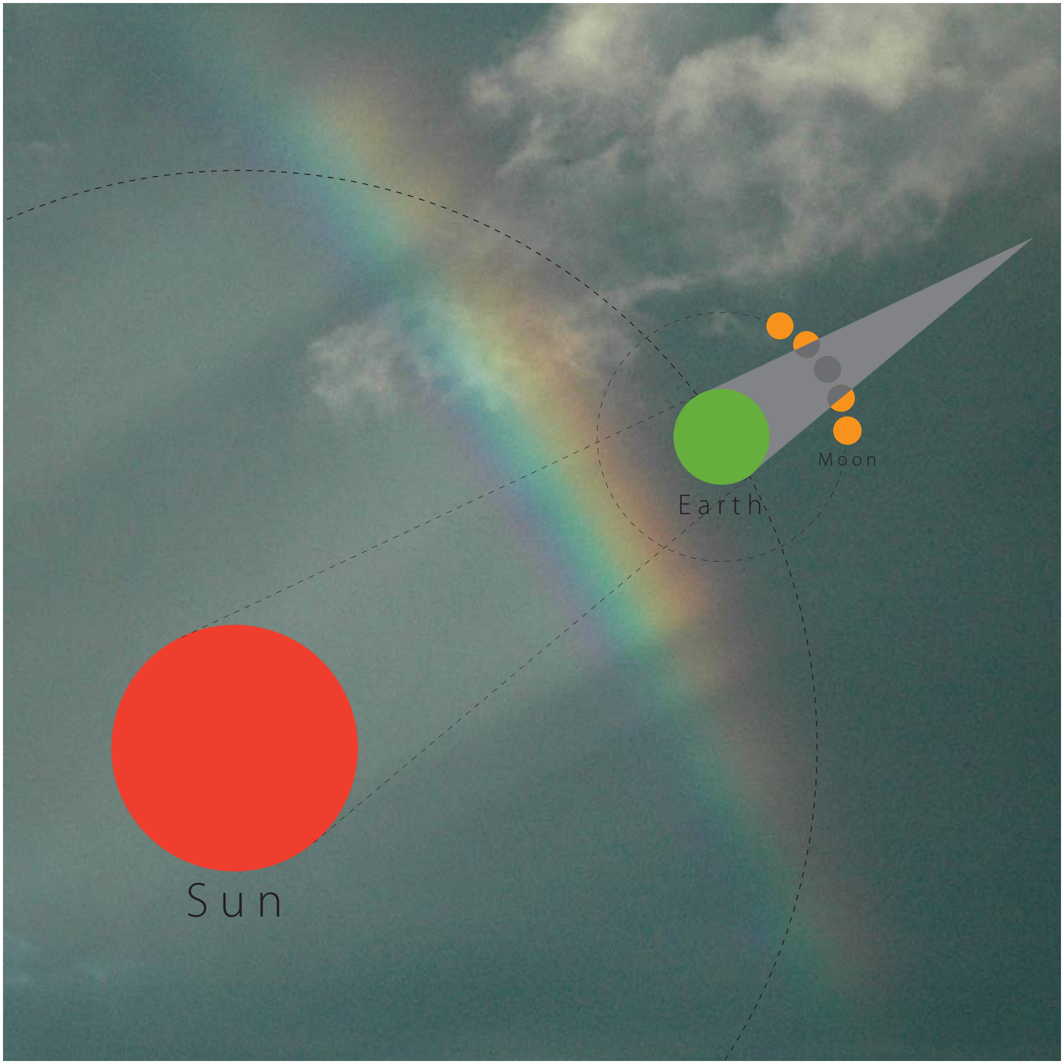
The Earth's rotation also generates higher temperatures in the light of day from the sun's direct heat and lower temperatures at night from its absence. And while the Earth spins like a top on its axis every twenty four hours it is also travelling an elliptical orbit around the sun once a year, the angle of its axis and its position upon the orbit dictating the seasons.

Light features strongly in our language in common terms such as daylight, sunlight, moonlight, street light, headlight, lighthouse and lights out. But there are more inspirational uses such as divine light, the leaded lights in church and cathedral windows and a light-year in which light travels about six million million miles. A loved one can be the light of our life. Light, which is fundamental to the sense of sight, is the third requirement for life.

The sun's brilliant life-sustaining light casts a conical shadow of the Earth into space and as the moon orbits the Earth it is eclipsed by the shadow whenever it passes through it. Earth's rotation around the sun follows an elliptical path across an invisible flat plane in space. If the Earth and sun were connected by a cord, if the Earth's axis was a pencil with its lead at the south pole and if the invisible plane was paper, the Earth would take a year to draw its own ellipse.

An aspect of light that concerns plants on planet Earth is the spectrum: the division of daylight into red, orange, yellow, green, blue, indigo and violet light, discovered by Sir Isaac Newton in 1666. The spectrum colours reflect or absorb light. Daylight, the full spectrum of all seven colours, reflects totally. Black, the absence of all seven colours, absorbs totally. Green, the colour of foliage, absorbs light from all six of the other spectrum colours and is at the centre of the spectrum, the place that protects plants most from the infra-red and ultra-violet radiation at the spectrum's edges.

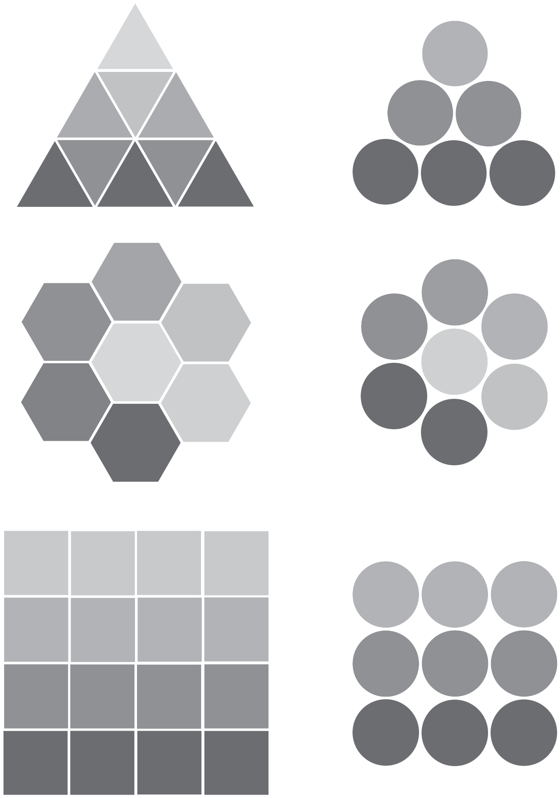
Geometry reveals the spectrum's most beautiful manifestation when sunlight is refracted through raindrops in a rainbow's majestic arch.


Moon
Earth
Sun

MATTER

Matter can only exist within space. Without matter space would be empty and the universe would be void. Conversely, if matter occupied space entirely the universe would be solid and devoid of movement or light. In reality matter occupies only a small percentage of space so that the movement of matter and transmission of light are both possible. The Sun, the Earth and the other planets and moons in our solar system all exist as moving matter in space, in interdependent relationships to each other yet within the great cosmic currents of the universe. On Earth, matter exists in two kinds, as creatures with life such as animals, birds, fish and iving plants or as matter without life such as minerals, water or gases. All matter, whether conscious or unconscious, has existence. Existence has mass. And mass has form.

Some simple forms such as starfish or snowflakes exist as pure, geometrically defined forms. The human body is more complex but individual elements of our form are also pure geometry, our spherical eyes, for example, observing the world through precise, circular irises. In general, spherical or circular forms have movement while angular forms such as mineral crystals are static.



Mineral crystals grow in triangular, square or hexagonal sections, the only shapes in nature that pack together without intervening spaces. There are no crystals with circular sections because circles pack with intervening spaces that have either three or four curves to their boundary, but it is interesting that, just like crystals, circles form triangular, hexagonal or square configurations when they are placed together in groups.

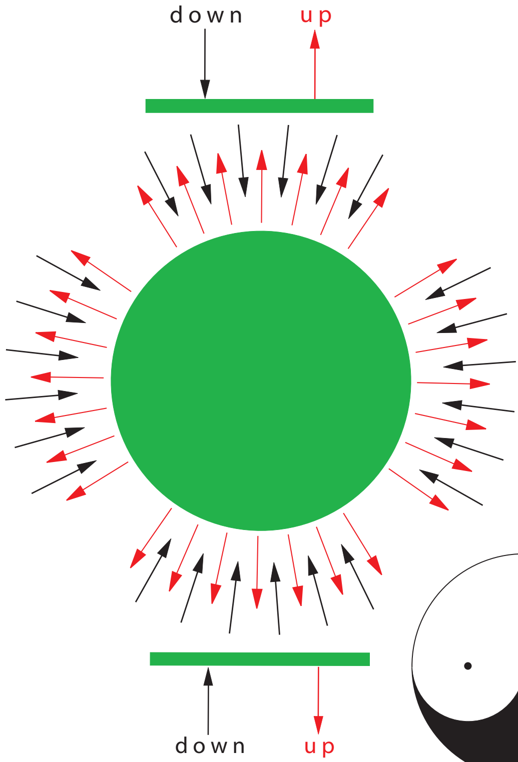
OPPOSITES

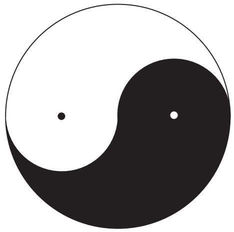
Our world is full to overflowing with opposites, many of which, like birth and death or male and female, are fundamental to our existence as beings. Other's such as night and day, summer and winter, hot and cold or wet and dry, define the character of our daily experience. But there are also bodily opposites such as pleasure and pain, weakness and strength or sickness and health and philosophical opposites such as good and evil, love and hate or right and wrong. And then there are more elusive opposites such as up and down. The northern hemisphere's up and down is the southern hemisphere's down and up, a paradox determined by gravity because down is always towards the centre of the Earth and up is always away from it. Although we view our local sector of the Earth's surface as flat it is, in reality, part of a great sphere. And a sphere's centre of gravity is, as it says, at its centre.

Our language is full of opposites. We argue black is white, feel high or low and now and then can take it or leave it.

Geometry also has opposites, the most obvious being the circle and square and their three dimensional counterparts, the sphere and cube, one curved continuously in all directions, the other formed from six equal square planes, at right angles to each other.

The most famous geometrical opposites are the yin and yang which symbolize the opposing principles in Chinese philosophy and religion, yin being negative, feminine and dark, yang being positive, masculine and light. Significantly, the two shapes are identical and, together, unite to complete the perfection of the full circle.





GEOMETRY

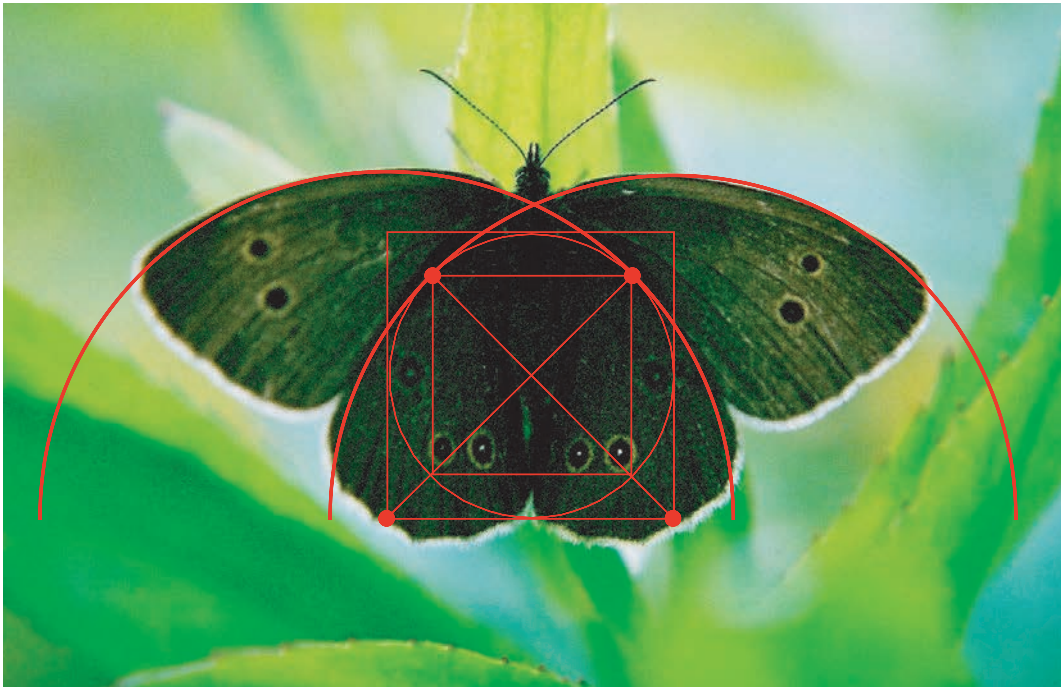
Geometry is the bedrock upon which the natural world is built. It brings order to the world of matter, dictates the perfect spherical forms of the planets and regulates their elliptical paths through space. From Earth we can observe the distant ball of sun or moon, but it is perhaps as a child with a ball in our hand that we first recognise the perfection of a sphere with its surface curvature identical in all directions and from all points of view.

The sphere is the perfect form because it contains the maximum volume within the minimum surface area of any known shape. The sun and all other spherical bodies in space are therefore the most densely packed three dimensional forms possible for the containment of matter. The universe stores matter in the most economic way there is.

The earliest civilisations studied the heavens meticulously, recording the rising and setting of the sun and moon throughout the year's changing seasons and it was inevitable that people who spent their lives working in the open air should be influenced by the circularity of the sun and moon. Circular dwellings, burial mounds and monuments were among the earliest of human constructions. England's prehistoric temple at Stonehenge is the most famous example but there are countless smaller circular bell and disc barrows and circular hut foundations within circular protective enclosures.

Viewing the sun and moon from a distance, we can imagine cutting their spheres in half, like an orange and lemon, so that their forms would become hemispheres: the upper half rising like a dome, the lower half hanging like a bowl. As functional forms on Earth, the dome *withholds* weather and shelters us from it. Built from snow, the dome is an igloo. In London, Wren's magnificent dome crowns Saint Paul's cathedral. On a gigantic scale in Cornwall, Eden's biome domes protect sensitive plants. A bowl *holds* whatever we wish to collect within it. Filled with air and floating on water, the bowl is a coracle. Filled with hot broth it is a soup bowl. From observation of the sun and moon we gain understanding and from understanding we can develop useful ideas.

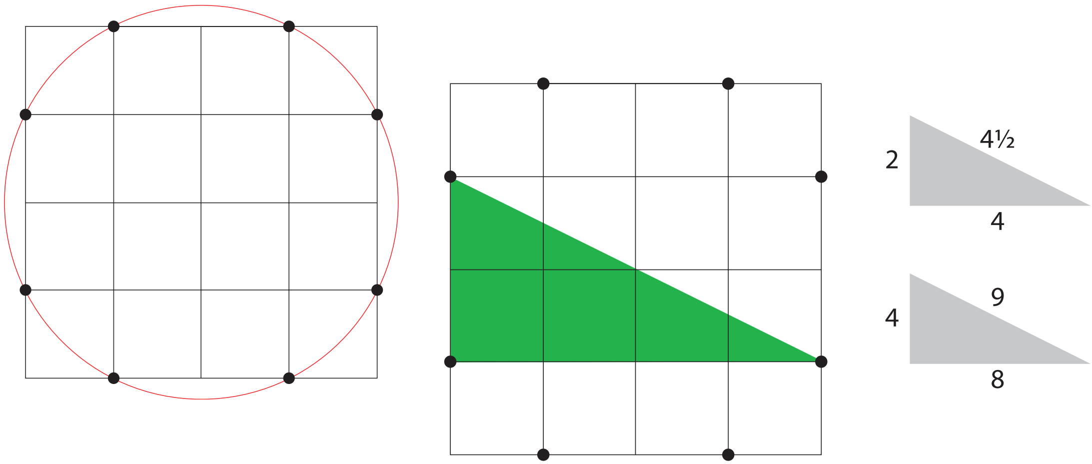
One of geometry's earliest functions was to measure, record and reinstate plots of land that were silted over in the River Nile's annual floods. The ancient Egyptians used a right angled knotted rope triangle with sides of 3, 4 and 5 units of measurement. With thirteen knots, the first and last knots marked the same point so that there were 12 units between the remaining knots. The Egyptians passed their knowledge on to Greek geometers who described the technique in their own words *Ge*, the Earth and *metron*, to



measure, which combined as *ge metron*, are the origin of the English word geometry.

Geometry is found in the structure of many living forms. For example, if a circle is drawn between two squares so that it touches both, the bottom corners of the large square and the top corners of the small square mark four geometrical points from which new arcs of circles can be drawn. The radii for the arcs are diagonal to the squares so that the bottom left corner of the large square is the axis for an arc drawn through the upper right corner of the small square and vice versa. The ends of the diagonals are shown as dots. The two arcs intersect to define the leading edge curvatures of all four wings of a Ringlet butterfly at rest in the sun. The four lower ring marks fit exactly along the base line of the small square and two others fit between the small square and the circle. The antennae echo the diagonals.

