Holistic Geometry

We assume wholeness as a starting point. Yet with the limitation of perception, all we can see are parts. We present herein a geometric 'creation story' which demonstrates the connection between the parts and the whole. This, we believe, is the role of geometry. Is there a way to model wholeness and its transformations?

WHOLENESS AND TENSEGRITY

Tensegrity is the balancing of counteracting forces of tension and compression which gives structures their shape, strength and flexibility. It is through the mechanism of tensegrity that wholeness persists in the parts, and it is through the mechanism of tensegrity that wholeness can be restored.

We offer the premise that, from the whole, there are symmetrical divisions. The first of these divisions we call 2-fold symmetry. By inference, we can call the state that precedes the first division 1-fold symmetry. We model 1-fold symmetry with a matrix of 6-pentagonal tensegrity spheres.

DIVISIONS AND TRANSFORMATIONS

We illustrate the transformation from 6-pentagonal tensegrity spheres (1-fold symmetry) to 6-decagonal tensegrity spheres (2-fold symmetry).

We proceed to transform 2-fold symmetry to other symmetries such as 3-fold, 5-fold and others. We find, upon studying subsequent transformations, that 2-fold symmetry remains the substructure of all the other symmetries.

GEOMETRY AND *PHYSICS*

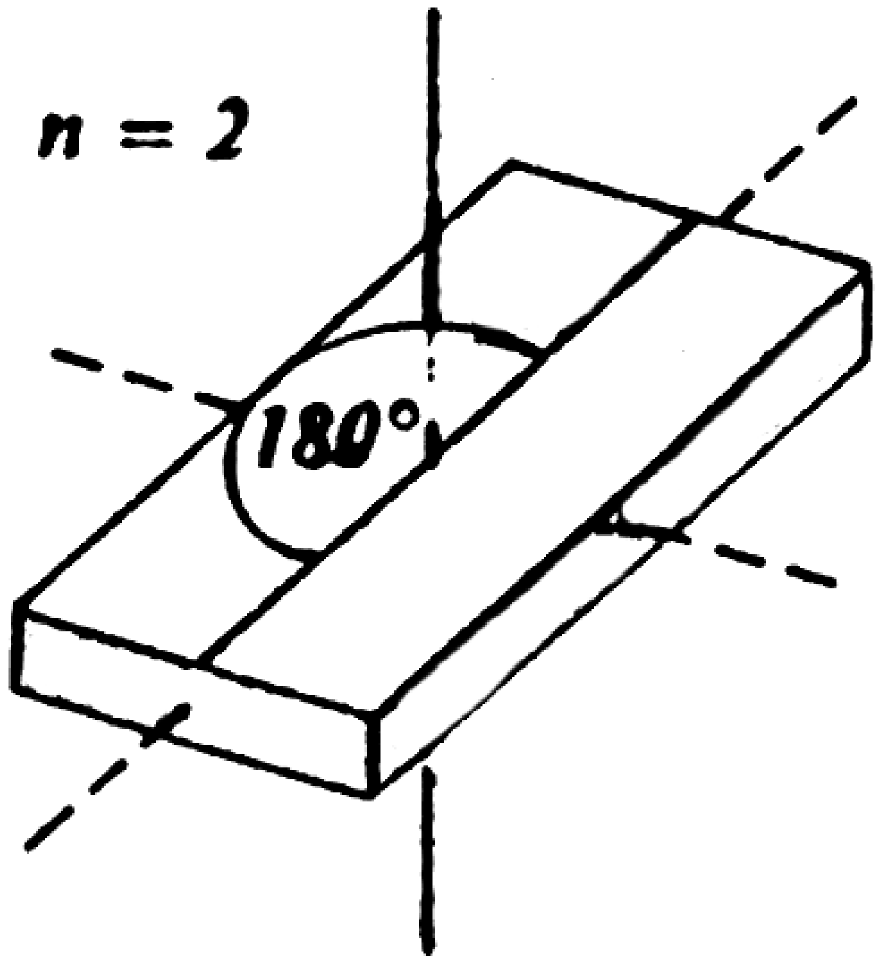
Using geometry as a typological model for physics, we apply its symmetries and their hierarchical generation of polyhedra to the exploration of the origin of electromagnetic waves and their transformations into photons. The transformation of the 6-pentagonal tensegrity spheres (1-fold) to the 6-decagonal tensegrity spheres (2-fold) and its subsequent transformation into tensegrity rhombic triacontahedra is a model of this process.

