

## RESEARCH ARTICLE

# Structural form as an analogical source for structures of nature: two examples

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**Abstract:** Anaximander's 6th century BC model of the cosmos was arguably influenced by analogies drawn from the monumental stone temple architecture of his day, with specific aspects of the model being related to the overall temple or its structural elements, or even its construction processes. Similarly, the scientists who discovered a new allotrope of carbon in 1985 were inspired by the geodesic domes of Buckminster Fuller to arrive at a structural configuration for the molecule. This shows that designed structural artifacts can play a role in scientific model formation by serving as sources of analogy for the structures of nature.

**Keywords:** Analogy, Anaximander, buckminsterfullerene, elegance, geometry, structure.

## INTRODUCTION

The purpose of this paper is to explore the role of architectural structures as physical objects that serve to generate analogies for scientific theories. Can designed objects in fact serve as analogies for models of natural objects? Analogy is not foreign to structural engineering, but the flow of analogy is mostly from nature to structure; i.e. from natural to design objects or from science to engineering. Images of a fallen tree trunk, a rock cave and a tree vine are often used to serve as analogies for the three main bridge forms, namely, the beam, arch and suspension bridge. More sophisticated are the membrane and sand heap analogies employed for representing elastic and plastic torsional stress distributions in cross sections.

This paper gives two examples where the flow of analogy was reversed, in that constructed structures served as analogies for proposing structures for entities in nature. The first example is where Anaximander, a 6<sup>th</sup> century BC Greek philosopher, used a set of architectural or structural analogies to propose a structure for the cosmos. The second is where the geodesic domes of Buckminster Fuller were used to propose the structure for a new allotrope of carbon discovered in 1985. The intention of the paper is not to make a definitive case for man-made structures to be used as analogies for nature. It is rather to argue that there can be times where the usual analogical direction is reversed, and that we should not ignore it.

It should be noted that the two examples given would probably be defined by Hesse (1966) as 'homologies', where the correspondence between source and target entities (Holyoak & Thagard, 1995) is purely structural as opposed to functional; the term 'analogy' in a strict sense is reserved for the latter (Hesse, 1966). There are also no internal causal relationships between the elements of the source or target entities, which is once again characteristic of a mere homology. However, we use the term 'analogy' in this paper, since it is also used for both types of correspondence in a general sense.

It must be appreciated that the use of analogies and analogical reasoning may not have the same intellectual rigour that 'demonstrative' evidence or strict proofs do. Yet all creative work is arguably possible, even in such

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a proof-oriented discipline as mathematics, only due to what Polya (1954) calls ‘plausible’ reasoning, within which he places analogy. He says, “A serious student of mathematics, intending to make it his life’s work, must learn demonstrative reasoning; it is his profession and the distinctive mark of his science. Yet, for real success he must also learn plausible reasoning; this is the kind of reasoning on which his creative work will depend” (p. vi).

The above complementary nature of plausible and demonstrative reasoning is virtually the same as that between Popper’s (1989a) ‘conjecture’ and ‘refutation’, which will be alluded to later as well. Lloyd (2015), an undisputed authority on ancient philosophy and science (especially of ancient Greece) also refers to the ability of analogies to generate conjectures and says that they were particularly useful in contexts where confirmation by direct observation was not possible. Further, despite Aristotle’s general skepticism of metaphor (something very close to analogy), Lloyd (2015) says that “Aristotle, in one of his rare moments of appreciation of metaphor.... wrote in the *Poetics* (1459a5-8) that skill in its use was a mark of genius and cannot be taught” (p. 106).

Ksiazkiewicz (2015) points out that the idea of ‘nature-as-architecture’ was a dominant theme in enlightenment architectural theory, when she describes how the fabrication process of vitrified iron age forts in the Scottish Highlands was used to postulate ideas about geological processes. She describes how MacCulloch (1773–1835), a ‘scrupulous geologist’ saw it fit to ‘invert’ the normal flow of analogy, in a way very similar to that argued in this paper: “MacCulloch ingeniously inverted the order of precedence between natural operations observed in nature and artificial practices in architecture: as nature and art were governed by the same laws, artificial actions functioned as adequate analogies for natural operations”.

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## ANAXIMANDER’S TECHNOLOGICAL ANALOGIES

Anaximander lived in the 6<sup>th</sup> century BC in Miletus, on the West coast of what is now Turkey. He is regarded as the greatest of the three Milesian philosophers of that time, perhaps being a student of Thales and a teacher of Anaximenes. We focus here on his cosmological model, in which for the first time, the ‘free suspension’ of the Earth in space was proposed.