THE RHIND MATHEMATICAL PAPYRUS

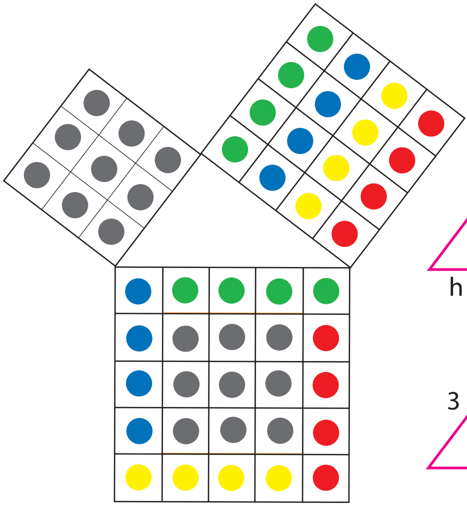


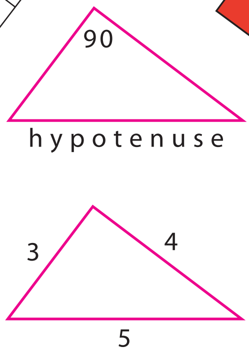
Geometry has been with us for at least four thousand years. The Rhind mathematical papyrus, a series of fourteen papyrus sheets glued end to end to form a scroll, was written in 2000 BC by Egyptian scribes. It shows solutions to geometrical problems relating to triangles, rectangles, pyramids and the squaring of the circle (making the area of a circle and square equal). The Egyptian method was to quarter each side of a square and to draw a circle through the first quarters of each side, a method remarkably close to modern mathematical calculations.

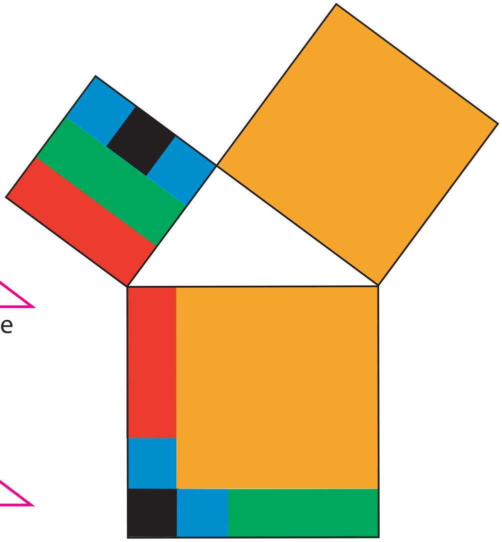
A line drawn across the square between opposite first quarters generates a right angled triangle with sides of 2, 4 and 4½ or, in whole numbers, 4, 8 and 9. It can be seen that the 9 is also a diameter of the circle. The geometry was useful in calculating the volume of grain in cylindrical silos and arose in response to the productive fertility of the lower Nile and the need to store grain efficiently.

The papyrus, which is now in the British Museum, was purchased in Luxor between 1855 and 1857 by Henry Rhind and was subsequently named after him.

PYTHAGORAS' THEOREM







In a 3 4 5 triangle, the square on the hypotenuse (5 x 5 = **25**)
*= the **sum** of the squares on the other two sides* (3 x 3 = **9**) + (4 x 4 = **16**)
and **9 + 16 = 25**

Pythagoras was born at Samos in Greece around 582 BC and lived until 500 BC. He discovered that the sides of the ancient Egyptian right angled 3, 4, 5 sided triangle had a special relationship.

Side 5, opposite the right angle, is called the hypotenuse and Pythagoras' famous theorem states that a square drawn on the hypotenuse is equal in area to the smaller squares drawn on sides 3 and 4 added together.

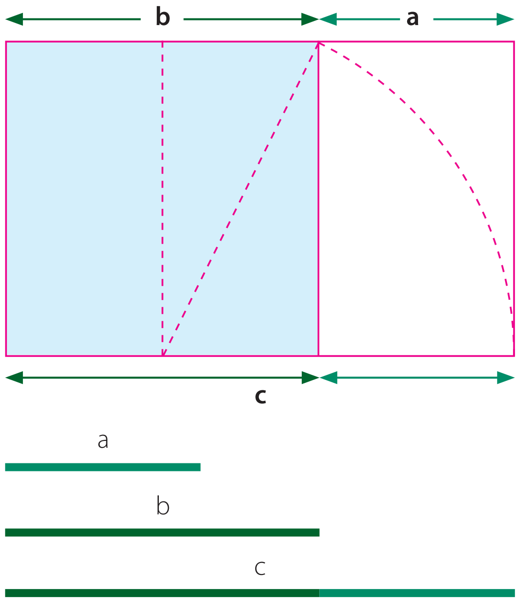
There are over three hundred ways of proving Pythagoras' theorem (Google Pythagoras). The two proofs here are visual, using colours to show the units of area in each square so that the square of 3 and the square of 4 can each be seen individually and then added together to fill the square of 5.

THE GOLDEN RECTANGLE

The golden rectangle, which was discovered by Greek geometers around 500 BC, has special geometrical proportions.

If a square is divided into two halves, the diagonal of one half can be used as the radius of a circle to draw an arc down to the square's base line. In the diagram the square is shown as a grey tone. And if the square is extended to the end of the arc the square plus the extra white area forms a *horizontal* golden rectangle. The extra white area on its own is also a golden rectangle but is smaller and *vertical*. The proportions of the large and small rectangles are exactly the same. The two golden rectangles demonstrate a basic geometrical property, that when certain constructions are enlarged or reduced they change their direction. Golden rectangles are always at right angles so those that are either larger or smaller than a horizontal rectangle are vertical. And vice versa.

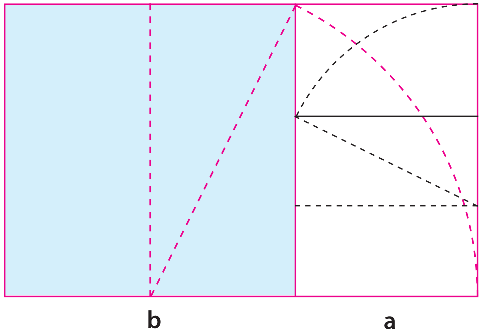
The golden rectangle's length is divided into two sectors. In the diagram the extension **a** is smaller and **b,** the length of the blue tone square, larger. The ratio of the smaller to larger sectors, **a : b**, is the same as the ratio of the larger sector to the whole length, **b** : (**a** + **b**). These ratios are not simply measurements. They are known as dynamic ratios because they can be detected in the natural growth patterns of many living plants and creatures. The distance between branches as they grow from a tree's trunk can be the same as the golden rectangle ratios. For example, from the ground to the first branch equals the rectangle's whole side **a + b**, the distance between branches one and two equals sector **b**, between branches two and three equals sector **a** and so on up the trunk with the distances between branches diminishing in the same proportional ratios.

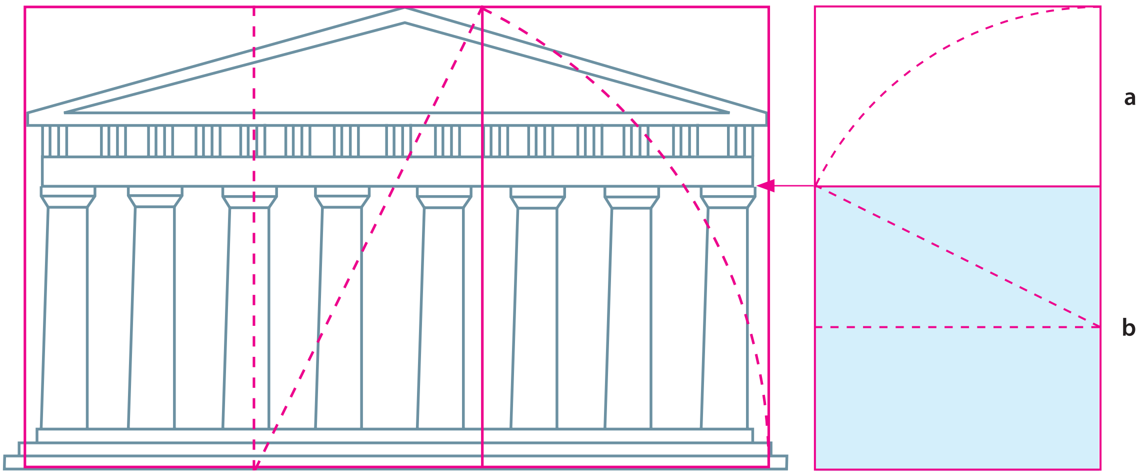


THE PARTHENON

In classical Greece and later, in the Renaissance, the golden rectangle was used in the proportioning of architecture, most famously in the facade of the Parthenon in Athens. The large horizontal rectangle **b +** **a** gives the overall proportions of the whole facade. When the small vertical rectangle **a** is divided into the same divisions as the large horizontal rectangle the division between its square and small rectangle marks the division between the top of each column's abacus and the building's entablature.

Many of the superb sculptures from the Parthenon are exhibited in the British Museum in London, itself built in classical style.





THE LOGARITHMIC SPIRAL

The golden rectangle can be used to construct a logarithmic spiral that is found in nature. The spiral, which has the same geometrical proportional ratios as its parent golden rectangle, can be drawn in two ways, by working downwards in scale inside a golden rectangle or by working upwards in scale outside a golden rectangle.

Reduction inside the golden rectangle ~

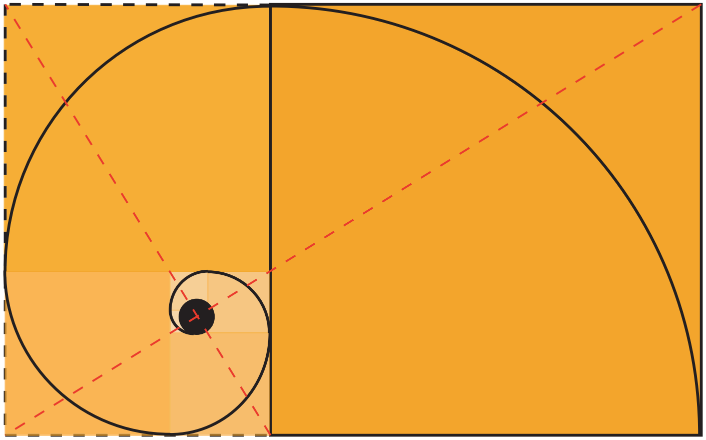
If diagonals are drawn across the large horizontal rectangle and the small vertical rectangle they automatically cross at the eye of the spiral. Where the large horizontal rectangle's diagonal crosses the edge of the square into the small rectangle it marks the corner of a second, smaller square. And where the small vertical rectangle's diagonal crosses the edge of the second square it marks the corner of a third even smaller square. Within each consecutive golden rectangle there is a smaller square and beside each square there is another, smaller golden rectangle. In the diagram the squares grow paler in tone as they diminish in scale and the process continues until it becomes too small to draw with accuracy at the eye of the spiral.

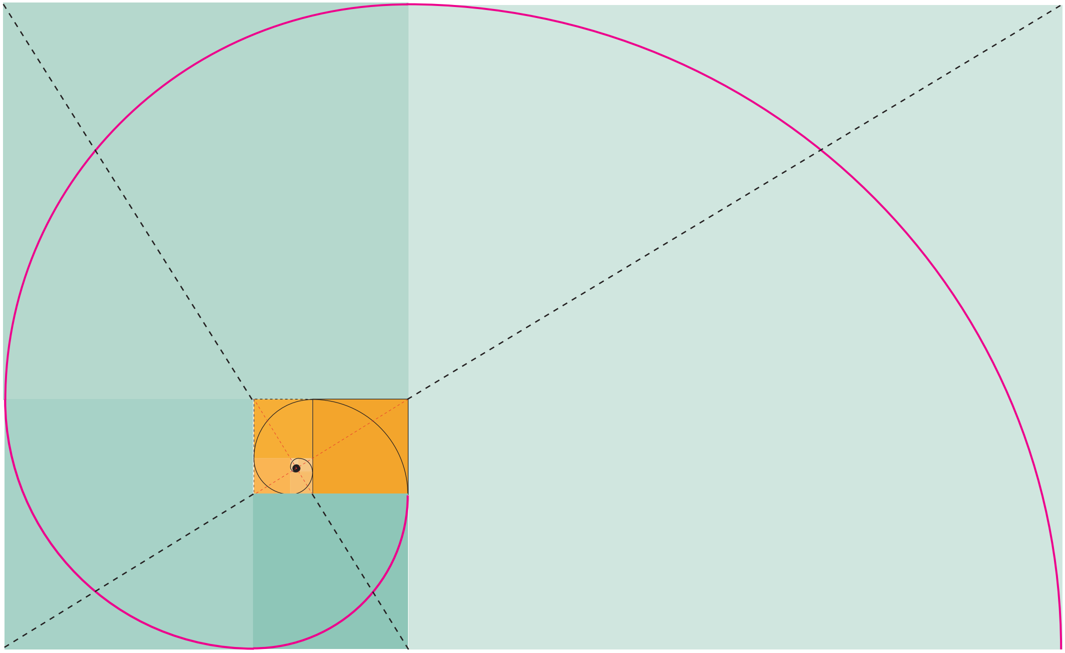
Expansion outside the golden rectangle ~

If a square is drawn adjacent to the long side of a golden rectangle the two together form a larger golden rectangle. As consecutive squares are constructed, ever larger golden rectangles are generated in a spiral around the original one. In the lower diagram the original yellow horizontal golden rectangle plus the dark square below it form a new vertical golden rectangle. The new vertical golden rectangle plus the medium tone square to its left form a new, larger horizontal golden rectangle, and so on. The spiral can be continued ad infinitum.

Because the rectangle's ratios can be found in nature and because nature was seen as the work of God the rectangle became known as the golden rectangle and its proportions as the divine proportion. Contemplating the spiral can carry the mind beyond the boundaries of our everyday world. As the spiral diminishes within the eye it becomes microscopic and, in the opposite direction, expands to infinite scale. The spiral leads in towards the invisible world of the atom and out towards the eternal expanse of the universe but everywhere its proportions, like all other geometrical proportions, remain constant.

The spiral records the natural growth of molluscs that inhabit spiral shells. As the physical body of the mollusc develops in size, its shell grows along the spiral's axis, its length and width expanding steadily as it allows for the growth of the mollusc.





THE FIBONACCI SERIES

The proportional relationships of the golden rectangle's base line and related areas are also present in the sectors of the logarithmic spiral. The proportional relationships were first expressed numerically by Leonardo, son of Bonacci (Leonardo Fibonacci) who was born in Pisa in 1170 and lived to 1250. He wrote Liber Abaci, the *Book of the Abacus*, which introduced Arabic numerals into Europe and taught their use in calculations. Presenting his readers with mathematical problems, Fibonacci gave the following as an example . . . . . *A man put a pair of rabbits in a place surrounded by a wall. How many pairs of rabbits can be produced in a year if each pair begets a new pair every month and rabbits begin to bear young two months after their own birth?* The increase in rabbit numbers is expressed in the number sequence

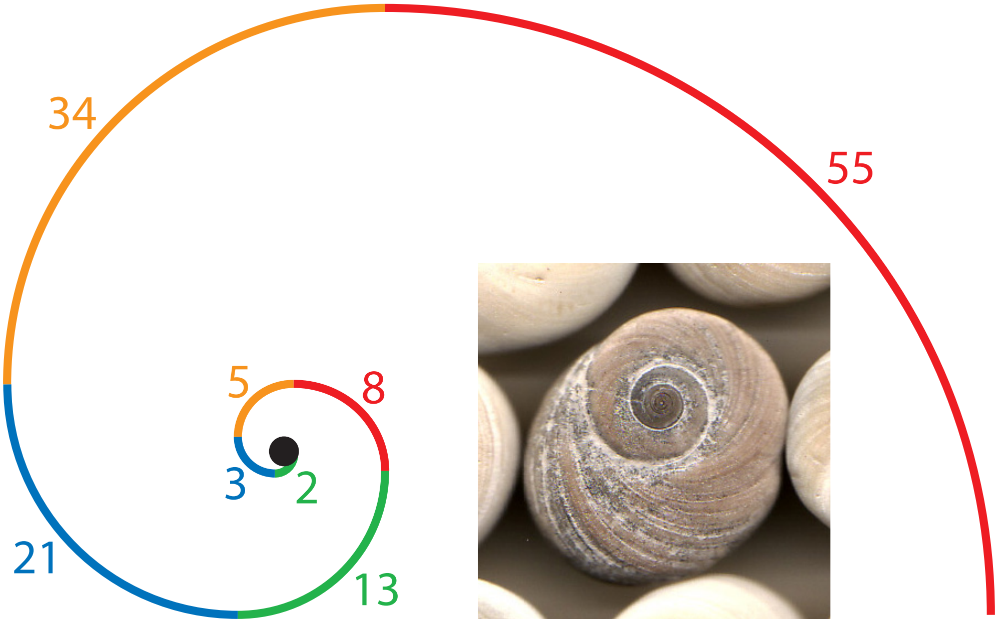
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 etc

which has become known as the Fibonacci series. Commencing at zero, each consecutive number is the sum of the previous two, 0+1=1, 1+1=2, 1+2=3, 2+3=5 and so on.