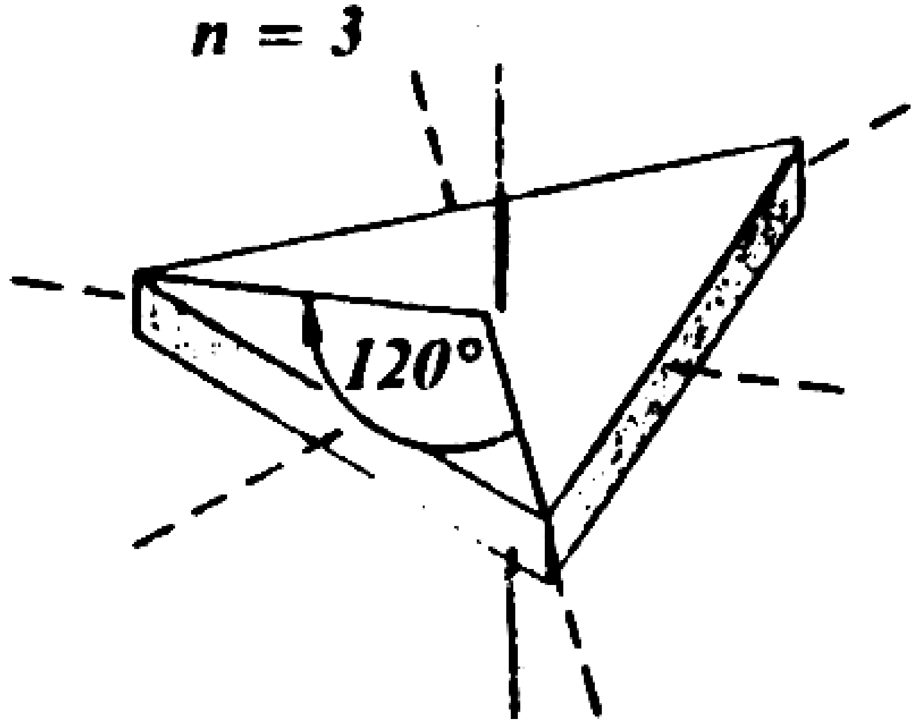
SYMMETRY

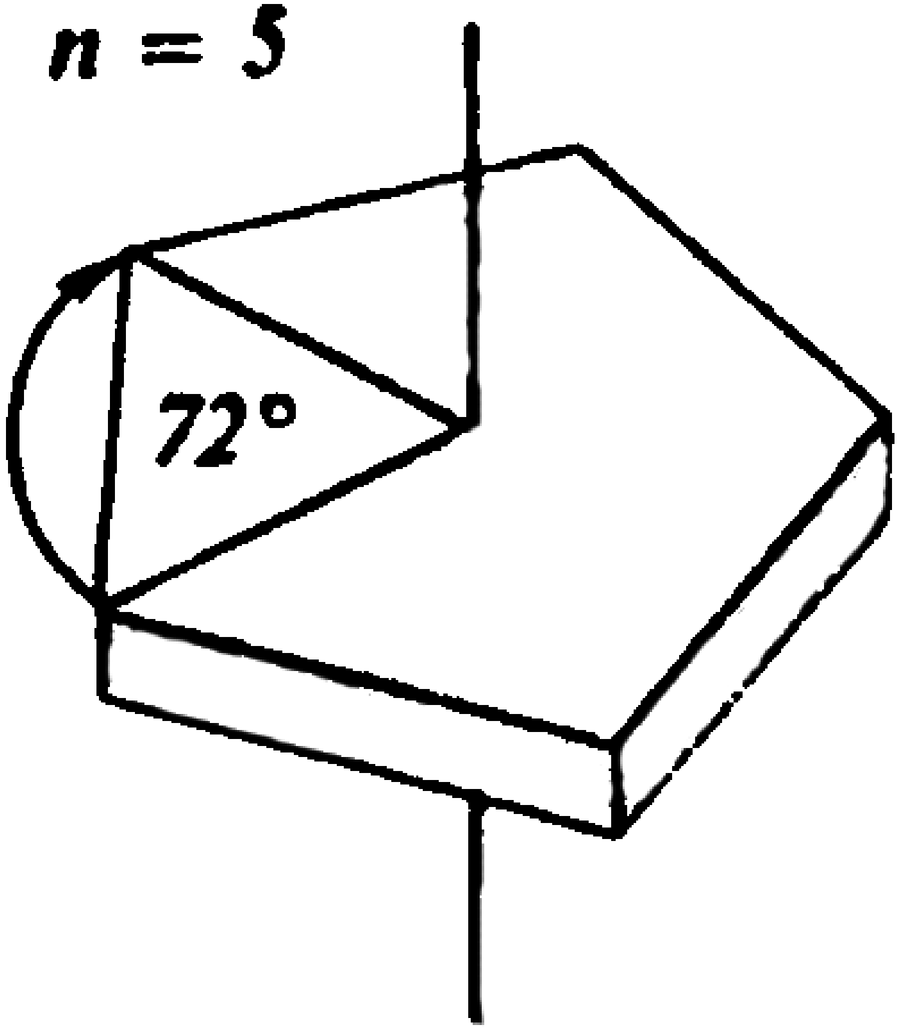
Symmetry is found everywhere; it underlies all natural structures. Symmetry is invariance under transformation. The particular symmetry that we are interested in is rotational symmetry.

ROTATIONAL SYMMETRY

What is rotational symmetry? It is the rotation of an object through 360º, the number of sub-rotations (n) required to return to its original position.



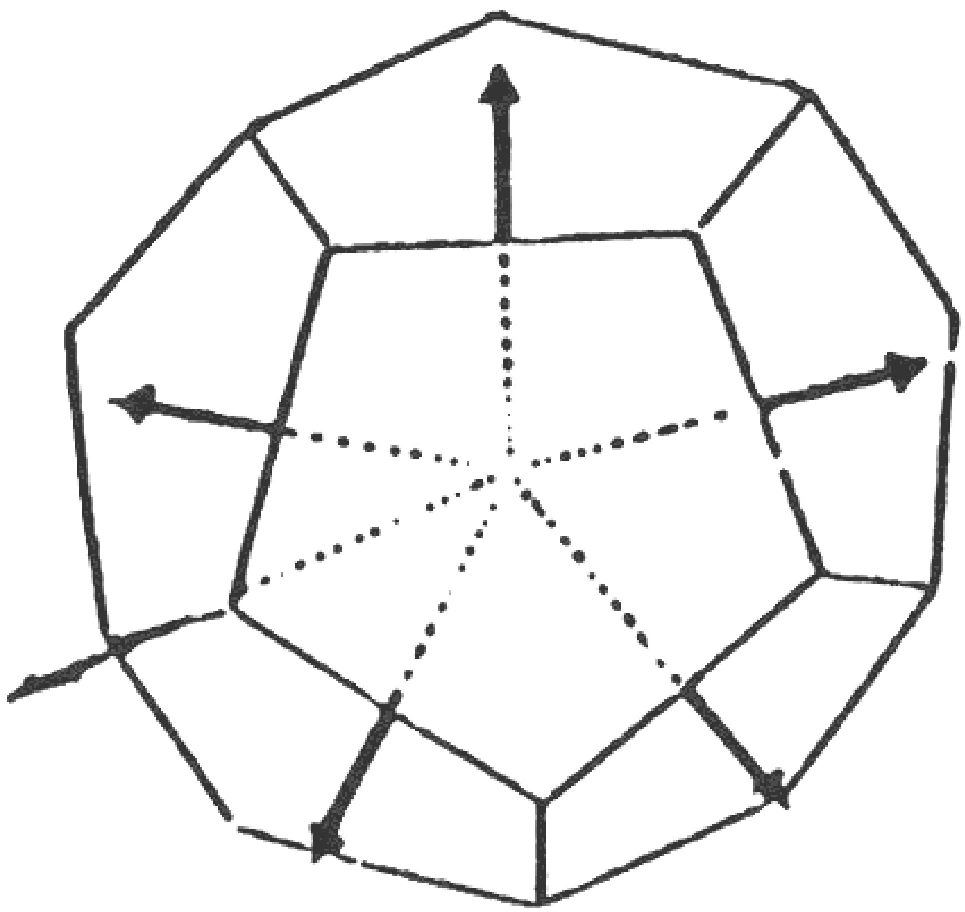

n = 3
120°


n = 5
72°

Rotational Symmetry

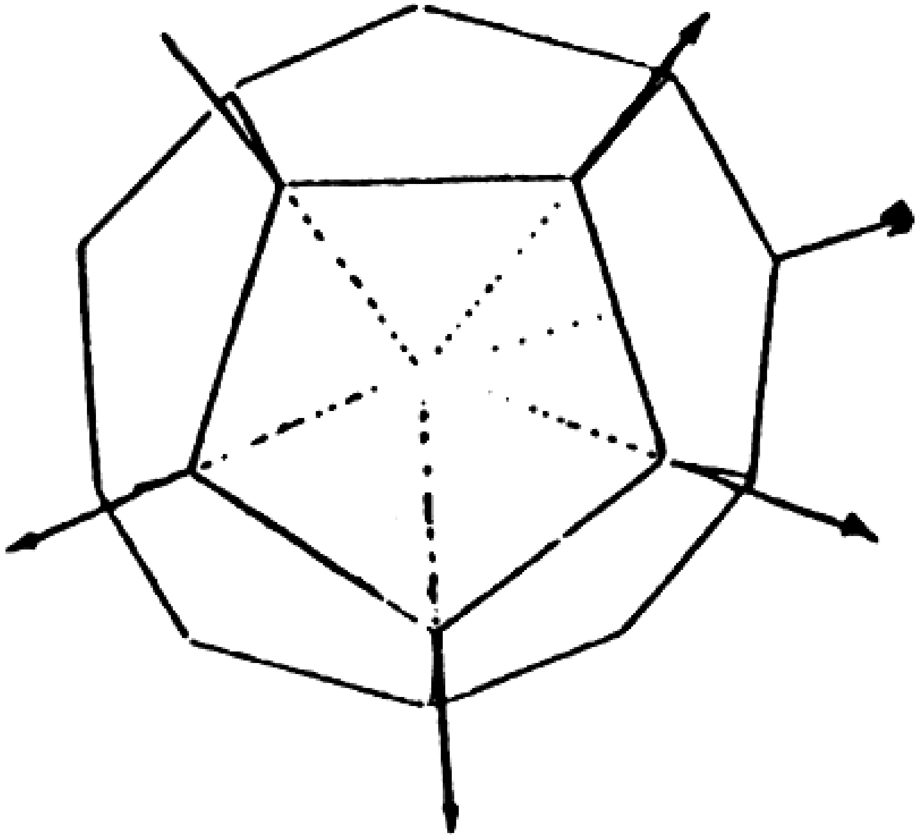
AXES OF SYMMETRY

Rotational symmetry also determines the number and direction of axes. For example, using the dodecahedron as a model (see below), we can examine directions in space. Five-fold symmetry can have only six axes in space, corresponding to the lines going from the center of the dodecahedron to its 12 faces. Three-fold symmetry can have 10 axes, going from the center to the 20 vertices of the dodecahedron. Two-fold symmetry can have 15 axes, going from the center to the midpoint of its 30 edges. The total number of axes is 31.