Hahn (2001) argues that Anaximander’s model of the cosmos was strongly influenced by the architectural objects and practices of his day. The notion of

philosophy being influenced by mere physical objects may be anathema to those who consider it as belonging to the realm of ‘pure thought’. However, Hahn bolsters his case by showing that: (i) the doxography clearly alludes to technological objects used in and around the temples of Anaximander’s day (note: doxography is the compiling of extracts from ancient Greek philosophers to which editorial content has been added; hence, although there is but a fragment of writing that can be traced directly to Anaximander, there is much that is attributed to him by later writers); (ii) Anaximander was contemporaneous with monumental temple architecture, specifically with the temples of Artemis, Apollo and Hera at Ephesus, Didyma and Samos, respectively; and (iii) the philosophers of that period had significant common ground with the architects – for example, both Thales and Anaximander used applied geometry in their natural philosophy, as did the architects. Anaximander is also credited with a prose text to describe nature (as opposed to the poetic descriptions used up to that time), a feature similar to the prose being used by architects in his day to document the principles of their profession. Further, the descriptions attributed to Anaximander are rational rather than mythological; similar to the way that the architects too were forced to be rational, e.g. about weights and strengths of materials, when the sizes of their temples increased.

There are broadly two types of analogies described in what follows. One is based on simple geometric ratios, sometimes derived from poetic literature (which continued to have some influence on both Anaximander and the architects). In such cases, both the temple architecture and Anaximander’s cosmological model could have been based on this common source, and the source-target relationship between temple and cosmos is rather weak. Such analogies based on simple ratios will probably have nothing to do with natural laws, and Aristotle himself had been very critical of them (Lloyd, 2015). Furthermore, such aspects of the cosmological model have clearly been disproved with the growth of science and the increasing use of observational testing.

The other type of analogy is structural however, and more significant; and for Anaximander’s cosmology has proved to be enduring in a remarkable sort of way – for example, the free suspension of earth in space and the notion that space has depth. This paper presents possible temple-based sources for such enduring features in his cosmological model, although there is no direct doxographical evidence for the same. Such evidence is present however, as pointed out below, for other structural features such as the (cylindrical) shape of the earth, and

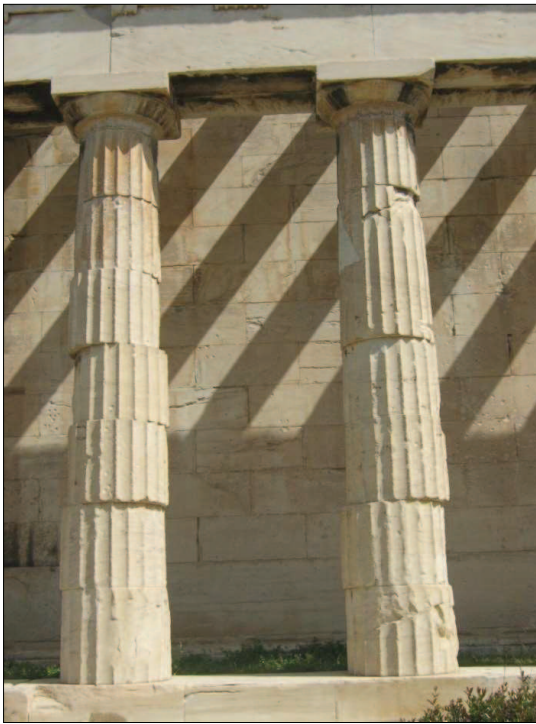
the wheels and ‘breathing holes’ of the celestial bodies. Although these latter features have been refuted by the growth of science, it is fairly reasonable to assume that temple architecture and construction did in fact influence many, if not most aspects of Anaximander’s cosmological model. Temples throughout the ages have been seen as reaching from the earth (man’s abode) to the heavens (the abode of the gods) and mediating cosmic power in the reverse direction. Hence, it may not have been too much of a stretch for Anaximander’s imagination to posit that various aspects of the temple were “analogies for the cosmos itself” (Hahn, 2010).

### THE EARTH AS A COLUMN DRUM

The early Greek temples had timber columns to support thatched roofs. However, the monumental temple architecture of the 6<sup>th</sup> century BC was characterised by wider temples and roof tiles held in place on clay beds. Timber columns were no longer able to carry the upper parts of the temples and their roofs, and hence a stronger material for columns was required. Stone was the obvious choice, but transporting full height columns would have been virtually impossible because of their weight. Hence, the columns were formed of a series of

column drums placed one above the other (Figure 1). It is a typical column drum that was used as an analogy for the earth. Hippolytus [*Refutatio*, I, 6.3; D-K 12A11.3] says, “The shape of the earth is concave, rounded, similar to the drum of a column”; while Pseudo-Plutarch [*Strom* 2; D-K 12A10] says, “He [sc. Anaximander] says that the shape of the earth is cylindrical, and that it has a depth that is one-third of its width”.