The Fibonacci series can be found in the proportions of golden rectangles. If a succession of decreasing golden rectangles are drawn so that each contains a square and each square contains a quarter circle, connection of the quarter circles results in a logarithmic spiral.The lengths of the consecutive quarter circles conform to the Fibonacci series. Only part of the sequence can be seen in the coloured spiral because the smallest numbers are lost within the eye at the spiral's centre, the part of the spiral that is too small to draw accurately.

The spiral exists in many guises, as spiral nebulae in space, in the vortices of tornados and whirlwinds, in the curling of a sheep's horn, in the rotation of water draining from a bath, in the florets of sunflower seed heads, as the trapdoors of Australian sea shells (lower ri, the spiral of a bee's or butterfly's tongue and, famously, in the cross section of the Mediterranean Nautilus shell. Fibonacci numbers also govern the numbers of petals arranged radially around a flower's head, an ox-eye daisy, for example, having 21. In certain flowers and seeds spirals run in opposite directions, crossing each other to form the pattern of a sunflower's florets or a pine cone's protective seed casings. Sunflowers usually have 34 clockwise and 55 anticlock-wise spirals depending on species.

At Eden the Core building's timber roof pattern is a visually exciting grid construction of laminated timber with an interwoven warp and weft of 21 and 34 intersecting spirals.


34
55
5
8
3
2
21
13

CIRCULARITY and ANGULARITY

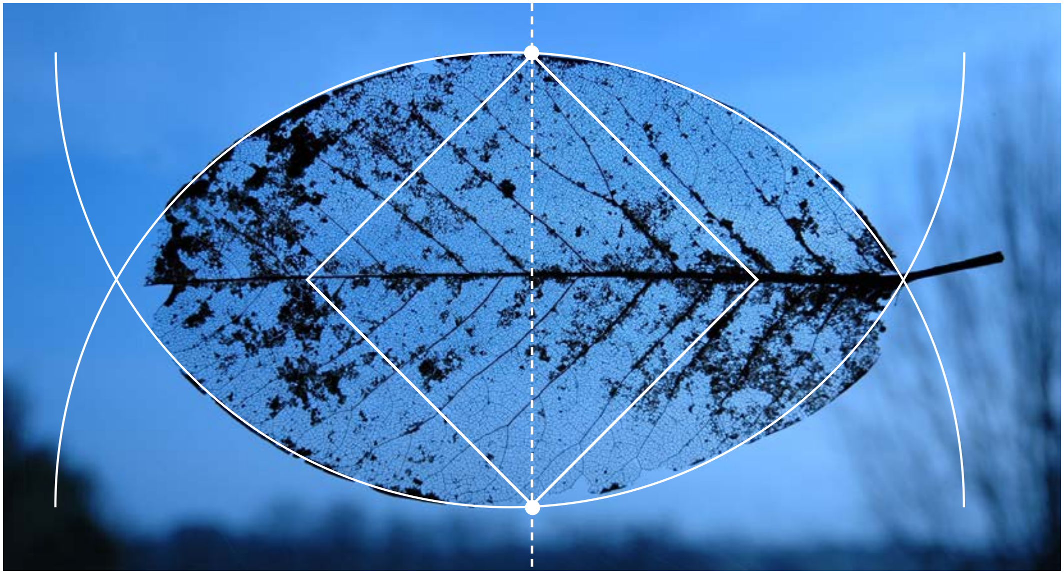
I picked up this leaf skeleton about forty years ago from a footpath beside the River Lagan at Shaws Bridge near Belfast when, among hundreds if not thousands of fallen Autumn leaves, it's perfect shape caught my eye. For a long time I kept it pressed flat inside a book but then, one day, I came upon it, decided to analyse it and discovered the geometrical basis of the leaf's shape.

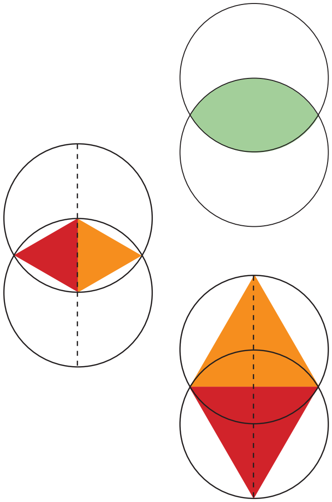
If two circles with identical radius are drawn with their centres on a straight line so that each circumference passes through the axis of the other they overlap to form a central leaf shape between two crescent moon arcs. It can be seen that, despite some slight damage, the leaf fits the geometry very accurately.
In the diagram, the centres of the two circles are shown as white dots on the vertical line and the distance between the dots is the radius of both circles. If you fix your eye on one dot and follow the other round its circle the radius is obvious. The shape formed by the overlap of the circles is called the vesica piscis (fish bladder or sac, from its fish like shape). The fish is the earliest Christian symbol and the vesica is often found in medieval ecclesiastical architecture as a vertical mandorla surrounding the figure of Christ in majesty. It can be found carved in stone above the Prior's door at Ely Cathedral.

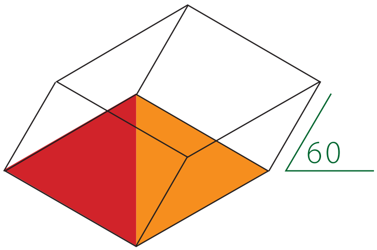
The leaf embodies the two major geometrical characteristics of circularity and angularity, its outer boundary following arcs of circle while its ribs and central spine are at angles. Circularity and angularity are opposites that co-exist in harmonic relationships. They are fundamentals of the language of geometry and are similar to the way that plus and minus are fundamental to the language of mathematics. But they are not positive and negative values in the sense that one is worth more than the other: both are equal. They could more readily be thought of as male and female forces where combination of the two generates the new leaf.

The leaf's geometry is also the source of precision equilateral triangles, two small ones within the vesica that frames the leaf and two large ones within the full geometrical construction. The two pairs of equilaterals demonstrate the geometrical property of duplicated forms that face in opposite directions like mirror images. Every angle in each triangle is exactly 60°.

In my garden I have a massive stone from nearby Tan y Foel quarry in Wales that has fractured naturally into the same diamond formation between its horizontal bedding planes. The stone is also parallelogrammic with the top surface offset from the base by 60°, the same angle as the triangle's points.






60

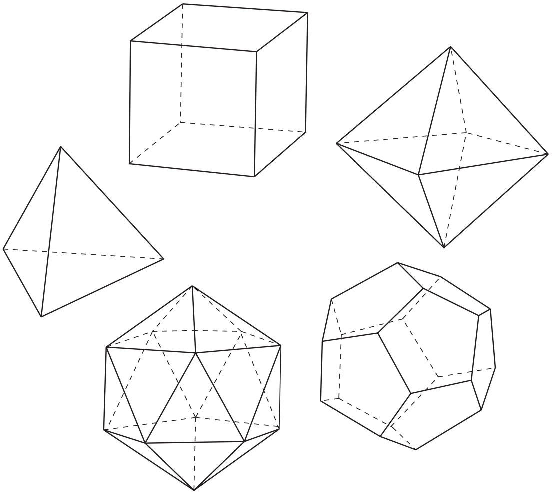
TAKE FIVE

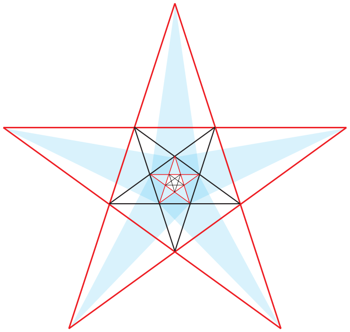
All the Fibonacci numbers are significant in nature. For example, while 0 represents the invisible forces, 8, 13, 21 and 34 are often the number of petals in a flower but the number 5 is perhaps the most interesting and intriguing. 5 appears in human form in the five additions to the abdomen, the head, two arms and two legs. Our hands and feet also terminate in five digits and we have five senses: sight, hearing, touch, taste and smell. The head's two ears, two nostrils and mouth also collectively number five.

Many flowers have five petals. The azure campanula's slender, curved single petals are arranged in a radial star around its stem while the blue periwinkle's five broad petals meet edge to edge to form a perfect pentagon with distinct changes of angle. In both flowers the petals meet at a small central concave sided pentagon and both display a pale ghost pentagon on their petals. The unfurling bud of the pink passes through a perfect pentagonal phase prior to the flower opening fully. The yellow Rose of Sharon throws its five petals into space with greater abandon. The delicate white stitchwort's five petals are divided by serrations into an illusion of ten to match its ten stamens. The gossamer delicacy of morning glory swells from a tiny central pentagon, each face of which leads to one point of a pentagram star at the flower's pentagonal rim. The flower's fabric is like folded parachute silk and the trumpet bears the geometrical creases where it was folded and rolled up in the bud.

Many fruits also exhibit pentagonal characteristics. The tomato's five sepals form a perfect pentagram star, symbol of the Pythagorean school of geometry in Greece in 500 BC. The pentagram star can be drawn freehand in a single unbroken line and can be seen scribed into the masonry of Canterbury cathedral where it is thought to be the personal monogram of Lanfranc, first Norman archbishop of the cathedral in 1070.

There are only five solid three dimensional faceted forms that can exist with identical adjacent faces. The triangular pyramid or tetrahedron has four equilateral triangular faces. The cube or hexahedron has six square faces. The double pyramid or octahedron has eight triangular faces and is like two pyramids joined base to base. The dodecahedron has twelve pentagonal faces. The icosahedron has twenty equilateral triangular faces and is like two five sided pyramids separated by a band of ten alternating triangles. The five solid forms are known as the Platonic solids after Plato, who lived in Athens in 450 BC. Each of the five solids will fit exactly into a hollow sphere so that all of the angular points just touch the sphere's curving surface.





AND SIX

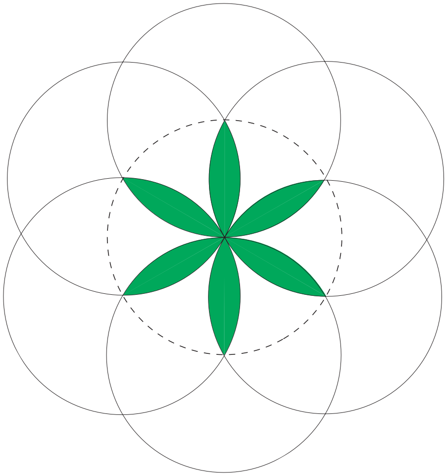
Six circles of equal radius drawn around the circumference of a seventh, also of the same radius, generate a daisy wheel, the six petals of which are identical in shape to those of the Ely lily. The daisy wheel is also the source of the hexagon, formed by connecting the six petal tips, and is the underlying geometry for the gigantic hexagonal basalt columns of the Giant's Causeway on the Antrim coast in Northern Ireland and their counterparts at the entrance to Fingals' Cave on the Scottish island of Staffa.

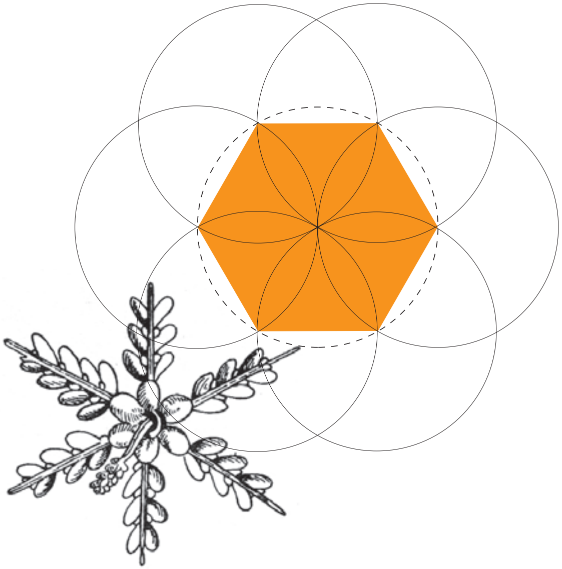
On a smaller scale, the hexagon is the form chosen by bees and wasps for the construction of their cells. This is in preference to either triangular or square cells which, like hexagons, also pack edge to edge endlessly. Pappus of Alexandria, who lived in the third century AD, wrote a beautiful description *on the Sagacity of Bees* in which he concludes *. . . Bees, then, know just this fact which is of service to themselves, that the hexagon is greater than the square and the triangle and will hold more honey for the same expenditure of material used in constructing the different figures.* The photograph shows the hexagonal initial core cell structure of an incomplete wasps' nest which, had their work reached fruition, would have been protected within a spherical exterior.

If six lines are drawn from the outer tip of each daisy wheel petal to the wheel's axis, the lines will be exactly 60° apart. The six lines are the plan on which the architecture of the snowflake is built. Although there are thousands of different snowflake patterns the crystals all conform to six radials at 60° around a central axis, like that drawn by Dominic Cassini in about 1600, or to the equilateral triangles, Stars of David or hexagons that are based upon them.

Cacti in Eden's Warm Temperate Biome are living three dimensional structures based upon a daisy wheel plan. If the cactus was cut through horizontally, inked and stamped on paper its pattern would be virtually identical to a six petalled daisy wheel. Other cacti have twelve equally spaced flanges, two for each 60˚ angle of the wheel or every 30˚. Other cacti have four flanges set at right angles to a central axis. The cacti grow to precision geometrical plans.

Six further circles of equal radius can be drawn from the six external intersections of the daisy wheel. The new circles also intersect and if further circles of equal radius are drawn from their intersections an expanding network of interlaced circles begins to form. The network reaches to infinity in all directions and is the source of myriads of equilateral triangles and hexagons of all sizes from that at the diagram's centre to galactic scale.





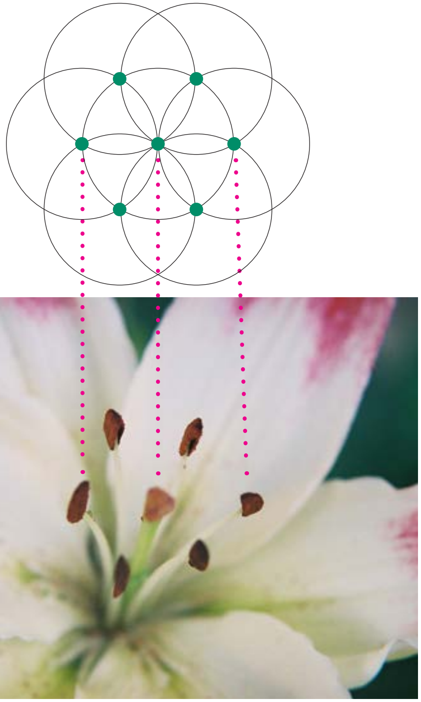
SIX, SEVEN, EIGHT and NINE RADIALS

The petals of many flowers are set radially around the head of their stem. A lily, for example, has six petals set at equal 60˚ angles in two layers of three. Each layer of three petals describes an equilateral triangle between its petal tips. When the lily flower is still in bud it is also triangular in cross section with the petals wrapped tightly around the pistil and stamens at its centre. As it opens, the stamens grow away from the pistil, passing through a perfect geometrical phase until the flower opens fully and they become distorted by the influence of wind, rain and the intrusion of bees and hoverflies seeking nectar. In the perfect geometrical phase the central pistil and six surrounding stamens follow the spatial organisation of the daisy wheel's geometry with its central axis and six petal tips. The geometrical pattern continues to the last detail with the pistil's triangular tip and the circle of petal shaped anthers at the stamen's ends.

Certain flowers have the ability to grow in a variety of geometrical forms. The red poppies, an exotic variety photographed at Powys Castle's wonderful terrace gardens in Wales, develop seed heads spoked like cartwheels. The three sets of radials shown are seven, eight and nine. Division of the circle into eight sectors is a simple matter of halving but division into seven and nine demands several stages of geometrical drawing to divide the circle into the required number of sectors. Though the drawing can be accomplished easily using a compass and straight edge and requires no calculation it remains a matter of wonder that the flowers have the innate ability to divide circles with precision radials. Clearly they are dancing to nature's geometrical tune.

The radials have a practical function and mark divisions in the seed head where small hatches open to allow the ripened seeds to escape. The more common yellow Welsh poppy with its smaller, more slender seed head usually has four or five radials. The number of radials in the seed head can be seen from the number of tiny radials at the flower's centre, those in the photograph having four and five radials. The top photograph shows dried seed heads after the petals have fallen away and the hatches have opened and curled back over the seed pod to allow dispersal of the seeds.

An identical hatch system can be found in pine cones. And at Eden these hatches are the inspiration for the roof of The Core building which is composed of copper scales, with individual scales hinged up in the form of little angular glazed dormer windows to let light into the building's interior. Externally, the roof has the look of an open pine cone.



TEN RADIALS and UPWARDS

Although some flowers have more than ten radial petals ten seems to be the number at which most three dimensional fruit and seed forms begin. The three dimensional forms are either solid, such as fruits that are eaten and their seed spread by birds or the fragile and lacy seeds that are carried by the wind.