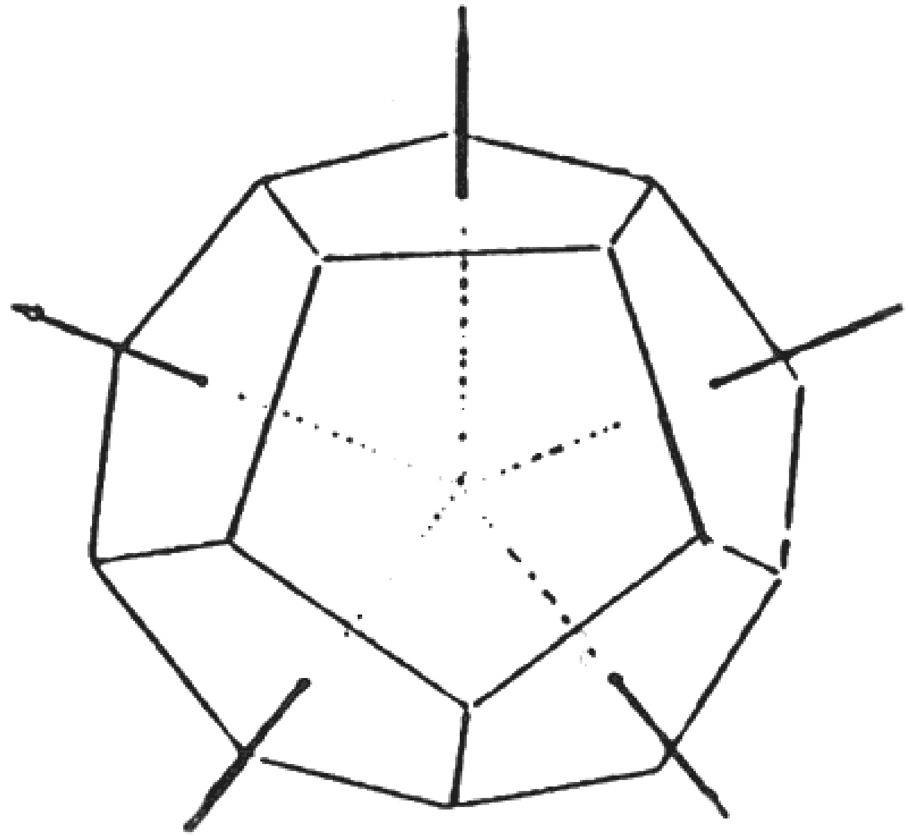
Two-Fold Symmetry

15 axes



Three-Fold Symmetry

10 axes



Five-Fold Symmetry

6 axes

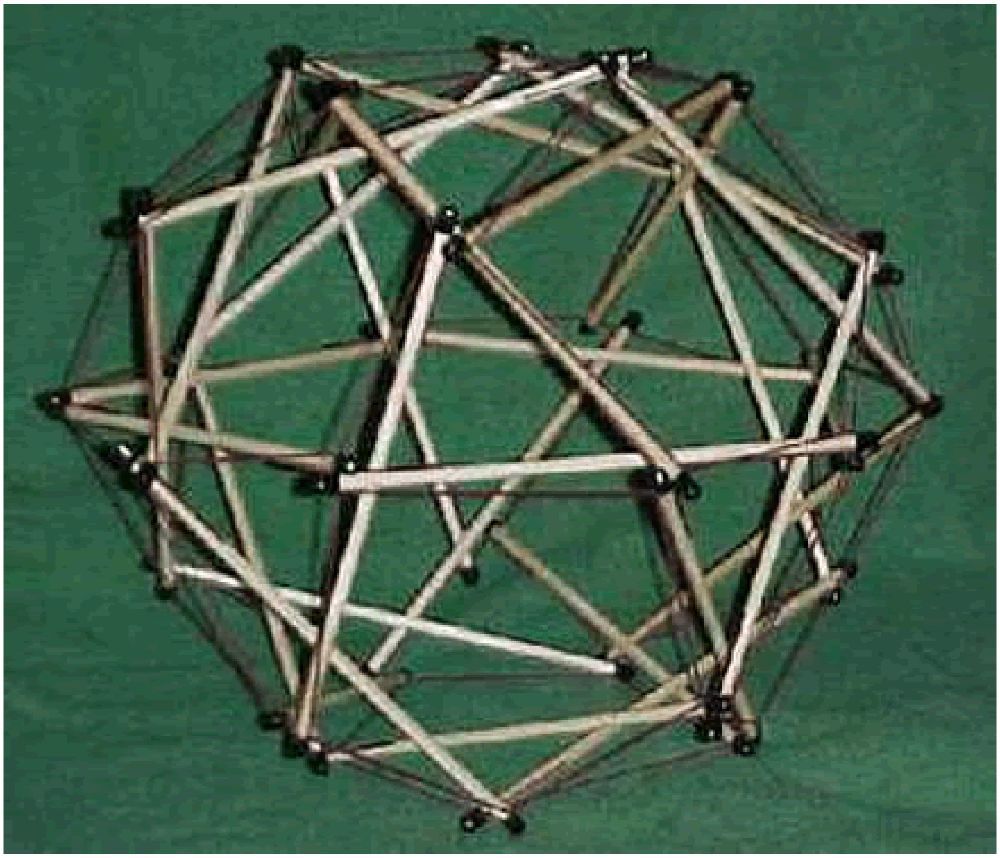
ONE-FOLD SYMMETRY

Can we speculate that there is a more basic symmetry than 2-fold symmetry? Is there a symmetry characterized by 'oneness' rather than 'twoness'? Hypothetically, if there were '1-fold symmetry', the number of axes times the symmetry number should equal 30. For example, in 5-fold symmetry, 5 x 6 = 30; in 3-fold symmetry, 3 x 10 = 30; in 2-fold symmetry, 2 x 15 = 30. Therefore, 1-fold symmetry should have 30 axes.

If we hypothesize 30 axes in 1-fold symmetry, we must postulate the existence of a structure which is made of 30 non-parallel struts. If 2-fold symmetry has an axial rotation of 180º, then 1-fold symmetry must have a longitudinal oscillation of 360º for each strut.

Fuller, in describing the dynamics of the atom, describes such a shape. (Synergetics 1, 726.01).
He calls it the 6-pentagonal tensegrity sphere (6-PTS), or the symmetrical 6-Great-Circle-Planed, Pentagonally Equated Tensegrity Sphere. "A basic

tensegrity sphere can be constituted of six equatorial-planed pentagons, each of which consists of five independent and non-touching compression struts, totaling 30 separate non-touching compression struts in all". The end of each tensegrity strut is connected to the middle of the tension cable to which it is adjacent.



To build a 6-pentagonal tensegrity sphere, one needs 30 struts (sticks, straws, popsicle sticks), and 30 elastics. Make slots in the ends of the struts, through which to connect the elastics. There is a product called ***Tensegrity***, which contains all these materials plus instructions for building tensegrity models.

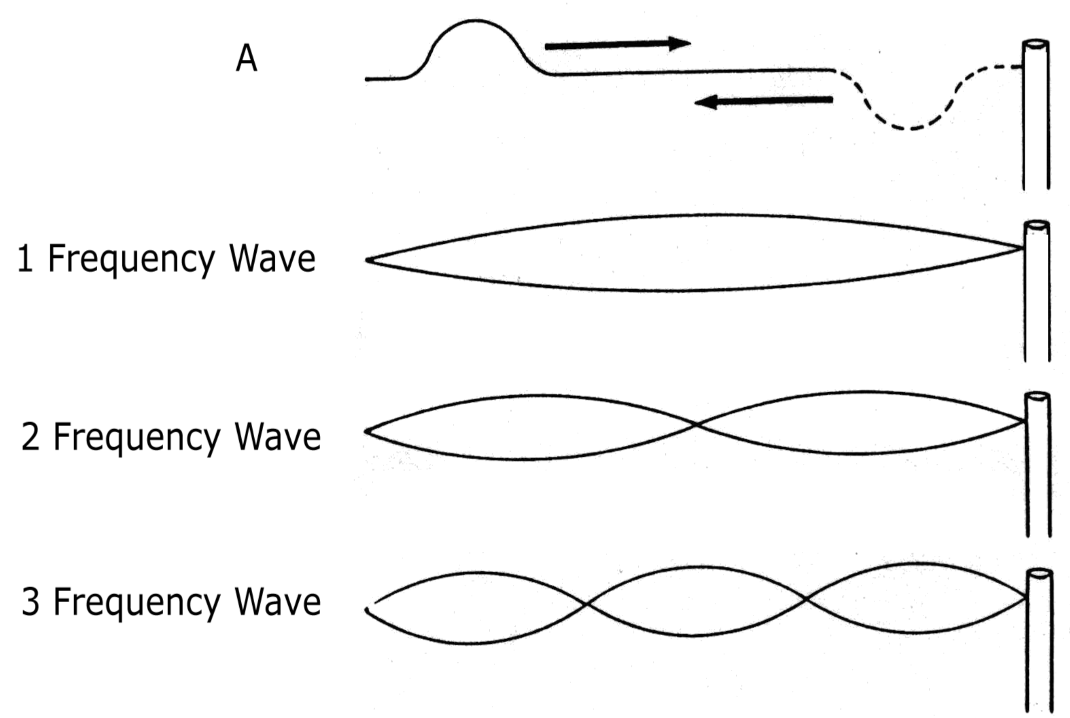
There are no instructions for building the 6-PTS, but there are instructions for building an icosahedron. An icosahedron consists of 20 triangular faces (openings) and 12 vertices. A vertex is formed where the ends of five struts overlap. The short fragments of elastics at each vertex form a pentagon.

In order to convert the icosahedron into the 6-PTS, slide the ends of the struts at a vertex along the elastic, which enlarges the pentagonal vertex. Repeat at each vertex. Gradually slide the end of each strut towards the midpoint of its elastic. When all the ends of the struts are slid to the midpoint of their elastics, they will meet, forming a 6-Pentagonal Tensegrity Sphere (6-PTS) in which the six great circle equatorial pentagons are clearly visible.

WAVE NUMBER

Buckminster Fuller contends that there are only two possible co-variables operative in all design in the universe: they are modifications of angles and wave numbers.

What do we mean by 'wave number'? A wave number is the reciprocal of the wave length. This is a term usually reserved for physics, especially in reference to waves and wavelengths. Gary Zukav, in his book *The Dancing Wu Li Masters,* says: "One way of understanding standing wave number is to use a clothesline. Suppose that we tie one end of a rope to a pole and then pull it tight. On this rope there are no waves at all. Now suppose we flick our wrist sharply downward and upward. A hump appears in the rope and travels down the rope to the pole, where it turns upside down and returns to our hand. This traveling hump (A) is a traveling wave.

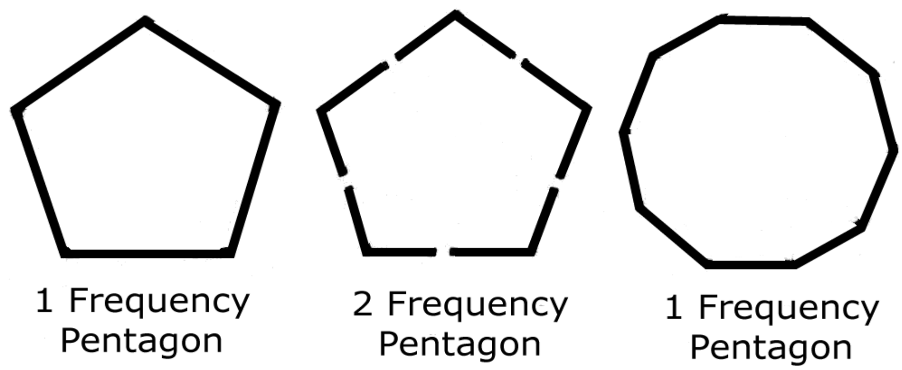


By sending a series of humps down the rope we can set up patterns of standing waves. (The simplest pattern is shown above). The pattern is formed by the superposition of two traveling waves: a direct one and a reflected one traveling in the opposite direction. It is the pattern, not the rope, which does not move. The widest point in the wave remains stationary, and so do the points at the ends of the standing wave. These points are called nodes. There are two of them in the simplest standing pattern, one at our hand and one at the pole where the rope is attached. These stationary patterns, superpositions of traveling waves, are called standing waves. No matter how long or short our rope is, there can only be a whole number of standing waves. That is, it can have a pattern of one standing wave, or a pattern of two standing waves, or a pattern of 3, 4, and so on standing waves, but it can never have a pattern of one and a half standing waves, or a pattern of two and one-fourth standing waves. The standing wave must divide the rope evenly into whole sections. Another way to say this is that we can increase or decrease the number of standing waves on a rope only by a whole number of them."

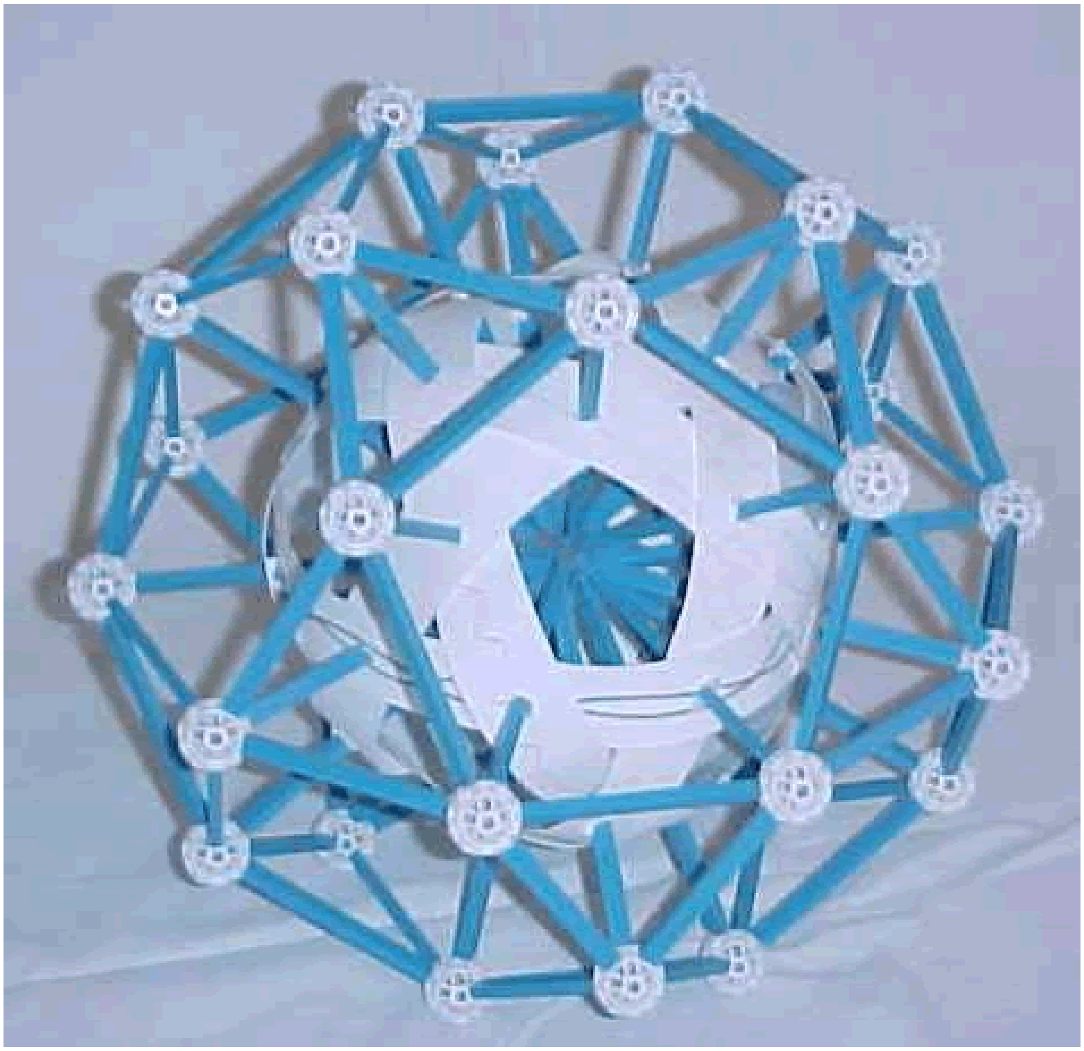
Wave number is a way of describing wavelengths. In the wave number diagram above is a 1-wave number, a 2-wave number and a 3-wave number. The original wave (one) divided into segments (n) equals wave number.