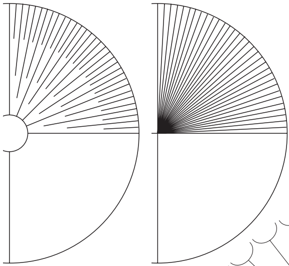
Red currants have a structure akin to hot air balloons, swollen under the pressure of ripening juices as if fired from propane cylinders. The ten divisions, which are clearly marked by seams that withhold the swelling of the fruit, each expand to give the fruit's sphere the same quilted surface character as the Eden biomes. The dividing seams meet in a small pentagon at the fruit's pole, five seams meeting the pentagon's angles and five joining the centre points of the pentagon's sides. This can be seen clearly in the white fruit where the pentagon is head on.

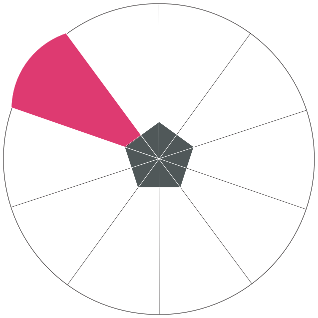
In the case of the red currant the seeds are internal, awaiting the blackbird's need for a gourmet meal and the subsequent free flight to their place of growth. However, the invisible presence of moving air is fundamental to the flight of both the blackbird and the seed.

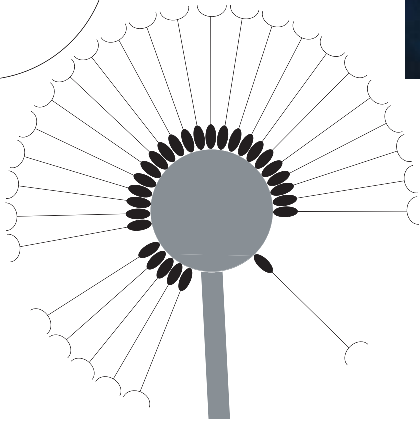
The dandelion applies the opposite strategy and develops external seeds that are carried upwards on passing breezes or are blown into the air by small children learning to count out the hours of a summer's day.

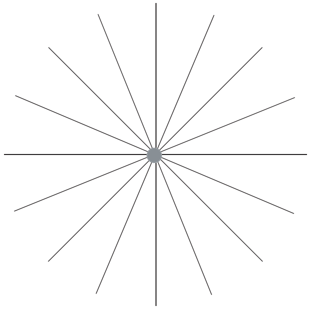
Looking at external seeds there is a direct connection between the number of radials and their actual dimensions. It is impossible for all the radials to meet at a theoretical central point because, even if very fine, their structures would collide. So, as the number of radials increases, their thickness decreases. Nature's solution to the problem of supporting more seeds is the only logical one open to it, that the radials should meet on the surface of a cylinder or sphere where there is room for them to fit side by side. There are two kinds of spheres, the first has a single seed at its centre, the second a multiple seed centre like a dandelion head. In the case of a single seed all radials are connected to it. On the dandelion head, each radial, which has its own individual seed, fans out at its outer extremity into a circular array of hair-like filaments that act as a miniature parachute that catches the lightest breeze.

The toadstool solves the collision of radials by developing gills of different lengths. Only a few gills radiate from the stem but, as the distance between them expands towards the cap's rim, further gills are added and so on. The question of collision is identical whether the radials are alive and growing or drawn by pen on paper so the fungus shows complete spatial mastery in its pragmatic solution to this basic geometrical problem.









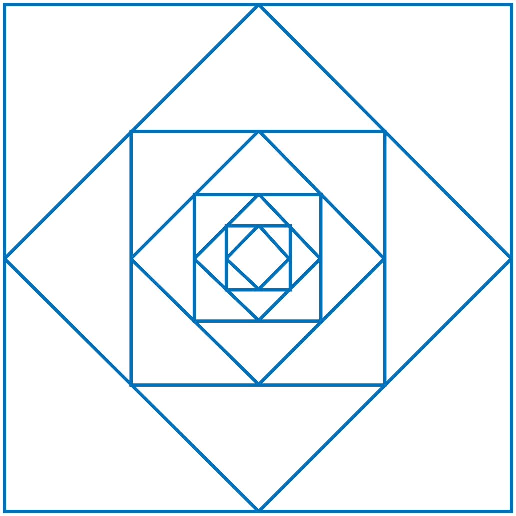
THE WHIRLING SQUARES

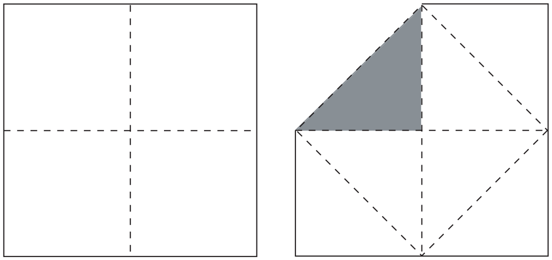
The whirling squares are drawn with every square set as a diamond in relation to its neighbouring squares. If squares one, three, five and all consecutive odd numbers, are squares then squares two, four, six and all consecutive even numbers are diamonds. Or vice versa. Each square or diamond is exactly half the area of the next bigger one and exactly twice the area of the next smaller one. This can be proved easily by folding a square of paper into half both ways to divide it into four quarters and then folding each corner to the centre to define the diamond. It is clear that the square contains eight triangles while the diamond contains four, so the diamond is half the area of the square. It follows that how ever many whirling squares there are they all have a double or half relationship to their neighbouring squares and the sequence therefore maintains a harmonic proportional relationship throughout. The diagonal of each square or diamond is equal in length to the side of the next larger square or diamond. Every square or diamond is at 45˚ to its neighbours.

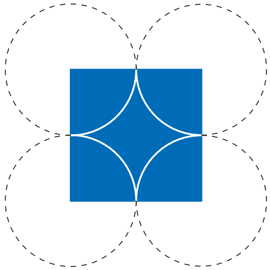
The whirling squares are another geometrical sequence that leads the mind to optical infinities. If the eye focusses inwards from the largest towards the smallest square it looks into an ever diminishing tunnel and outwards, from the smallest to the largest, into ever expanding space.

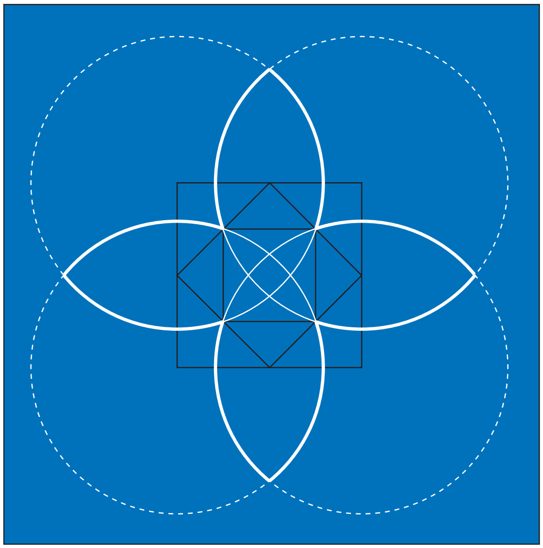
Unexpectedly, the whirling squares can be detected in the structure of flowers. While the campanula commonly produces flowers with five petals it sometimes produces them with four. The four petalled campanula has extraordinary symmetry with a perfect square at its centre, differentiated by its pale colour from that of the surrounding petals. If the pale square is drawn as the smallest square of three whirling squares, the four corners of the largest square are the axes for four circles that intersect to define the curvature of the petals. Within the flower's pale square its pistil continues whirling and is set as a smaller diamond at the centre of the petals' white square. The pistil's concave sides can be drawn from the four corners of the pale square as four quarter circles.

The campanula's geometrical characteristics continue with the division of each petal into two, the line bisecting each pair of opposite petals from one external tip to the other. These lines mark the fold in each petal that opens out as it blossoms. They were already there in the bud where the fabric of the petals was folded as immaculately as a silk parachute. It is one of life's unanswerable questions as to how the campanula learned to fold its petals within the bud to such precise geometrical configurations.









THE RIGHT ANGLE

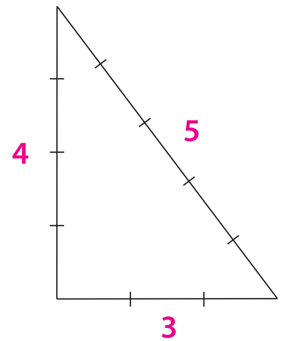
Certain flowers arrange their petals at 90˚ to their stem so that they project symmetrically in four directions. The large petals of the pink clematis surround a circular cluster of stamens. The little holly flower has just four stamens and these are also positioned at 90˚ to each other but at 45˚ to the petals so that, if it were a compass, the flower would record north, north-east, east, south-east, south and so on. The tiny flower of the miniature willowherb is similar except that its petals are linear rather than curved and run parallel to the four 90˚ angles. Under its petals the four pointed sepals are set, like the holly's stamens, at 45˚.

Drawing right angles without the aid of modern set squares is not easy. The basic method, using 3 4 5 triangulation requires the precision construction of three angles and three sides, each angle of differing degrees and each side of differing length so that there are six unequal elements to be resolved.

Compass geometry offers a much simpler method free from the need to construct angles and devoid of measurements. Two circles of identical radius are drawn on a horizontal line so that each has its axis on the line and passes through the axis of the other. The two circles intersect to form a vertical vesica piscis, the shape formed by the overlap of the circles. If the vesica is bisected by a vertical line it cuts the horizontal line at right angles. A perfect set square, shown in yellow, with angles of 30˚ 60˚ and 90˚can be drawn between the lines and the vesica's arc.

A shorthand, but equally accurate compass based method was recorded by the medieval German master mason Mathes Roriczer of Regensburg in 1460 in his booklet entitled *Geometria Deutsch*. Two lines are drawn along a straight edge so that they intersect at any angle. A circle is drawn, with its axis at the intersection of the lines. The circle's circumference must cut the two straight lines in a minimum of three places and if the three cuts are joined they form a perfect right angle. Because the circle is drawn from the intersection of the lines, both lines are automatically diameters of the circle and any angle drawn from opposite ends of a diameter to the arc of a hemisphere gives a precise angle of 90˚.

Nature has an instinctive hold on many geometrical constructions and the primary reason seems to be that forms such as seeds, flowers and fruit are connected to the parent plant by the most delicate of stems and are therefore able to form in space. Because there is no impediment to their growth they increase freely in all directions to attain their preordained and optimum forms.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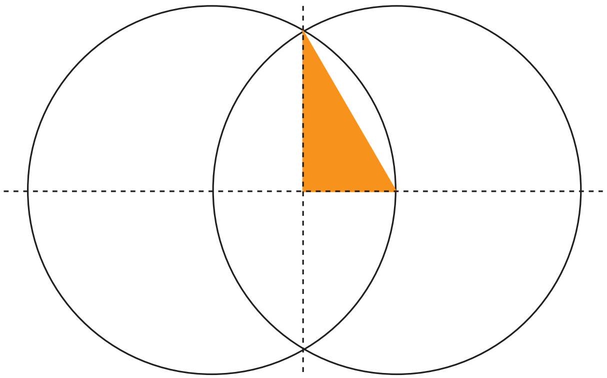

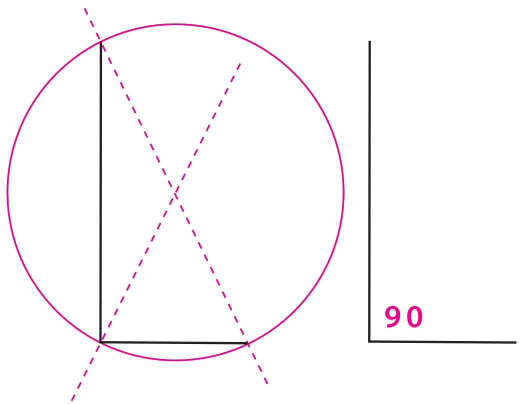
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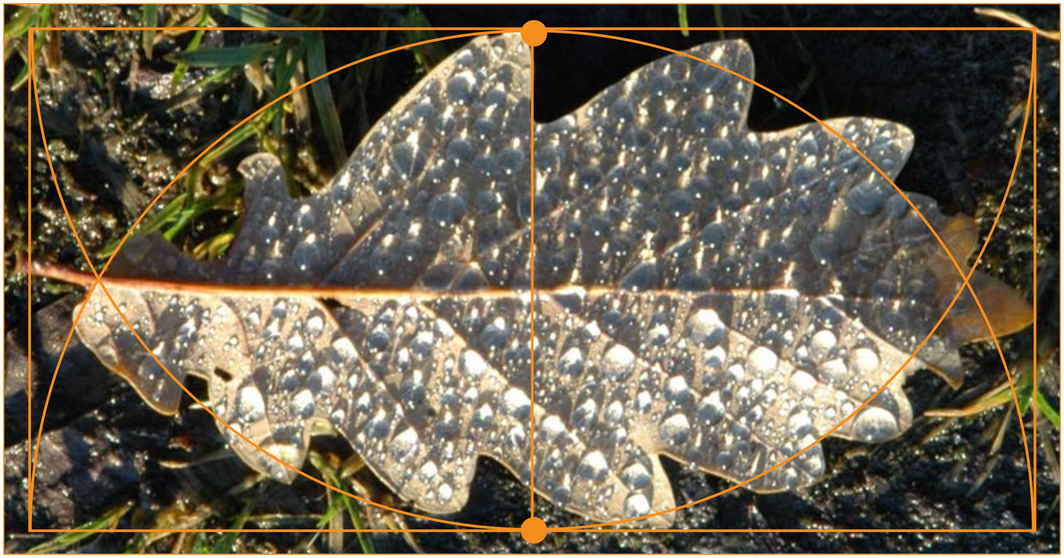
RECOGNISING IT WHEN YOU SEE IT

It is not difficult when looking at natural forms such as leaves to recognise those that follow precision geometries. The upper leaf, which has been described previously, has an external boundary made from two perfect arcs of circle. If a compass is set to the distance between the two points and then an arc is drawn from each point, the two arcs intersect at the two ends of the leaf. The whole leaf is determined by a single radius and its form is divided into mirror image halves along its spinal rib.

Other leaves of more complex form, such as the lower oak leaf have less obvious geometries yet still retain a sense of symmetry in their form. The strange thing is that while the eye can recognise the leaf's symmetry at a glance, which is why I noticed it, the actual reason for it requires some analytical effort. The simplest method of analysis is to photograph or scan the leaf and then to work geometrically on the two dimensional image. If the extreme width and length of the oak leaf are framed within a rectangle and the rectangle measured it is exactly a double square. If two points are placed at the junction of the squares they pin point the axes of two half circles that cross each other in mirror image. It can be seen that the distance between the intersections of the circles and the ends of the double square define the stem length, on the left, and the leaf tip, on the right. It can also be seen that the leaf, whilst not following the circle arcs with precision, neverthless follows them in a general way. In places the leaf boundary breaks out beyond the arcs of circle and in other places it remains within them but, on average, it conforms to the geometrical plan. It is as if, given a felt pen, we are asked to draw a swift, freehand oak leaf within two overlapped arcs of circle. The freedom of our wrist movement as we draw the leaf is synonymous with the freedom of the leaf's growth into space from the shelter of the bud. Like the upper leaf, its spinal rib runs between the intersections of the circle arcs and it also expresses the relationship between circularity and angularity.

The surface of the oak leaf is covered in dew droplets waiting to be evaporated by the rising sun and these show the fact that droplets of liquid are dancing to the same geometrical tune as the leaves. The dew drops are collected into near perfect spheres. Their smallness and lightness means that gravity has little effect upon them and they are free to form spheres, the most economic form in the universe for containing matter. It was seeing the spherical dew drops illuminated by the early morning sun's radiance that made me photograph the leaf. Half an hour later the dew drops had evaporated.