TENSEGRITY STRUTS AND CHANGING WAVE NUMBER

A single tensegrity strut, in 2-fold symmetry, can be considered to be a wave. It can be of any length. A 2-wave number strut occurs when a 1-wave number strut (original wave) is divided into two whole tensegrity struts, each half the length of the original strut. For example, the 6-pentagonal tensegrity sphere is composed of 30 struts which, when divided, become 60 tensegrity struts.



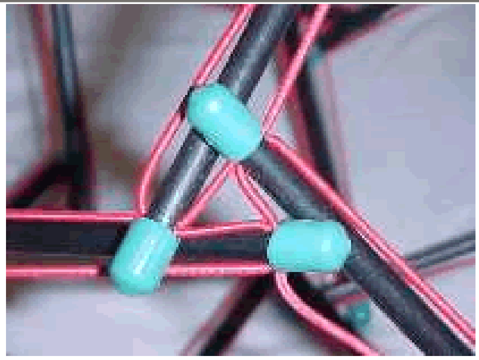
The five struts of a pentagon in the original wave become the 10 struts of the decagon as the symmetry shifts. The above diagram of the 'equator' of a 6-pentagonal tensegrity sphere illustrates this shift. When a pentagon goes from 1-wave number to 2-wave number, its edges double to become a decagon. We now have a 6-decagonal tensegrity sphere in which we have changed both angle and wave number.



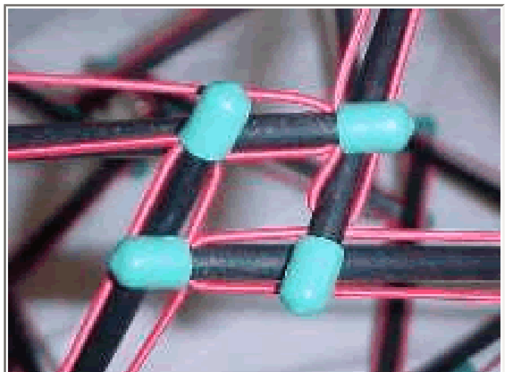
The general shape of the 6-decagonal tensegrity sphere can be made with the Zometool blue struts. The 6-decagonal tensegrity sphere is a icosidodecahedron. The 30 vertices account for five orthogonal (xyz) coordinate systems.

DUALITY AND TRANSFORMATION

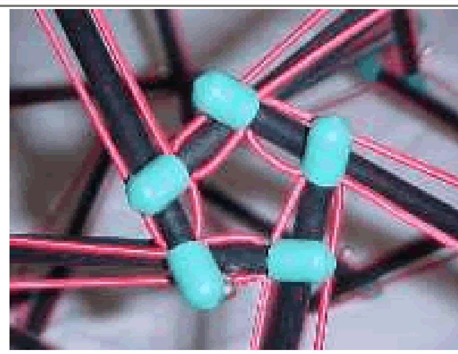
Our next transformation is from 2-fold to 5-fold symmetry. This requires no change in wave number; only angle. The icosidodecahedron, which has 30 vertices and 60 edges transforms into the rhombic triacontahedron. Its 30 vertices become the 30 faces and 60 edges of the triacontahedron. They are duals of one another. This is demonstrated most directly in a tensegrity model. Their vertices are shown below.



3-strut vertex



4-strut vertex



5-strut vertex

Each vertex of the icosidodecahedron is composed of four overlapping struts (above center) connected by the ends of their elastics. These short segments form a very small rhombic diamond. Enlarge each diamond by sliding the struts along their elastics, progressively reducing the size of the pentagons and triangles until the pentagons and triangles become the new vertices of the triacontahedron, and the original rhombic diamond vertices become the new faces of the rhombic triacontahedron. (above left and right).

A SECOND TYPE OF DUALITY TRANSFORMATION

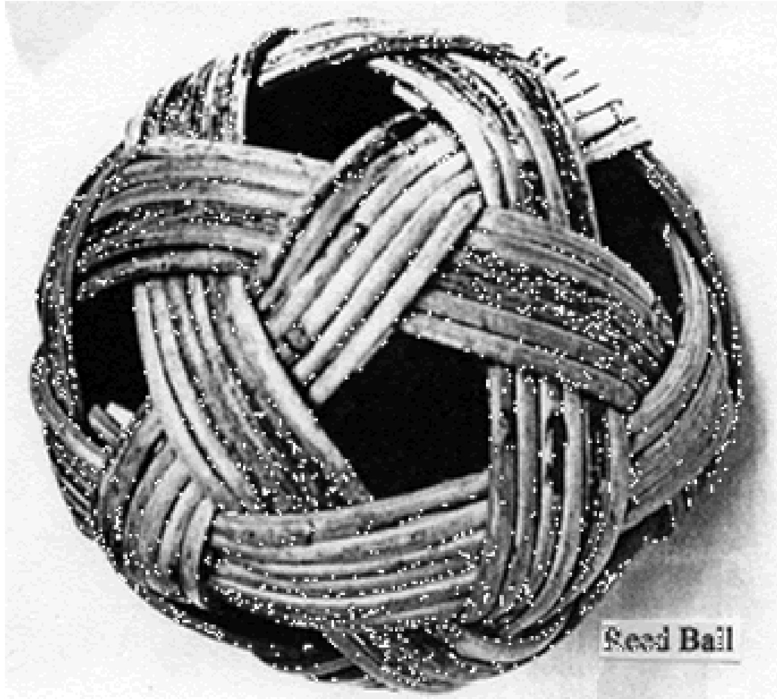
If the struts defining the faces were reduced in length until only the segments defining the vertices remained, the faces would disappear and only the vertices would persist. The extreme contraction of a 6-decagonal tensegrity sphere (tensegrity icosidodecahedron) would leave 30 rhombic vertices, which become the 30 faces of the rhombic triacontahedron. Likewise, the extreme contraction of the rhombic triacontahedron has 12 pentagonal and 20 triangular vertices, which become the 32 faces of the 6-decagonal tensegrity sphere. There is an engaging toy model which illustrates this duality: the expanding and contracting icosidodecahedron ***Hoberman*** Sphere.

SUMMARY OF THE THREE POLYHEDRA

6-Pentagonal Tensegrity Sphere	6-Decagonal Tensegrity Sphere	Tensegrity Rhombic Triacontahedron
1-fold symmetry 30 struts no vertices no faces	2-fold symmetry 60 struts 30 vertices 32 faces (openings)	2-fold, 5-fold symmetry 60 struts 32 vertices 30 faces (openings)

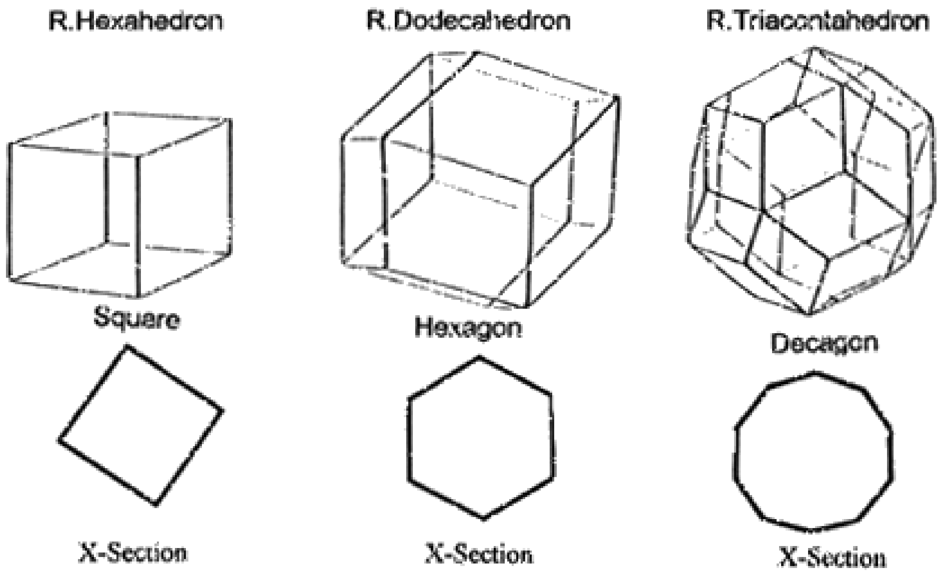
MODEL OF A WAVE

Fuller saw the icosidodecahedron as the model of the electromagnetic wave. (Synergetics 11, 1033.112). What is required to model a wave?
The model must represent the electromagnetic properties of a wave, and 2-fold symmetry, which establishes the creation of two fields: electric and magnetic, can be represented by the icosidodecahedron. The two fields are perpendicular to one another, producing an electromagnetic wave which is perpendicular to both fields.



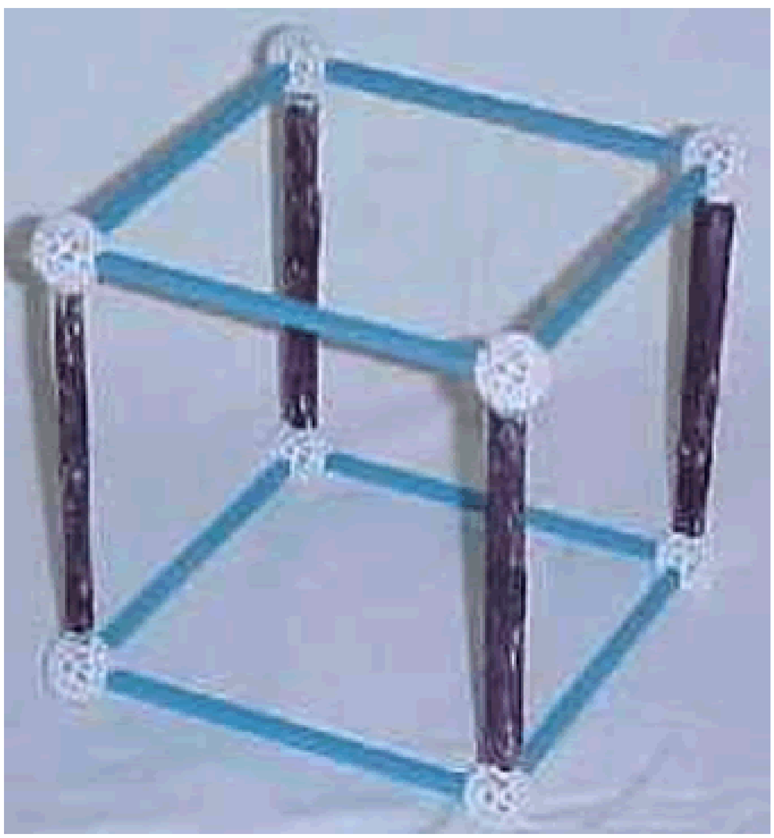
An electromagnetic wave is an open structure and never encloses or subdivides space. Fuller speaks of series and parallel circuitry in connection with open and closed systems. He notes that the icosidodecahedron is the only structure that models the openness of the wave (Synergetics 2; 527.09). It creates 12 pentagonal openings and 20 triangular openings. No matter how wide the six bands are, they could never fully enclose the structure: there are always 12 pentagonal openings exposed, making it impossible for it to be a container; to 'fence in space'. What you need to enclose space is series circuits in a parallel closed system.

What does it take to 'fence in' or enclose space? The enclosure must meet the following criteria:
There must be faces (planes) in which the angle between them (dihedral angle) is one of the 7 angles of 2-fold symmetry (36, 60, 72, 90, 108, 120, 144). There are only three polyhedra that meet this criterion (see below): the 90º dihedral angle of the rhombic hexahedron (the cube, whose cross-sectional plane is the square); the 120º dihedral angle of the rhombic dodecahedron, (whose cross-sectional plane is the hexagon) and the 144º dihedral angle of the rhombic triacontahedron, whose cross-sectional plane is the decagon. The progression of dihedral angles towards maximum enclosure (sphere) is: 1) the 90º cube, 2) the 120º rhombic dodecahedron, and finally, the 144º rhombic triacontahedron.



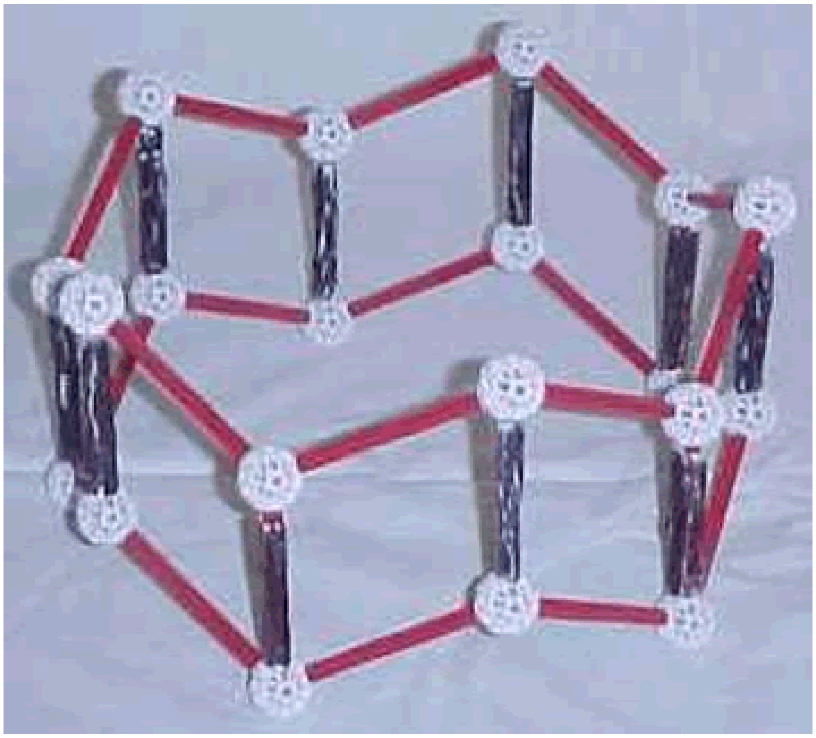
ENCLOSING SPACE: ZONES

CUBIC ZONE



Place a cube on a table. Note that, of the 12 edges of the cube, there are four edges that are parallel and perpendicular; they look like a 4-sided, 90º square fence. We call such an enclosure a 'zone'. Now flip the cube so that there is another 4-sided fence: a second zone. Flip the cube yet again, and you have another 4-sided fence: a third zone. The three fences (zones) completely enclose the 12 edges, establishing one cubic volume of space.