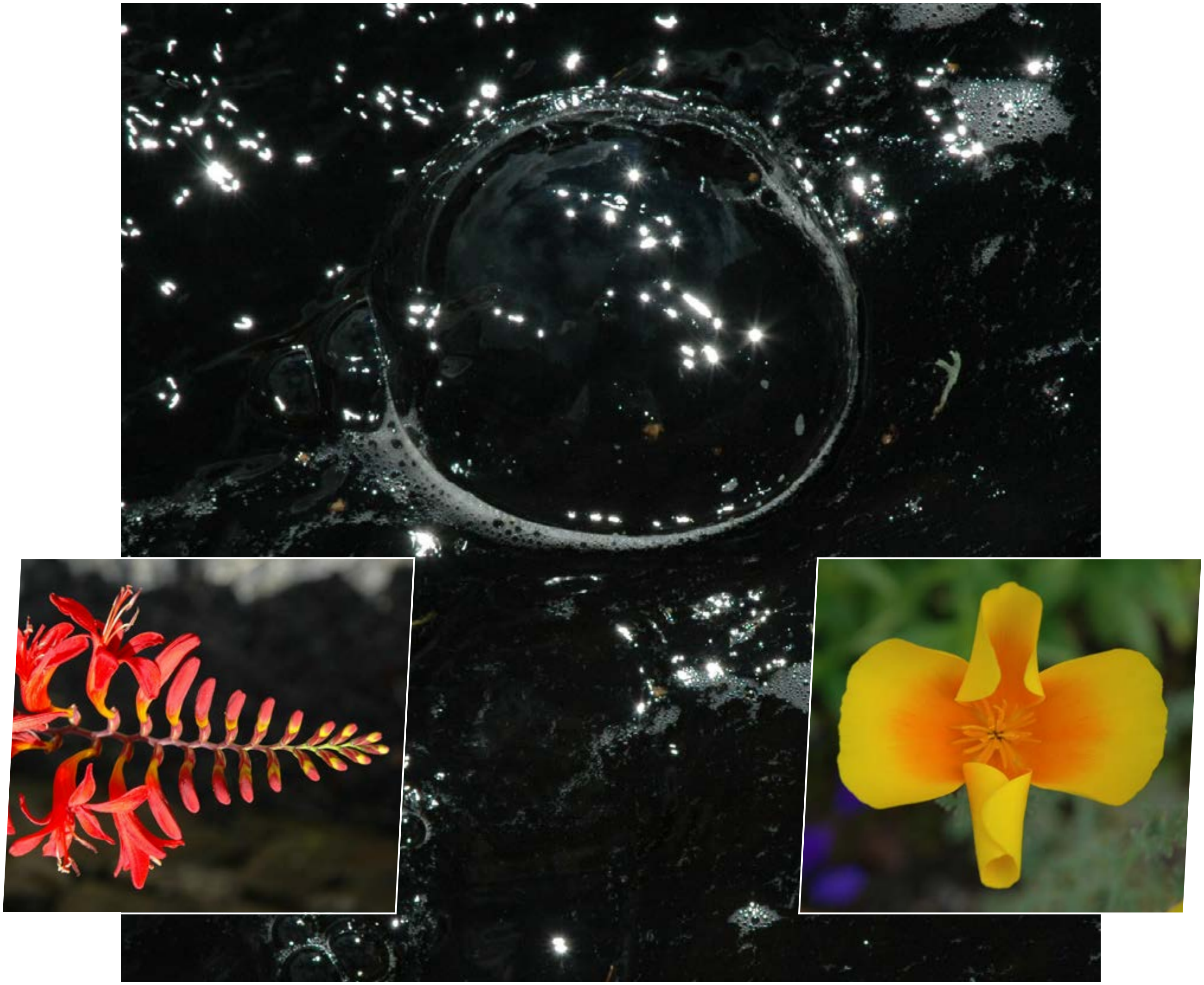
SYMMETRY

Overshadowed by sallows, the dark waters of the river Rhiew rush out of Wales towards their meeting with the Severn and their journey to the sea. In the many pools and eddies small bubbles form, swirl, coalesce to form larger but perfect hemispheres and, finally, burst, the circle of their foundations sinking back into the river's skin. The bubbles exist momentarily yet the cycle is endless with new bubbles constantly replacing those that are lost. In the swift flow of the river's current and the water's erratic passage over rocks each bubble repeats the same journey from birth to death, dancing to nature's geometrical tune. Watching the bubbles swirling past, brilliant sun bursts of light and the sky's moving clouds are reflected in their glassy domes so that they encapsulate a night sky or replicate the plan of oceans and continents, seen on the Earth from space.

Each bubble survives longer than might be expected because the delicate surface membrane's tension is identical at all points on the hemisphere. The hemisphere has its greatest dimension at the water's surface and is therefore ever lighter as it rises towards its apex, the same principle that is used in the construction of actual domes. The bubble, built from the same water that it rides on, is also flexible and resistant to shock, a principal that could be applied to experimental new architecture in earthquake zones. It is the perfect self supporting shape.

The bubble is perfect because it has symmetry. if the bubble could be cut into vertical slices like cake its curvatures would be identical in every slice and, if it was cut into horizontal slices, every slice would be a circle. Looking at the bubble's form in another way, a line drawn from anywhere on the hemisphere to the centre of the base circle is equal to the circle's radius so that all points on the hemisphere are exactly the same distance from the base circle's axis. The hemisphere is half of a full sphere which has the most perfect symmetry because a single dimension, the radius, describes its complete form. A child can design a bubble or a planet with a compass, the drawn circle being both plan and elevation.

There are other types of symmetry. In some plants the symmetry is either side of a line or stem like the brilliant flower buds of the Montbretia. The symmetry tapers so that, starting from the stem's base, the florets open in sequence until those at the apex of the stem open. Other flowers, such as the California poppy, dance a symmetric dance when they open at dawn and close again at dusk. The picture shows the poppy half way to closure, the petals curling symmetrically into tubular rolls in readiness for the night.



THE EYE

Like the Earth on which we live the eye is spherical, like a ball bearing in a socket that can move freely in all forward directions to give us wide ranging multi-directional vision. The eye's circular lens, the iris, is controlled by muscles that allow us to alter the focal length of the eye from close up observation to distance vision of the horizon. Moving the eye and focussing are spontaneous and effortless. Because we have two eyes we are able to compute geometrical triangulations to determine the location and distance of the things we see.

If we go through life using our eyes solely to watch for the arrival of a bus, to search the shelves in the supermarket or to absorb the images on TV we are passive viewers.

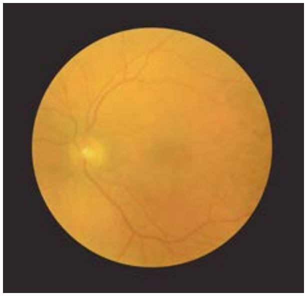
Alternatively, if we consciously observe the world around us, and particularly the natural world, we can become active viewers.

And if we make conscious efforts to understand what our eyes are revealing to us then we are on the road to understanding the true nature of the world that we inhabit.

Only then do we begin to construct a set of values that recognises the wonder, magnitude and diversity of our world, our place within it and our responsibility towards it.

Our eyes are passed down to us by our ancestors, through the invisible geometry of DNA, as priceless gifts from the universe.

The photograph shows the retina, viewed through the iris, in appearance like a full moon but in reality the interior of a living sphere within the protective bone structure of the skull. The pale area is the optic nerve where visual data is passed through to the brain for conversion to imagery of the world as we observe it.



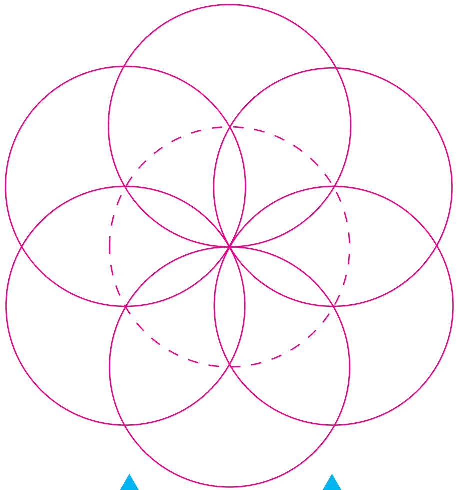
SECTION 2
GEOMETRY • ARCHITECTURE

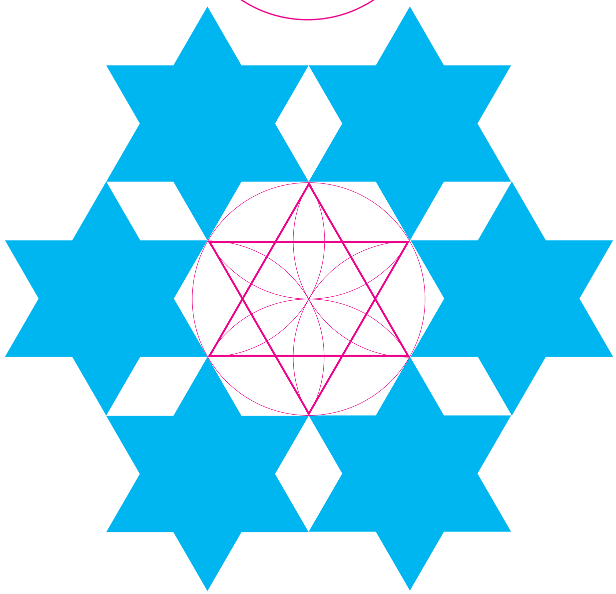
Tower, bridge and viewing platform adjacent to the Eden Project's Core building

THE DAISY WHEEL

The geometries found in nature can also be used for designing architecture. For example, the geometry that underlies the form of the snow flake and the bee's cell, six circles of equal radius drawn exactly around the circumference of an initial circle, forms a six-petalled flower pattern. It is known by timber frame carpenters as the daisy wheel. Connecting the daisy wheel's six petal tips by straight lines gives a number of precision two dimensional planes. Connection of all six petal tips gives a perfect hexagon. Connection of three alternate petal tips gives an equilateral triangle and connection of the remaining three petal tips gives a second equilateral triangle facing the opposite way. Combination of the two equilaterals gives the Star of David which is a common star tile in Islamic architecture. The boundaries of the two equilateral triangles cross each other in six places to form a central hexagon and six further, small equilateral triangles. Two small equilaterals combined form a small diamond. Star, hexagon and small diamond can be combined to form a continuous pattern.

Kennixton farmhouse, originally from the Gower Peninsula but now reconstructed at the National Museum of Wales at Saint Fagans, Cardiff, has some interior walls decorated with a traditional stencil pattern based on the six equal petals of the daisy wheel.





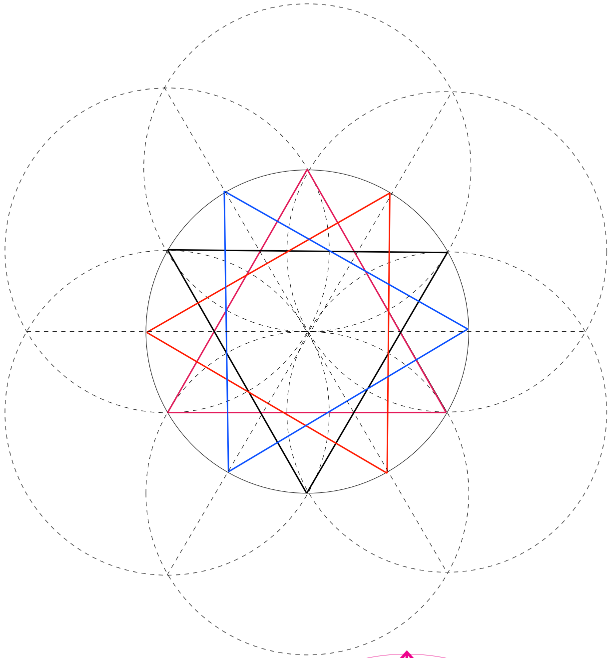
ROMAN DAISY WHEEL DESIGN

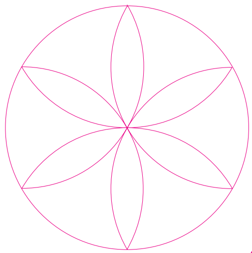
Beyond its function as a source of pattern, the daisy wheel can also be used for designing three dimensional structures. Marcus Vitruvius Polio, a Roman architect of the first century BC, wrote *The Ten Books on Architecture* in which he described the design of Greek and Roman amphitheatres. The Roman design evolves from a central daisy wheel.

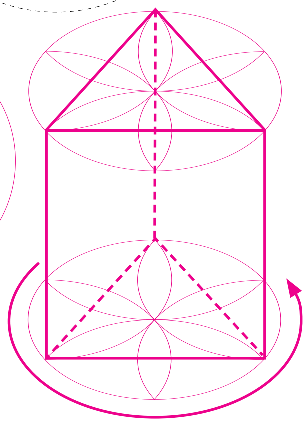
The daisy wheel is drawn fully, with six equal circles around the circumference of a central circle, so that lines connecting the intersections of the outer circles cut the central circle at six points. Additionally, the daisy wheel petal tips mark six further points, bringing the total to twelve equidistant points which can be connected by lines to form four equilateral triangles. The plan of the Roman theatre shows how the four triangles point to radial alignments in the auditorium where flights of steps rise between the circular arcs of the theatre's seating.

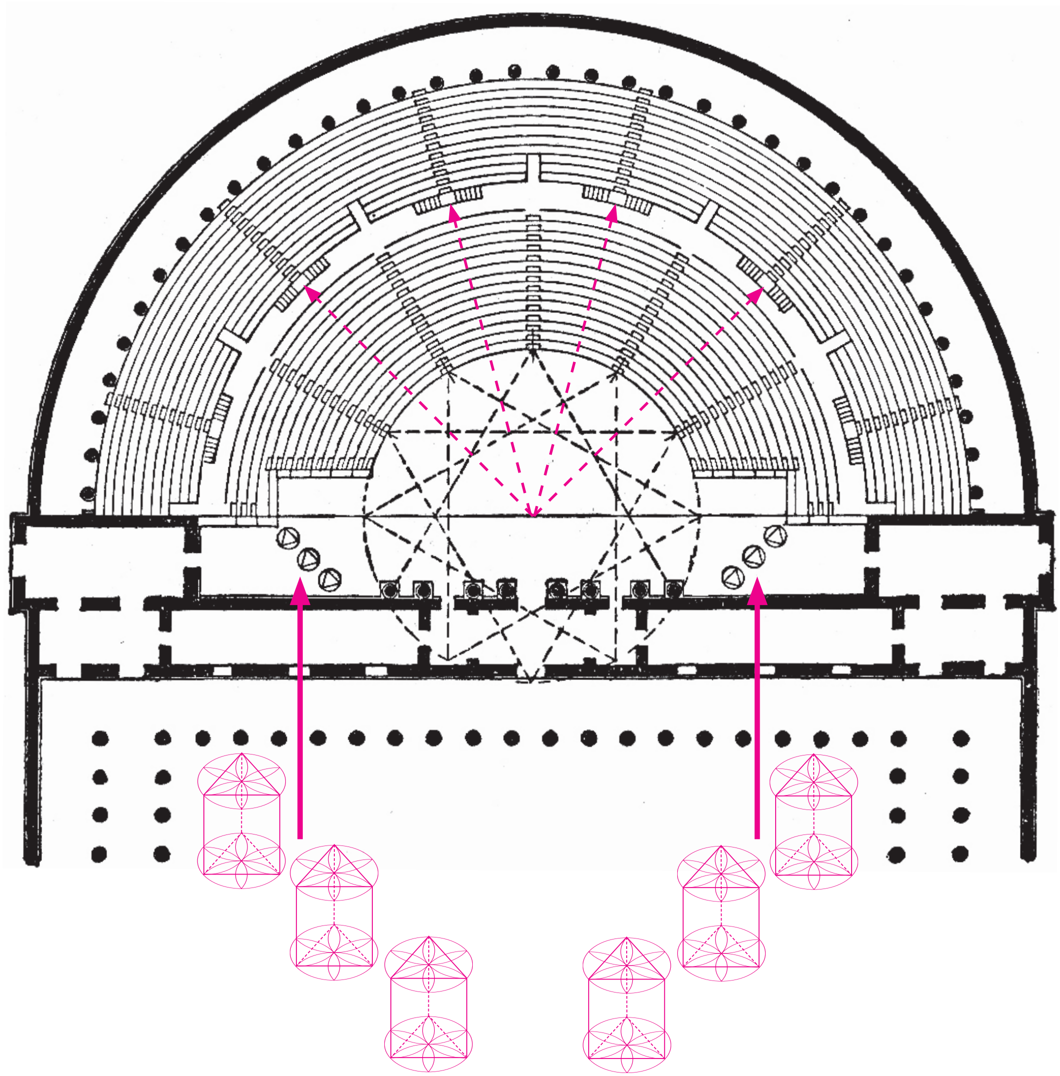
The daisy wheel is also the basis of the three vertical triangular constructions standing at either side of the stage, each face of which was painted. The triangles were rotated to enable rapid changes of scene.

If the floor plan of the half circular amphitheatre is viewed as a vertical elevation it can be seen either as a half circle Roman arch or, three dimensionally, as a hemispherical rotunda, two Roman architectural inventions.









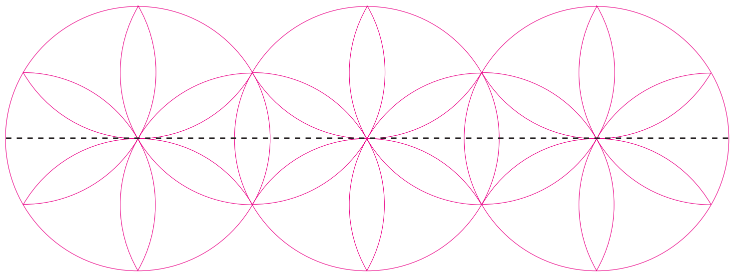
ROMANESQUE DAISY WHEEL DESIGN

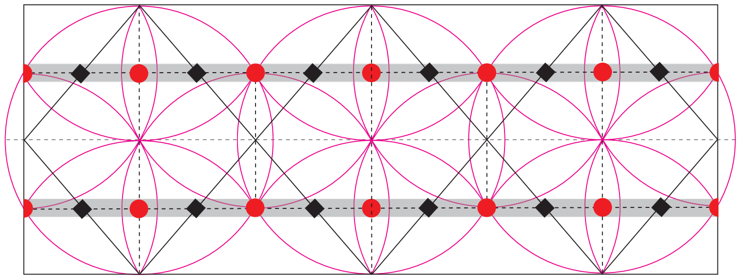
After the Norman invasion of 1066 there was a great rebuilding of cathedrals in England and Wales. The new cathedrals were significantly larger than the Anglo-Saxon cathedrals that they replaced and when the building of the new, Romanesque cathedral commenced at Ely in 1181 the nave floor plan was laid out to daisy wheel geometry.