RHOMBIC TRIACONTAHEDRAL ZONE



Like the cube, you will notice perpendicular 'fence posts' (edges). Ten parallel edges surround the zone in a zigzag vertical pattern. A jagged looking fence, but a fence nonetheless. Because there are 10 edges, this fence makes a decagon with a decagonal angle of 144º. As with the cube, flip the rhombic triacontahedron until you have identified all the fences. There will be six zones (fences) enclosing all 60 edges and establishing one rhombic triacontahedral volume of space. The 144º vector angles (connecting the edges) of the icosidodecahedron are transformed into the 144º angles connecting the planes (dihedral angles) of the rhombic triacontahedron. An electromagnetic zone is an example of parallel circuitry.

SUMMARY OF TRANSFORMATIONS

6-DECAGONAL TENSEGRITY SPHERE (wave)	6-DECAGONAL TENSEGRITY SPHERE (wave)	TENSEGRITY RHOMBIC TRIACONTAHEDRON (photon)
1-fold symmetry 6 pentagons 30 tensegrity struts ------- ------- ------- -------	2-fold symmetry 6 decagons 60 tensegrity struts 144º plane angles Electric and magnetic fields Series Circuitry Open Structure	2-fold, 5-fold symmetry 6 zones 60 tensegrity struts 144º dihedral angles Electric and magnetic fields Parallel Circuitry Closed Structure

CHIRALITY AND SYMMETRY SHIFT

All tensegrity constructions are chiral. They can be either left-handed or right-handed, (clockwise or counter-clockwise) depending on the rotational pattern of the vertices of the struts. In 1-fold symmetry, we postulate that both the left-handed and right-handed 6-Pentagonal Tensegrity Spheres occupy, or share, the same space. As expansion occurs, separation occurs, and the symmetry shifts from 1-fold to 2-fold: each 6-pentagonal tensegrity sphere becomes a left-handed and right-handed 6-Decagonal Tensegrity Sphere. In a subsequent contraction, the left and right 6-Decagonal Tensegrity Spheres (icosidodecahedra) become left and right tensegrity rhombic triacontahedra.

THE IMPLICATIONS OF THE PRE-WAVE/WAVE/PHOTON TRANSFORMATIONS

It follows from our premises that the source of all motion (energy) comes not from the wave, but its predecessor: the matrix of 6-pentagonal tensegrity spheres. In 1-fold symmetry there is a 360º axial rotation for each of the 30 struts. This motion does not create or do anything because the 30 struts in 6-pentagonal units are independent of one another. These struts are organized, not by the compression elements (the struts), but by the tension elements (the strings). The 6-PTS is in a pure state of 'non-doing', or a state of being. A matrix of 6-PTS, in close spherical packing, is all the potential motion necessary for the creation of waves. When the six pentagonal loops become six decagonal bands (through symmetry shifting), we now have the next stage of organization. All the 360º motion of the 6-PTS is subdivided into 180º oscillations, supplying all the motion for the creation of electric and magnetic fields and electro-magnetic waves.

The electro-magnetic waves are radiating; they do not form organized systems until they go through yet another symmetry shift, 2-fold symmetry icosidodecahedral waves, which then organize into a system of waves in the shape of a rhombic triacontahedron. The icosidodecahedron and the triacontahedron are geometric duals. This is the wave-particle transformation, a reversible process which also allows the particle to revert to the wave.

NEW PHYSICS: LIGHT AS FINITE

One of William Day's premises, in the introduction to his new physics (Bridge from Nowhere 1) is that the duration of light is finite. The three phase model (pre-wave, wave, photon) tends to support this premise. The limitation of the duration of light is not due to its 'tiredness', but to its tendency to equilibrate to its origins (6-Pentagonal Tensegrity Spheres). It may, however, take 15 billion years to do so.

STRING THEORY PHYSICS: HOW IT RELATES

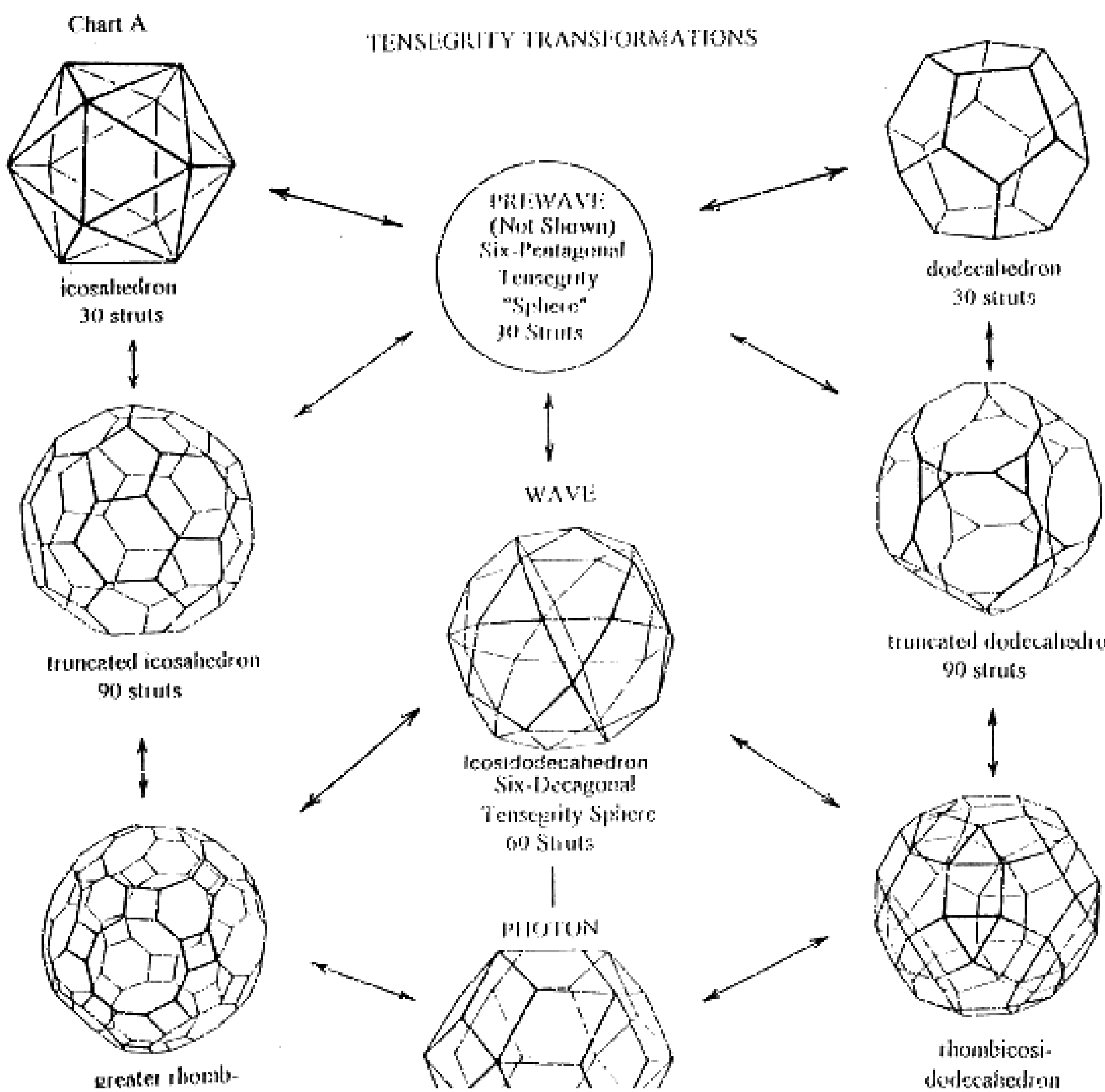
Brian Greene, a String Theory physicist, in his recent book *The Elegant Universe*, describes why physicists have given up on the geometry of zero dimensional points and replaced it with 1-dimensional strings that form 1-

dimensional loops. String Theory further postulates that these loops are curled up into a shape called the Calabi-Yau shape. They use the expression 'brane'. A brane is any extended object that arises in String Theory. A 1-brane is a 1-dimensional string, or loop. A 2-brane is a 2-dimensional membrane and a 3-brane is a 3-dimensional object, From our point of view, the pentagon can be viewed as a 1-brane string loop, the bands of the icosidodecahedron are the 2-brane, and the rhombic triacontahedron, the 3-brane object. Our 6-PTS is the equivalent of the Calabi-Yau shape of hyperspace.