The plan commences with three daisy wheels, clearly a reference to the Trinity, that are connected at their petal tips and spaced along a centre line. A rectangle can then be drawn around the circles using tangents for its long sides and with its short sides passing through the outer circles' pairs of petal tips.

Once the basic grid is in place a series of further geometrical developments can be made. First, vertical diameters are drawn across each daisy wheel, from the upper petal tip to the lower petal tip so that they intersect the nave's centre line. Then, the petal tips to the left and right are connected horizontally. Finally, diamonds are drawn between points on the centre line and the daisy wheel's upper and lower petal tips in all three circles of the grid.

The nave arcades alternate between pairs of cylindrical and angular piers, a classic example of circularity and angularity in harmony. The cylindrical piers are all placed on either the circumferences or the diameters





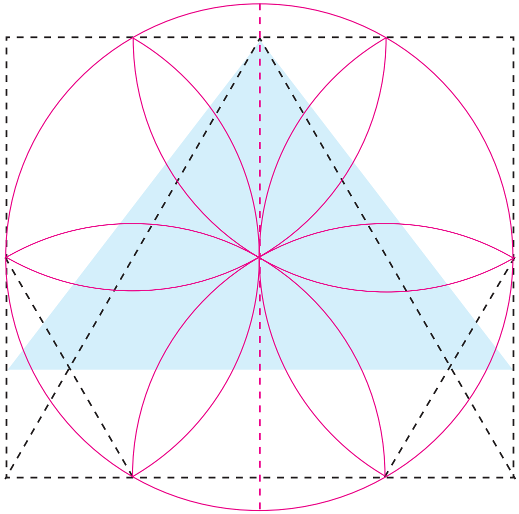
of the three daisy wheels so that circular columns stand on circle geometry. Conversely, the angular piers are placed at points where the diamonds cut across the arcade alignments so that angular piers stand on angular geometry. The geometry determines the precision harmonic visual vocabulary of the arcade's three dimensional stonework.

Two superbly sculpted doors enter Ely nave from the south, the Prior's door and the Monks' door which, fittingly, incorporates two daisy wheels within its intricate imagery.


The Prior's door


The Monks' door

THE TEMPLARS at CRESSING TEMPLE

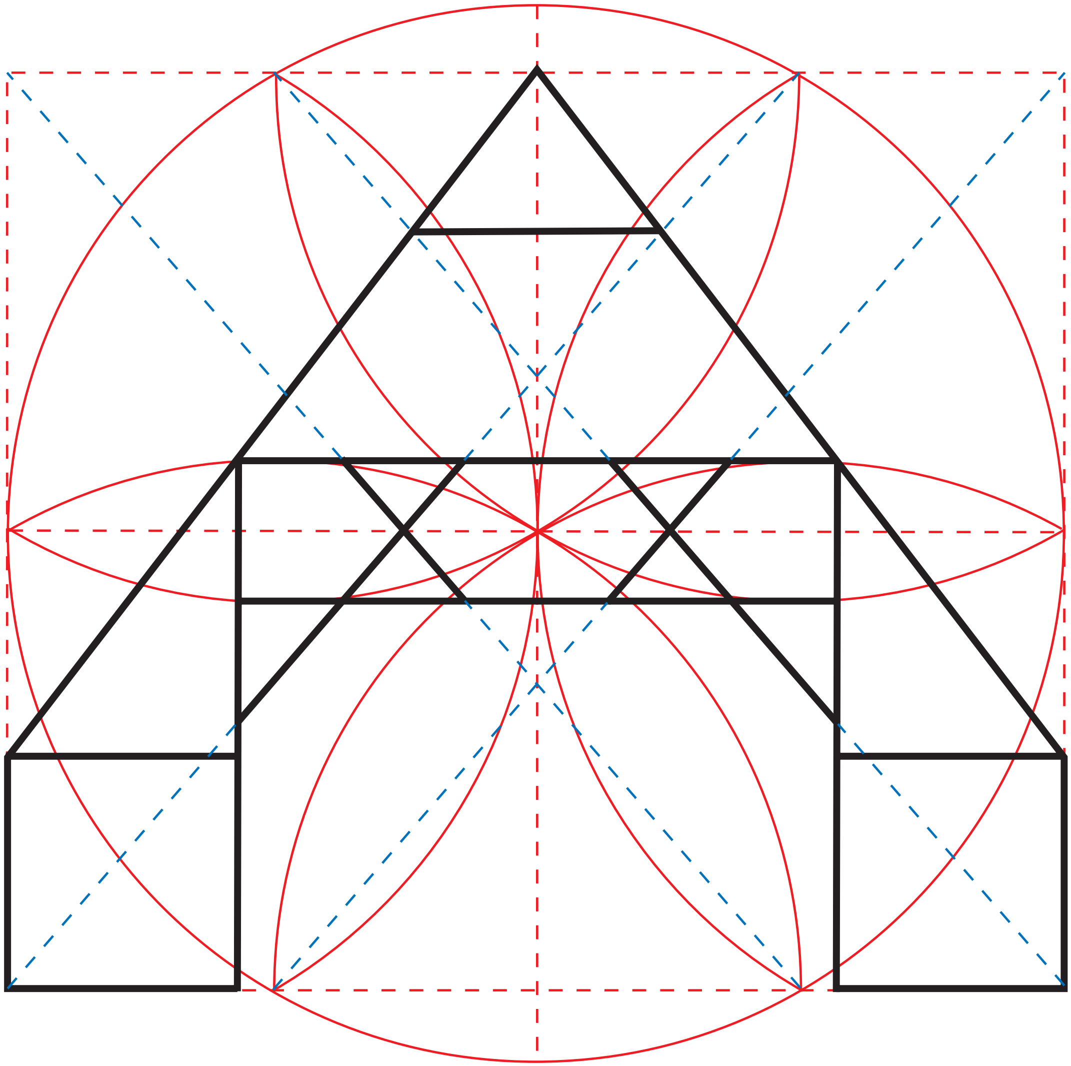


Cressing Temple in Essex takes its name from the monastic site established there in 1136 by the Knights Templar, an order of armed monks who protected the pilgrim routes to the Holy Land. The Templars were also expert agriculturalists and they erected two huge barns at Cressing to store their harvest. The barns are known today as the Barley Barn and Wheat Barn though these are relatively modern names. The barns are approximately 50 feet wide, 50 feet high and 150 feet long.

The floor plan of the barns is a development of the geometry of the Ely nave but here the focus is on the great oak trusses of the Barley Barn, which was constructed in 1220 to a design derived from a single daisy wheel. All six of the daisy wheel's petal tips are connected to form a horizontal rectangle and this rectangle determines the width of the truss at ground level and also establishes the height from ground level to ridge.

Defining the high pitch of the roof is simple. Two long lines can be drawn between the lower corners of the horizontal rectangle to its top centre to form an equilateral triangle. The triangle is intersected by two smaller lines drawn between the lower left and right daisy wheel petals and the intersections mark the top level of the barn's low outer walls. Where the wall top level meets the main rectangle it defines the level of the eaves and this point is connected to the roof's apex to give the roof pitch.

In the larger diagram, opposite, further diagonal alignments are drawn between the upper and lower petal tips and the main rectangle's corners and horizontal alignments drawn as tangents to the horizontal petals. From these alignments the full structure of the truss can be constructed as shown in heavy black line. Distinctive features of the trusses either side of the barn's midstrey are the double tie beams and the unusual X braces that cross between them.



THE DOUBLE SQUARE 1

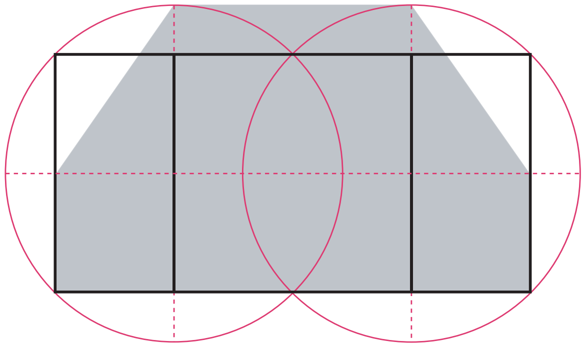
Abernodwydd was built near Llangadfan in Montgomeryshire in about 1678 but was re-constructed at the National Folk Museum of Wales at Saint Fagans in Cardiff. The house is timber framed and is double square on plan, designed to a geometrical module of two squares and their intimately related circles.

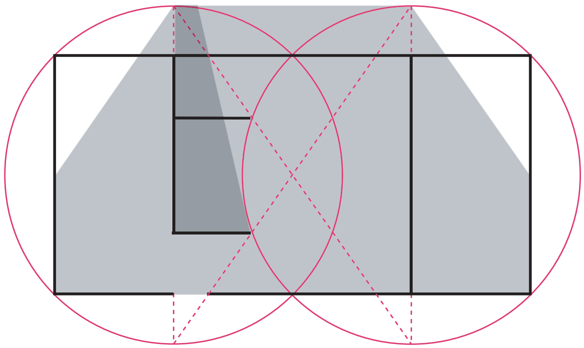
The floor plan's external boundary is defined by the two squares. The squares themselves are divided in half and the two centre halves combined so that the central room is a full square with half square rooms to either side. This gives the traditional three unit plan of the region. The walls between the rooms fall exactly on the diameters of the circles which, in the elevation, rise up to give the ridge level of the frame. The hipped ends to the roof are defined between the ends of the floor's centre line and the apex of each circle.

Diagonals drawn *on plan* between the two circles' diameters cut their left overlap to mark the two walls of the timber frame fireplace. The same geometry *in elevation* defines the side view of the timber frame chimney, in darker tone, as it rises through the house from lintel to ridge. The roof thatch is not part of the geometry.

The geometry can be seen either as a plan, if the double square is visualised from above, or as an elevation rising from ground level if the drawing is imagined from the side.

Abernodwydd, like all Welsh house and place names, has a meaning. Aber = an estuary or confluence of rivers and nodwydd = a needle. The house stood close to a narrow mountain stream that gleamed like the polished steel of a needle as it raced past on its downward journey.





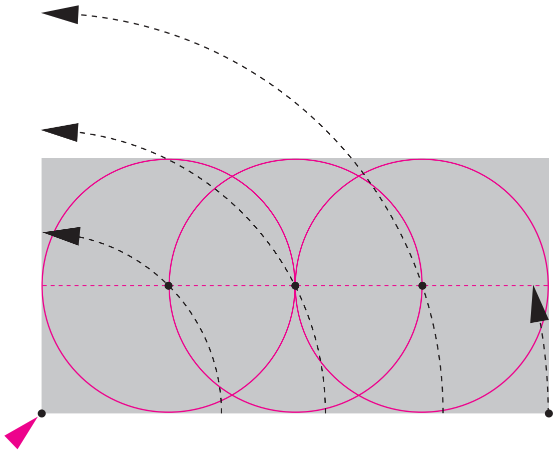
THE DOUBLE SQUARE 2

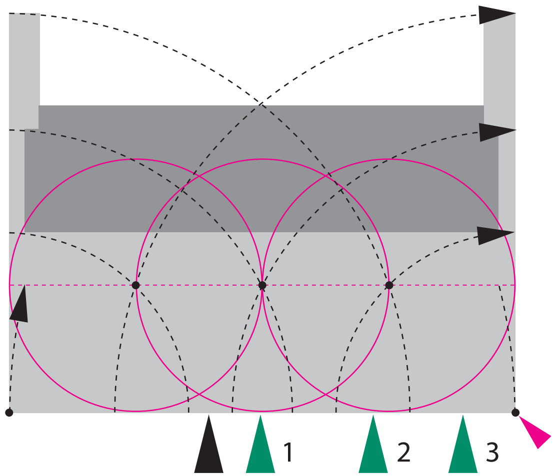
Dolbelydr (radiant meadow) was built in about 1578 beside the River Elwy near Denbigh in north Wales by Henry Salesbury, who wrote Grammatica Britannica, the first Welsh language grammar. A two storied first floor hall house distinguished by tall chimneys, Dolbelydr was acquired as a ruin by the Landmark Trust and painstakingly restored. .

Dolbelydr's floor plan is a double square, like Abernodwydd's, but the design flows from a different module: a three circle sequence drawn along a centre line. Lines boxing the circles give the double square plan.

The facade is drawn from the floor plan with three, quarter-circle arcs drawn from the lower left and right corners of the plan through the centres of the three circles. The lowest arcs give the eaves level, the middle arcs mark the transition from roof to chimney, the upper arcs mark the chimney tops and their intersection marks the roof's ridge level. Short arcs rising to the circles' centre line give the thickness of the wall's coping.

There are seven distances between the arcs at ground level: long, medium, short, central, short, medium and long. The short distance indicated by the black arrow is the location and exact width of the door. The central, medium and long distances marked by green arrows 1, 2 and 3 define the different lengths of windows across the facade.



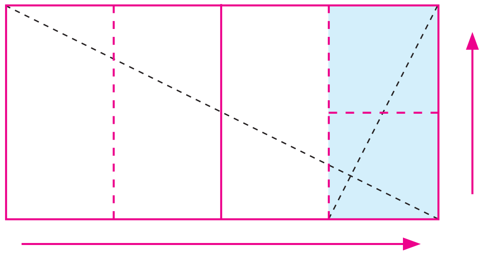


MELBOURNE

The city of Melbourne in Australia is, like Abernodwydd and Dolbelydr, a geometrical design based on a double square. The difference is one of scale because Melbourne's double square is a massive one mile by two. Each square is divided into sixteen blocks by roads that run at right angles to each other with the central axis of Elizabeth Street dividing the two squares. The diagonal of the full double square and the diagonal of half a square define the angles of alignment of many roads beyond the city boundary.

The layout of the double square is known as The Hoddle Grid after Robert Hoddle and Robert Russell, the government surveyors who were instructed to design the town in 1837. Their chosen site, beside a relatively straight section of the Yarra river, allowed them to design to a classic drawing board layout with elegant streets 99 feet in width.

The double square geometry follows the rules of all geometrical constructions in that changes in scale cause changes in direction. If the double square is halved into two squares and halved again into four half squares, the half squares themselves are, in fact, also small double squares. The original large double square is horizontal but the four small double squares are vertical, so that the subdivision and change in scale rotates the constructions through 90°.



In Melbourne's reality on the ground it is the diagonals of the large and small double squares that point at the four cardinal directions, north, east, south and west, with the city's parallel street grid determined entirely by the double square's slanting boundaries.

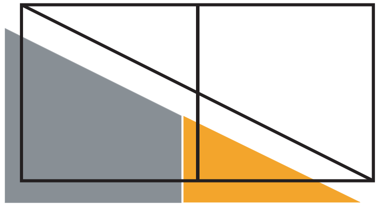

N
W
E
S
LATROBE STREET
LONSDALE STREET
BOURKE STREET
COLLINS STREET
FLINDERS STREET
SPENCER STREET
KING STREET
WILLIAM STREET
QUEEN STREET
SWANSTON STREET
RUSSELL STREET
EXHIBITION STREET
SPRING STREET
City Circle
Flinders Street Station
Spencer Street Station
FLAGSTAFF GARDENS
CARLTON GARDENS
TREASURY GARDENS
QUEEN VICTORIA GARDENS
ALEXANDRA GARDENS
Yarra
River
Queen Victoria Market
Melbourne Central
City Square
Chinatown
Greek Precinct

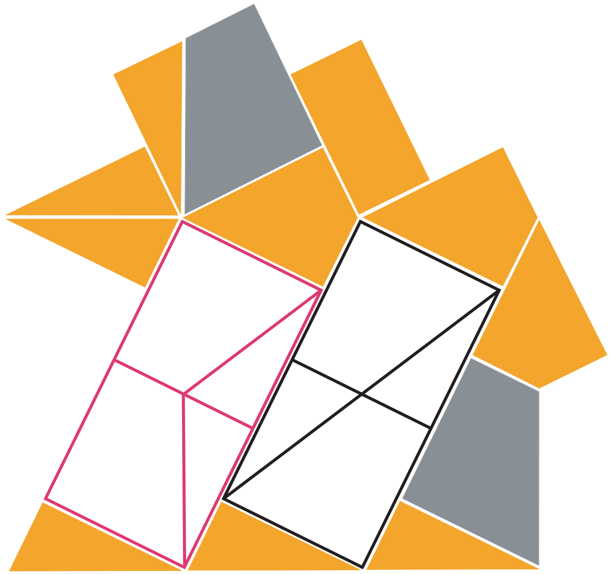
FEDERATION SQUARE 1

Federation Square stands on the south bank of the Yarra River, opposite Melbourne's double square city centre, on a platform spanning the suburban rail lines into Flinders Street station. The design of Federation Square is determined by the same double square as the city street plan but it is multiplied and re-assembled into some unexpected configurations. The outline of the pattern is expressed in steel and the infill in a variety of materials such as natural stone, glass and steel. Sections of the buildings are double skinned for sound and temperature insulation. The photograph looks from an interior through a double skin of glass, across an open sunlit court and onto the stone, steel and glass clad surface of the neighbouring-ing building's exterior.

The top drawing shows the basic double square and how its diagonal cuts the dividing line between the two squares to give two new shapes. The yellow and grey shapes together form a square. The two shapes can be multipled by mirror imaging, combining and/or rotation. The double square and its diagonal generate a series of harmonically inter-related modulor shapes that can be combined in ever changing areas of pattern.

By placing the yellow shapes at ground level the axis of the pattern is shifted out of vertical into a new, visually stimulating angle.





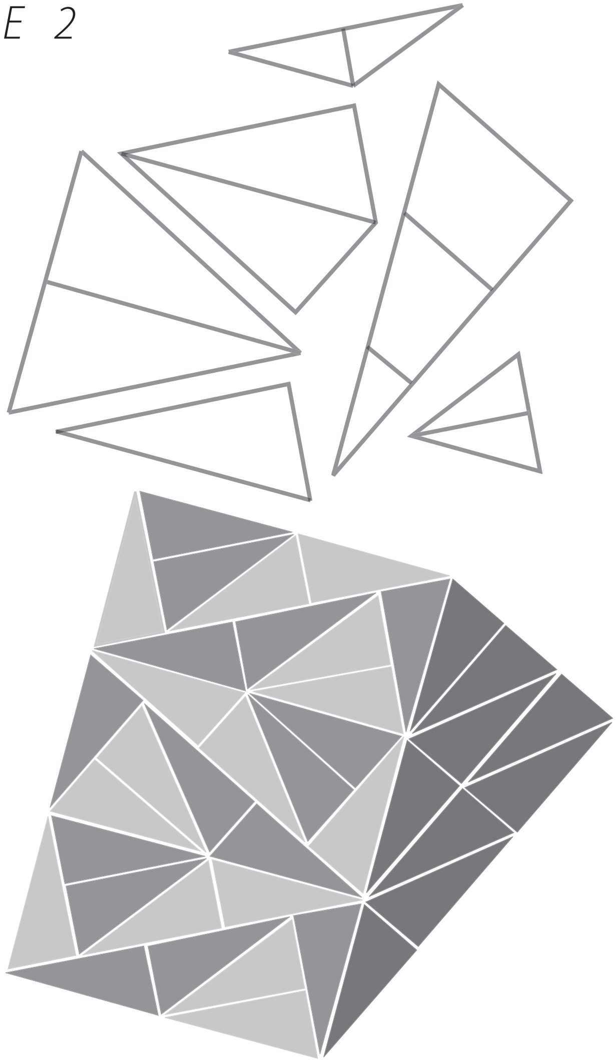
In the photograph two double squares rise from ground level and tilt to the right, as in the drawing above, the right hand one showing the division between the two squares and the full double square diagonal.

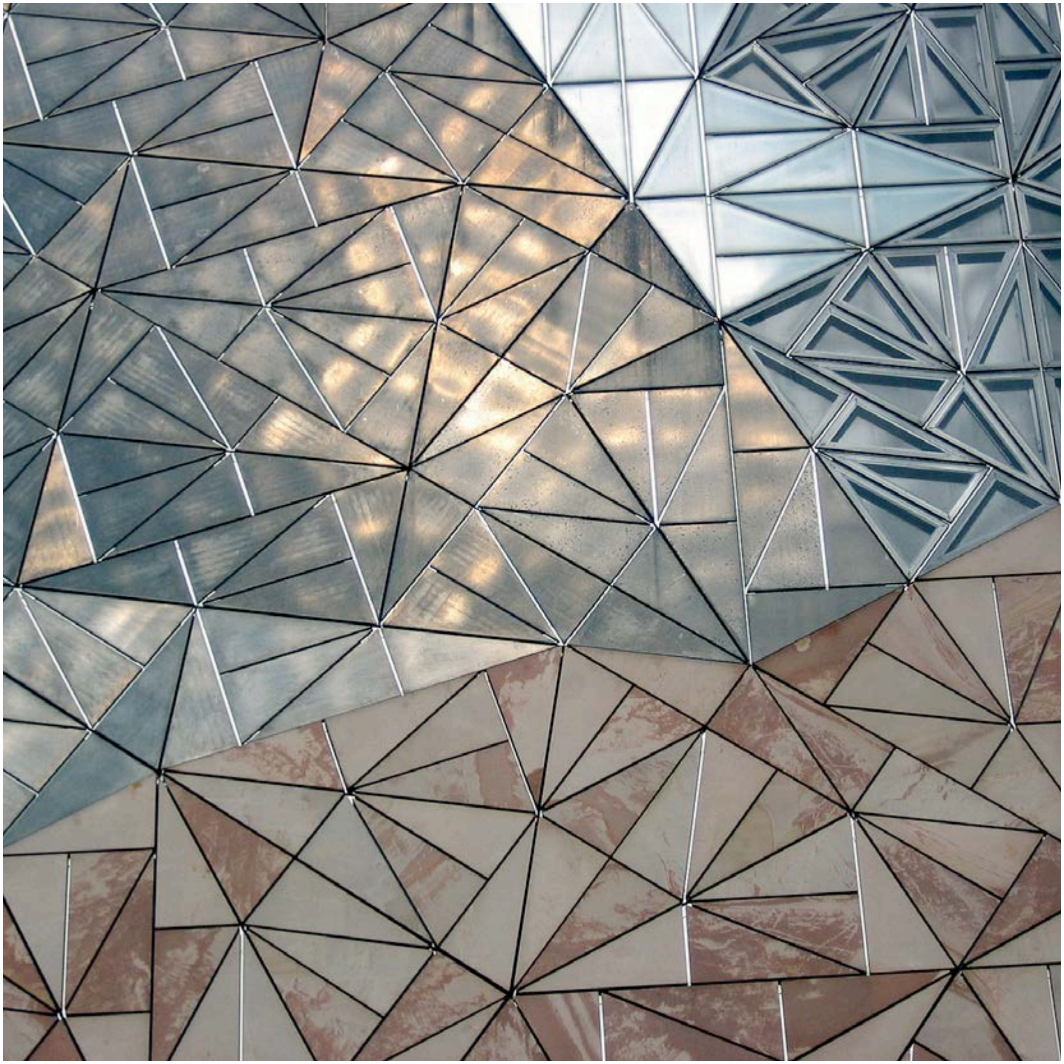
FEDERATION SQUARE 2

The buildings of Federation Square exhibit an extraordinary range of surface pattern. In the example on this page, which shows an area of exterior cladding, only the smaller triangular shape derived from the double square and its diagonals is used to form a continuous surface. The triangles are combined in many relationships: most simply as single triangles or pairs in mirror image but also as groups of eight in the form of a kite or in fours as half kites. A larger half kite group is composed of nine triangles. Many other groupings can be found if searched for so that a kite plus two further small triangles becomes a large triangle, and so on.

All of the configurations can be combined by further mirror imaging, revolving into new alignments or by combination when facing opposite directions so that two triangles can combine to form either a rectangle or a rhomboid. Also, because the triangles are right angled, it is possible to construct parallel alignments. The permutations are endless.

Visually the surface configurations appear disconcerting for while they are clearly carefully ordered they are simultaneously chaotic in that the observer's eye is led in a dazzling range of directions. While Federation Square challenges many of our deepest feelings about what architecture is, it is dancing to the beat of a powerful geometrical rhythm.



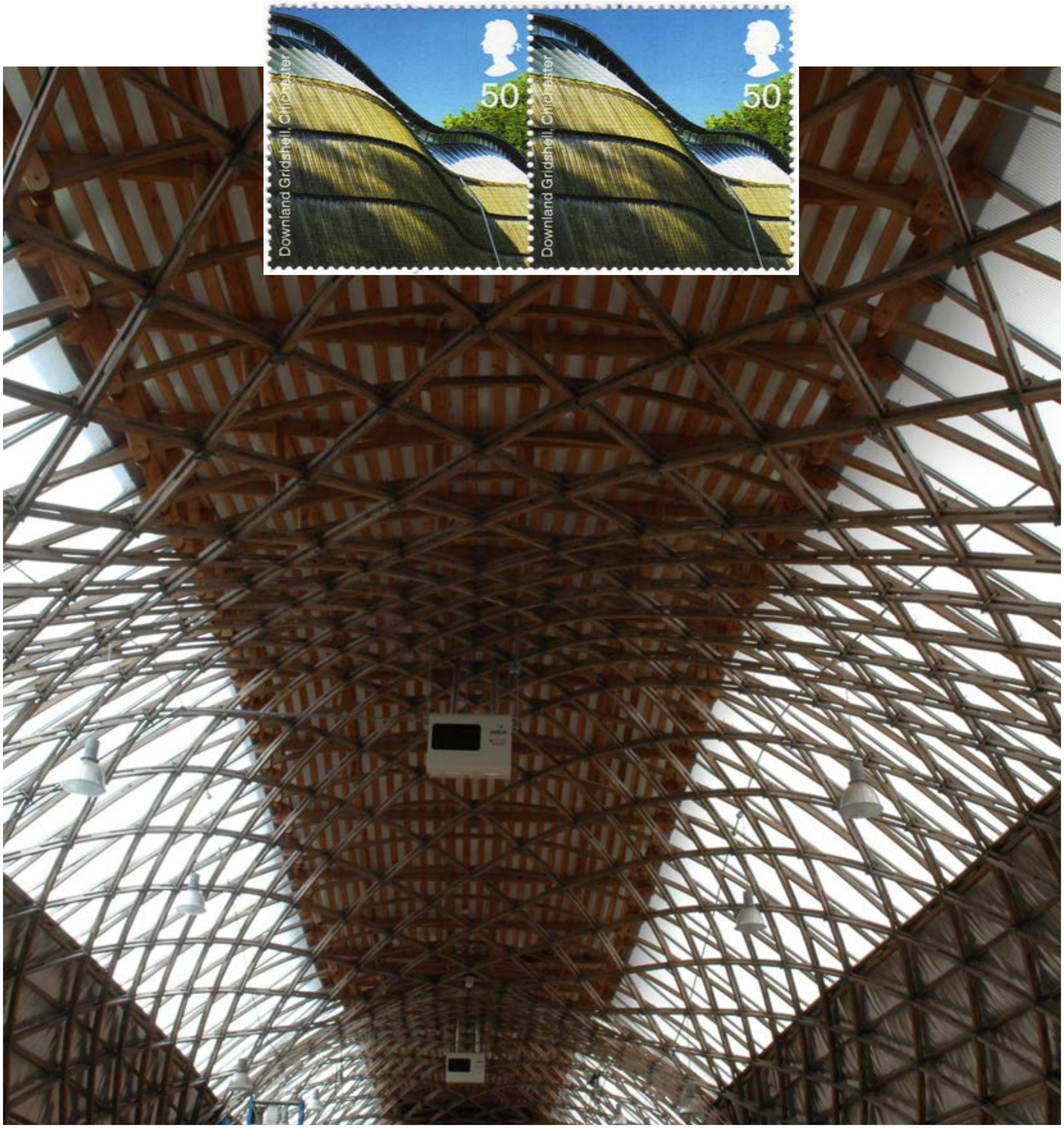


THE WEALD & DOWNLAND GRIDSHELL

The Weald and Downland Open Air Museum is a major centre for the conservation of historic buildings. It has a superb range of historic timber framed buildings, an enormous collection of early tools and artefacts and runs a comprehensive building conservation programme. A new timber framed building, using a grid network of slender timbers, was recently erected to house these activities. The gridshell is unlike traditional timber framed buildings in almost every way other than the use of oak as the structural material.

First, oak laths were spliced together into lengths that would span the whole building diagonally and then they were laid out horizontally so that they could be overlapped and held together at each intersection or node, using a purpose designed, three tiered metal clamp. The assembled mesh was then placed on a forest of vertical jacks and these were slowly lowered around the outside to allow the mesh to fall towards the ground. Gradually the controlled fall produced the curvature of the grid shell's cross section which, in turn, generated an undulating rhythm along the building's length. Glazing, insulation and weatherboarding complete the building's exterior.

It is interesting that a flat grid of diamonds can be reformed into a building that has the multiple curvature shown on a commemorative square 50P postage stamp. This is because the timber sections are small and therefore retain flexibility, a property that is lost when the timber's section increases. The difference is easy to see when a tree reacts to a strong wind for, while the mass of the trunk remains rigid, branches give under the wind's pressure and twigs dance freely in the flow of air. The lessons are there in the tree's behaviour. The Gridshell is like a giant wicker basket, its strength derived from the weaving together of many individually weak components, turned upside down and covered by a protective, waterproof skin.


Downland Gridshell, Chichester
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Downland Gridshell, Chichester
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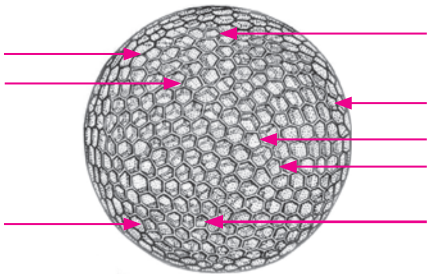
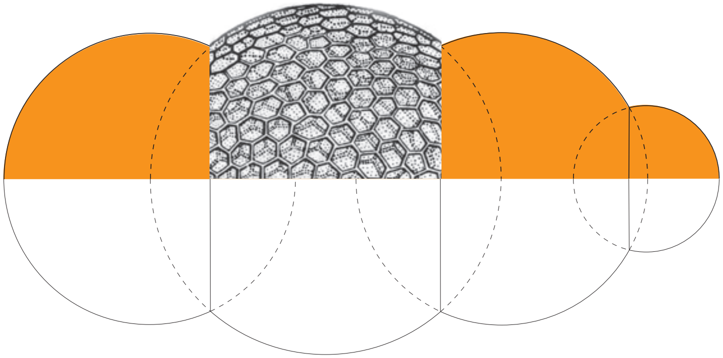
THE EDEN BIOMES 1

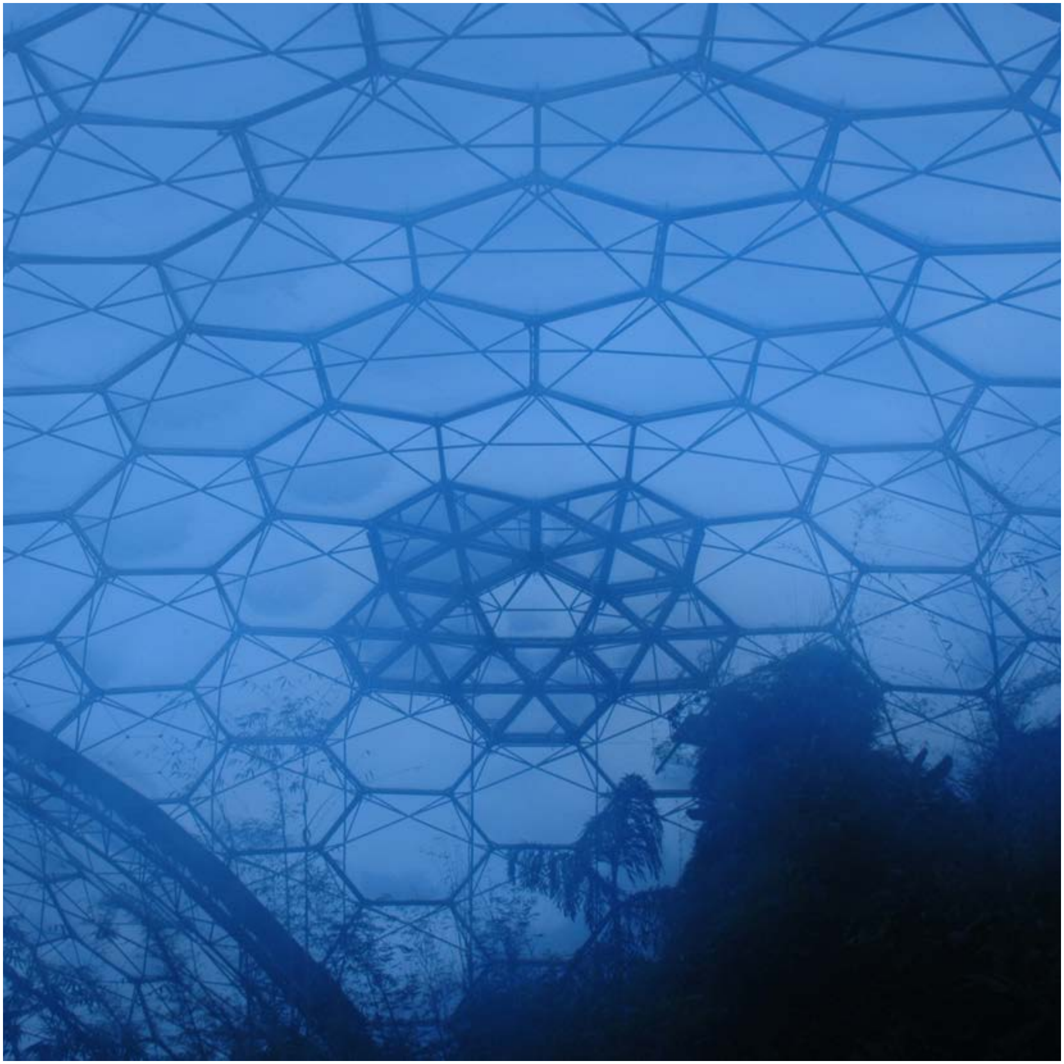




The Eden biomes encompass several aspects of geometry. Fundamentally, the biomes are hemispherical in form but, like the geometry of soap bubbles, they intersect along flat planes into a continuous ballooning form, though the flat planes are, in reality, great arched spaces between one section of a biome and the next. Each biome's foundations follow the surface of the land so that some parts of a biome are on level ground while other parts climb the cliffs around the boundaries of the Bodelva claypit.