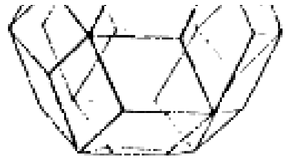
SUMMATION

1-fold symmetry is the beginning and end of holistic geometry. Everything after the beginning and before the end is 2-fold symmetry. All the geometry is in tensegrity. Every polyhedral edge can be seen as an abstraction (or long diagonal) of, and can be replaced by a 2-fold symmetry rhombic polyhedron.

For hierarchy of Polyhedra
See Chart A and Chart B



greater rhomb-
icosidodecahedron
180struts



Six-Zone Tensegrity
Rhombic Triacontahedron
60 Struts

rhombicosi-
dodecahedron
120 struts

All the shown models are considered to be tensegrity constructions.

TENSEGRITY: continuous tension balanced with discontinuous compression. The tension elements used here are elastics; the compression elements are the struts. Structures found in the body, bridges, bicycle wheels, etc are more accurately represented by tensegritous models than by rigid models (struts only).

TENSEGRITY STRUT: a strut of a given length, divided in this chart into halves or thirds, yielding 2 or 3 tensegrity struts respectively.

Marvin Solit, D.O.
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93 BELMONT ST.
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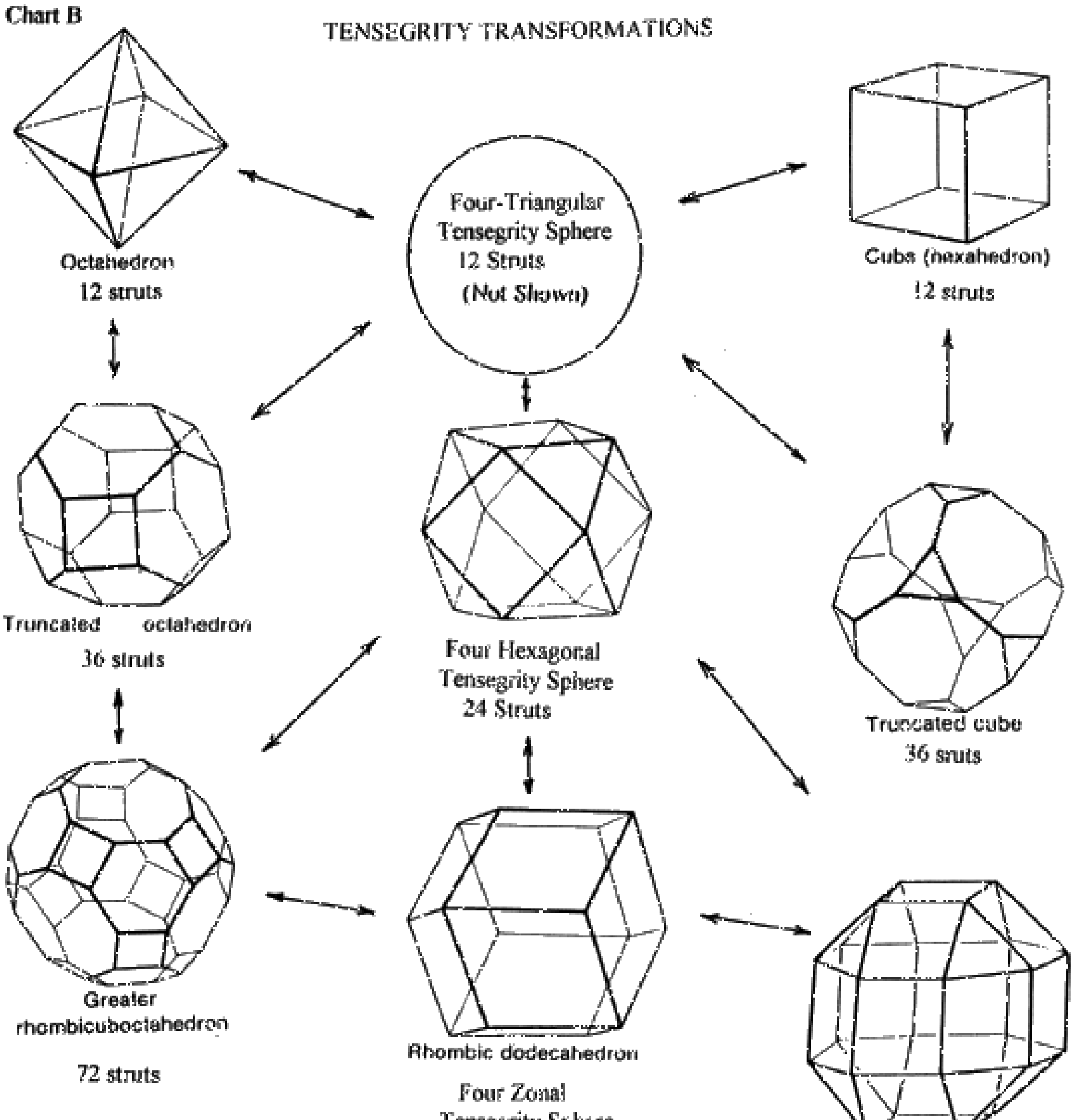
Chart B

TENSEGRITY TRANSFORMATIONS



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Addendum 'A'
March 9, 2001

Chiralty and Symmetry Shifting - Variations

The 6-Double Pentagonal Tensegrity Sphere (6DPTS)

In the modeling the left and right 6-Pentagonal Tensegrity Sphere (6PTS), the two models can occupy the same space, with each pentagon of the right 6PTS interweavin with a pentagon from the left 6PTS. This is similar to the interwoven triangles of the 'Star of David'--instead of interwoven triangles there are interwoven pentagons. This model is a 6-Double Pentagonal Tensegrity Sphere and it can be either left or right handed. As the symmetry shifts, the interwoven pentagons become united and coplanar, creating ten common edges of a decagon. The previous ten 108 degree angles of the pentagons become dominated by the ten 144 degree angles of the decagon. The new structure functions as a 6-Decagonal Tensegrity Sphere, a tensegrity icosidodecahedron.

Another Variation

The 6DPTS has 30 thirty vertices. Each vertex has four overlapping struts. If each of the 60-tensegrity struts were to maximally shorten in length, the 30 vertices would persist, and the new structure would be a tensegrity rhombic triacontahedron.

Hierarchy of Polyhedra
A polyhedra chart beginning with the thirty verti (an icosidodechedron)

Exploring Marvin Solit's Polyhedra Work---Bob Gray's WebSite
Click on: http://www.rwgrayprojects.com/Marvin/Intro.html

Associate Writer/Editor: Jean LeVaux
Technical Organization: David Pap, David Lovler
Webmaster: David Pap, Alan Fincke

www.holisticliving.info

93 Belmont Street
Cambridge, MA 02138
617 547-6621