The biome bubbles are formed from an interlocking grid of hexagons. However, although hexagons can interlock continuously across a flat plane it is physically impossible for them to form a continuous three dimensional surface such as a sphere or hemisphere. Nature understands this truth and in the case of certain microscopic forms such as Aulonia Hexagona, its skeletal grid comprises a mesh of hexagons interspersed with pentagons. In the drawing some pentagons are indicated by arrows. The pentagons allow the hexagons to establish the curvature necessary to form a dome. If the sphere of Aulonia is halved along its diameter and cut off at the ends it resembles the exterior form of a biome. The drawing shows the geometrical profile of the Humid Tropics Biome with its main dome constructed from Aulonia.

The Eden biomes also feature pentagons within their hexagon grids. The photograph, taken in the Humid Tropics Biome through a steamed up lens, shows a single pentagon at the centre of five hexagons that are in turn subdivided into six equilateral triangles which can be opened to regulate the temperature and humidity within the biome. The hexagon grids of the biomes are infilled with a triple translucent ethyltetrafluoroethylene skin (EFTE) that contains and protects their plant life supporting atmosphere.

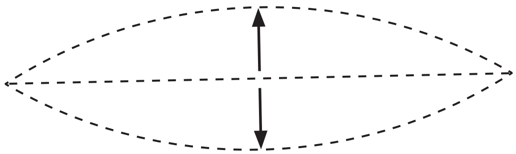


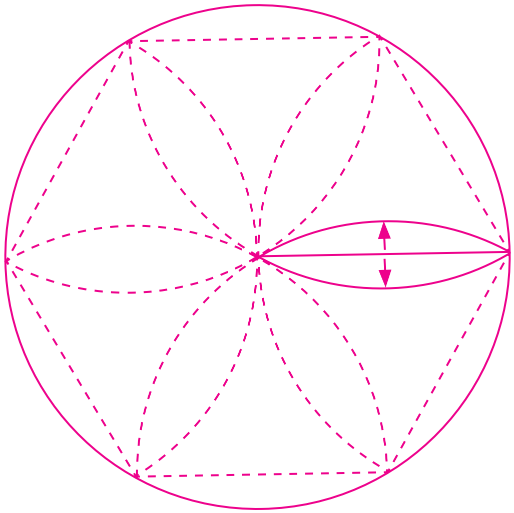
THE EDEN BIOMES 2

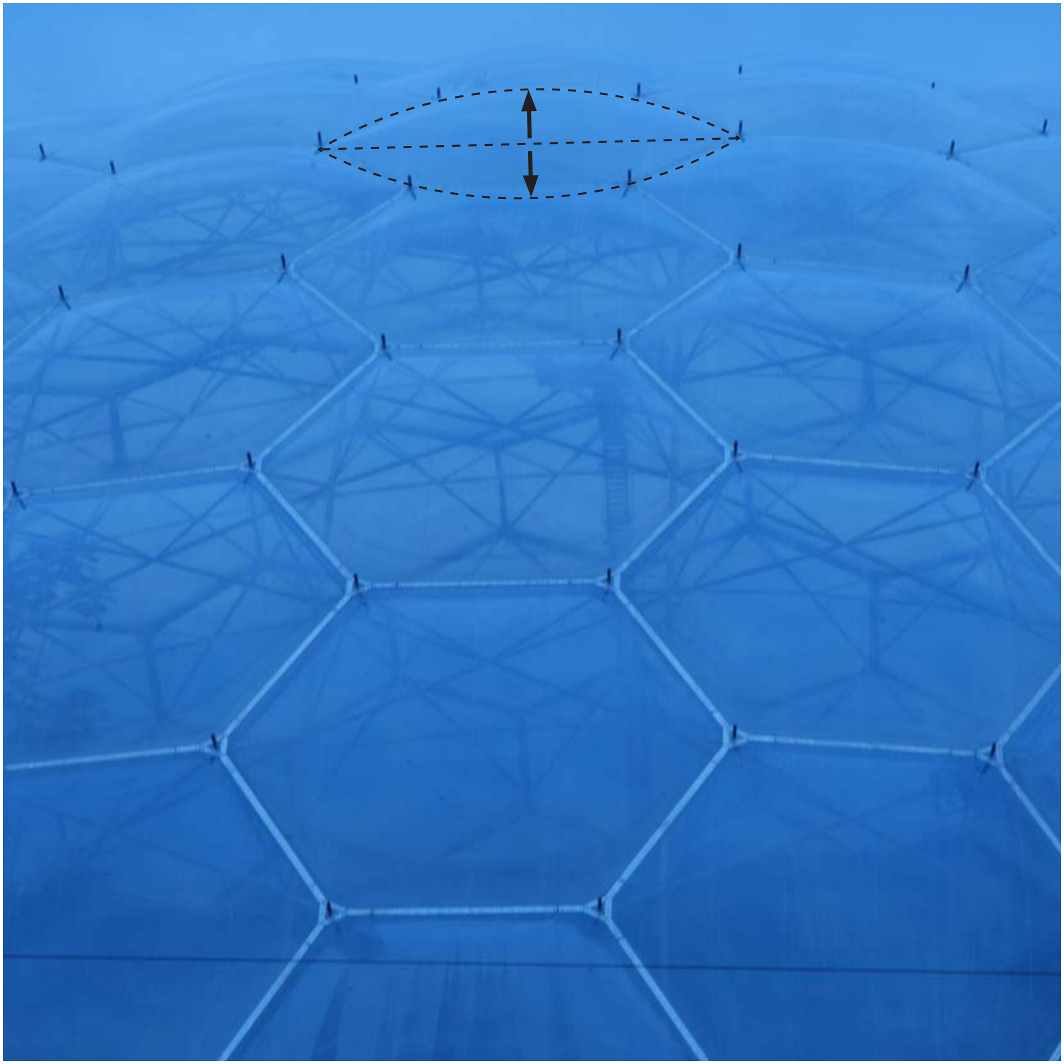
The main external hexagons of the biomes are filled with stretched translucent glazing pillows made from ethyltetrafluoroethylene. Assembled in three layers and with the space between the layers inflated into its distinctive curved form, each pillow spans the massive 33 feet diameter of its supporting hexagon.

The convex outward curve of the upper layer, which can be seen clearly in the photograph, is mirrored on the inside of the biome by a convex inward curve. The EFTE skin is curved because its elasticity allows it to stretch most at the centre of the hexagon, the furthest distance from where it is held firm at the hexagon's rim. Because the pressure in the outer and inner layers of the pillow is equal, the central dividing layer of the pillow remains flat, stretched like a drum skin between the sides of the hexagon.

It is interesting that the daisy wheel, which gives the geometry of the hexagon at its six petal tips also gives curvatures that are like those of the glazing pillow's outward and inward faces and also, if a daisy wheel petal is bisected along its length, the glazing pillow's flat central layer. The forces within the inflated pillows clearly conform to the same forces in nature that cause the snow flake and some six petalled flowers to follow the daisy wheel's geometrical instructions.







THE EDEN BIOMES 3

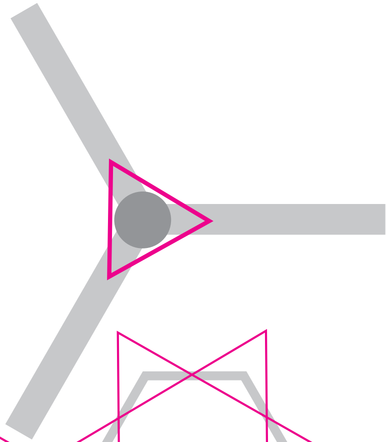
The biome's exterior grid of hexagons is supported inside the biome by a second, lower, finer grid of hexagons that are extended into six point stars (by an equilateral triangle on each face of the hexagon). The upper, outer grid is shown in grey tone and the lower grid in thin magenta line.

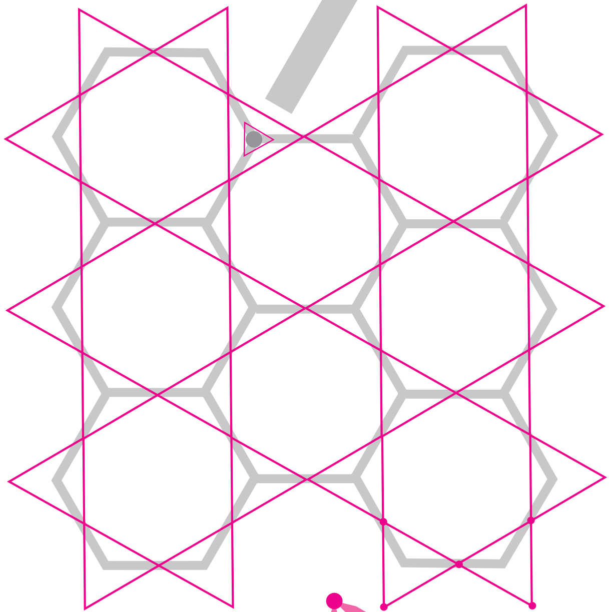
In the drawing it can be seen that each equilateral triangle of the magenta lower grid surrounds the point where three grey hexagons meet in the grey upper grid. The magenta equilateral triangles also cross the grey hexagons exactly half way along their sides. So, although there is space between the two grids, they are geometrically related.

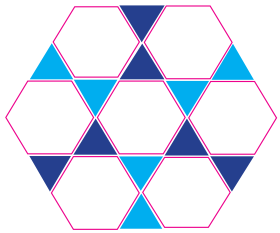
The points where the lines of each grid meet are called nodes. The thick tubular rods of the outer hexagon grid meet at nodes that connect three tubes. Seen from within the biome the nodes are spheres but from the outside appear as small equilateral triangles. The thin tubes of the inner hexagon star grid are also connected in threes by small spherical nodes. The two grids are linked by further thin tubes that run between their nodes.

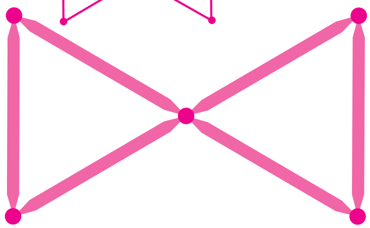
The star hexagons and mirrored equilateral triangles of the lower grid form a continuous pattern that can be found in the ceramic tiling of Islamic architecture.

The single biome hexagon opposite frames the distinctive roof of Eden's Core Building.









THE EDEN CORE 1

The force that drives the design of Eden's Core Building is *the force that drives the green fuse* in Dylan Thomas' poem and the same force that drives the natural growth and form of the pine cone.

The surface of the cone is divided into a series of diagonally placed scales that remain closed while the seeds are maturing but which open like trapdoors when they are ripe and ready for dispersal. Each trapdoor conceals a seed. The diagonal alignments of the scales are based on opposing spirals, one set corkscrewing to the left and the other set crossing them to the right.

The crossing spirals are the visual inspiration for the Core Building's roof, constructed from Glulam beams to the precise curvatures of the spirals and, at the core of the Core, like a massive seed in an swollen pod, rests a monumental granite sculpture based on the structure of a pine cone, still as a Buddha. The photograph shows one of the sculptor's precision explorations of this idea, where small hemispheres follow the ascending tracks of spirals to both left and right, growing larger as the cone expands from its base and smaller as it contracts towards its apex. Within the world of architectural ideas it is a possibility that on a large scale this sculpture could easily represent the exterior form of a massive new vertical biome at Eden but meantime it functions as the kernel around which the Core Building unfurls like a flower, solid as a rock yet simultaneously an organic blueprint of geometrical growth.

It is impossible to think of the Eden Core as it now is without casting the mind back to how it once was. The new Core stands in the massive space excavated from the once solid land of the old core, dug away to win china clay. There are parallels. Where the original core exported clay to the factories of Stoke on Trent and from there, as tableware, to the whole world, the new core exports a vision of how valuable our resources are, how we need to understand them and care for them. Where the old core was exhausted and abandoned, the new core is a powerful magnet, attracting visitors from all parts of the world to its visionary presentations. The new core emulates nature's ability to renew itself, a new growth rising from derelict waste land. It has the vitality of new ideas and the energy of a new vision, both of which are the seeds of a viable future. There is a massive lesson here, that even an empty space can be recycled and the key is a change in perception. If the focus is on extracting clay it is easy to presume that the job is over when it has gone yet the metamorphosis of the clay, through fire, into products is a clue to the metamorphosis of the space it came from.

THE EDEN CORE 2

The Core building's roof structure follows the principle of the sunflower seed head and pine cone in that two spirals run in opposite directions to each other to form a grid. With the sunflower and pine cone, the grid forms the locations for individual seeds within the overall matrix of the grid whereas, with the Core grid, the purpose is twofold, first to allow the opposing spirals to interlock with each other for strength and, second, for selected elements within the grid to punctuate the roof as light sources. The visual impact of this structure is striking because there is no precedent for it. We are accustomed to angular and linear buildings and are familiar with square or rectangular domestic spaces with horizontal ceilings or, on a greater scale, the vistas within cathedrals that carry the eye from west to east, from sunset towards sunrise. The vista in cathedral naves is linear, running away from the eye in a straight line between parallel lines of arcading. So the Core roof is a novel and stimulating surprise, carrying the eye in multiple directions along the expanding or contracting curvatures of numerous logarithmic spirals.

Like the volutes of Greek column capitals and the hand drawn logarithmic spirals constructed within golden rectangles, the Core roof's spirals have to solve a major problem, that they become so small that either drawing them or constructing them becomes impossible. In a classical Greek capital's volute the problem is solved by the spiral terminating at a small blank circle at the volute's centre. Known as the eye of the spiral, the little circle represents the sector of the spiral that it is impossible to draw with precision due to its diminutive scale. The Core roof solves the problem by having an open, circular area at the roof's centre so that the spirals terminate around its circumference. Within this open space stands the great granite sculpture with its external spirals, like a massive seed within its protective case.

The open space is defined, within the Core building, by a circle of windows. Tinted blue, they appear almost as if the space beyond is a huge aquarium and closer inspection reveals the ripples, spirals, undulations and eddies found in moving water. The images were photographed on large sheets of film submerged beneath the sea in the darkness of night and exposed by flashlight. The resulting negatives were used to etch the windows so that these secret portraits of tidal life, captured within the translucent medium of moving ocean water could eventually be seen within the equally translucent medium of glass, the tide's movement made still.

MOBILE HOMES

Nature solved the question of mobile homes long before humanity invented the wheel. Some of these homes are constructed and some are grown. Looking into the bed of a clear stream it is possible to see caddis fly larvae habitations: small cylinders built from tiny shards of split pebble or rock held together by strands of silk produced by the caddis fly's salivary glands. In a unique collaboration between humans and caddis flies, artists holding captive fly larvae have supplied them with unusual or precious materials such as gold, silver, platinum and broken coloured glass beads to use in the construction of their habitations. When the larvae metamorphose and emerge as flies their obsolete cylinders can be used by jewellers as components in necklaces, ear-rings or other pieces of jewellery.

The hermit crab saves itself the trouble of building a bespoke home by squatting in a home jettisoned by another crab of greater size than itself, living in the new abode while it slowly grows bigger. Eventually the existing shell becomes too tight for comfort and the search begins for another, bigger shell. If under threat the hermit retreats into the shell with just its pincer at the door to ward of unwelcome visitors.

The real mobile homes are those where the shell is integral to the living creature that lives within it. The Roman snail, named after the Romans who brought it with them when they invaded Britain, is a perfect mobile home-owner. The living snail and its shell grow in unison so that, as the snail grows longer and thicker, the shell expands and extends to provide the extra space needed for protection. This could be attained as a linear structure, like an expanding cone, but would be easier to damage than a spiral growth pattern where the external form is more compact and similar to a sphere which, having the minimum surface for the volume contained, requires less construction and is intrinsically stronger. The snail attains the perfect shell size for itself by constantly building incrementally larger rims to the edge of its shell. These increments can be seen in the photograph as thin lines tracking across the surface curvature of the shell, like the Earth's meridians in miniature.

The Roman snail originated on the east side of the country but, over the centuries, has established mobile home parks more or less everywhere. In the wetter, more westerly areas of Cornwall, Devon and Wales the native snail can be found, a third of the Roman snail's size but infinitely more beautiful with shells of plain coral yellow and others hooped, like children's humbugs, in spiral yellow and black bands.

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