The depth to width ratios of column drums varied both within and across temples, but the one-third ratio was quite common (Hahn, 2001). The description of being ‘rounded’ would refer to the circular plan form of the drums; that of being ‘concave’ may refer to the process of *anathyrosis*, where vertical contact between the drums was made only at the outer annulus (Figure 2), while the rest of the two plane surfaces of the drum were made slightly lower than the annulus and hence roughly concave. This was to reduce wobble due to



**Figure 1:** Column drums of the Hephaistheion at the Athens Agora displaced by seismic activity



**Figure 2:** *Anathyrosis* seen in column base of the Heraion at Samos



**Figure 3:** *Empolion* visible in column drums of the Temple of Zeus at Athens

uneven surface dressing, thus contributing to vertical stability. Horizontal stability, was ensured at least during placement, by a small timber dowel, called *empolion*, placed in a central hole (Figure 3).

Greece is in an earthquake region and as seen in Figure 1, the drums could get displaced due to the lateral ground motion. It appears that the articulation of the column into drums could assist their integrity during earthquakes (compared to monolithic columns), although this cannot be stated unequivocally (Psycharis *et al.*, 2000). Horizontal stability then arises due to the relative location of one drum with respect to another, with the drums restraining each other through friction but allowing stress relief through slip. Even static vertical stability can be seen as being due to such relative positioning, each drum forming part of a load carrying chain. The analogical significance of relative location is pointed out below.

### GEOCENTRIC COSMIC SYSTEM WITH DEPTH IN SPACE

We move from the nature of the earth to its place in the cosmos. The quotation from Aristotle [*De Caelo*, B13, 295b10ff; D-K 12A26] that ensures Anaximander's continuing eminence reads as follows: "There are some who say that the earth remains in place because it is in equilibrium, like Anaximander among the ancients. For a thing established in the centre, and equally related to the extremes, has no reason to move up or down or to the sides; and since it is impossible for it to move simultaneously in opposite directions, it will necessarily remain where it is". This is probably one of the earliest, if not first applications of the principle of sufficient reason, according to which everything which is true or real implies a reason why it is so and not otherwise.

Here then is the notion of 'free suspension'. How did Anaximander imagine this? His teacher Thales had said previously that the earth was supported by water, no doubt through the observation that Greece was surrounded by seas. Anaximander however broke with all observational evidence and pronounced, as recorded by Hippolytus [*Refutatio*, I, 6.3; D-K 12A11.3] that, "The earth is held aloft, held up by nothing; it remains in place because of its similar [i.e. uniform] distance from all things". Anaximander may have rejected Thales' theory on the basis that it led to infinite regress (Popper, 1994) – i.e. "If the earth is supported by water, what is the water supported by?", and so on. However, he still had to posit a new theory.

Both Popper (1989b) and Polanyi (1958) argue that observation has been the source of the greatest errors in the history of science, and that science progresses through bold conjectures. Popper (1989b) does admit a role for observational analogy however. It could be that Anaximander's theory of equilibrium as a result of the Earth's relative location may have been inspired by observing the equilibrium of the column drums through their relative location to other drums.

Apart from the notion of the Earth's free suspension, Anaximander's cosmological model also included the idea of depth in space. Differing distances from the Earth were attributed to the different heavenly bodies, rather than all of them being equidistant from the Earth on some kind of hemispherical canvas. According to Aetius [II, 21.1; D-K 12A21], "Anaximander says the sun is equal to the earth, but the circle from which it has its breathing hole and by which it is carried is 27 times the size of the earth". Hippolytus [*Refutatio*, 1, 6.5; D-K 12A11.5] says, "The circle of the sun is 27 times the size of (the earth), that of the moon [18 times]; the sun is highest, and the circles of the fixed stars are lowest".

Hahn (2001) argues that these relative dimensions must be visualised in plan, just as architects would visualise their own temples in plan; and also that the numbers should be construed as 'distances' and hence radii, as opposed to diameters. The heavenly bodies are described as 'wheels of fire' (elaborated on later) having radially oriented apertures through which their light reaches the earth. The thickness of the wheels (corresponding to the sizes of the bodies) are assumed as being equal to the size of the earth, while the distances between their inner radii and the earth would correspond to the distances mentioned in the doxography above. Anaximander's cosmos can then be visualised in plan as in Figure 4. The distance to the star circle is not stated in the doxography, but can be posited as 9 earth diameters, giving rise to an arithmetic series for the inner radii.

The number 9 appears in Greek poetry as signifying great distance. The poet Hesiod says that a bronze anvil took 9 days to fall from heaven to the Earth, and another 9 to fall from Earth to Tartarus (i.e. hell). However, more pertinently, the number 9 is the ratio between column height and diameter in Ionic columns – Ionia is the region in which Miletus was located. For example, they are much more slender than the Doric columns that have a ratio of only 6. Such recourse to proportions (rather than to stress analysis) characterised the design of structures even up to the middle of the last millennium (Addis, 1990; Dias, 2008).

Figure 5 shows an Ionic column at the Erechtheion in Athens; it should be noted however that the column drums here are much taller than their widths, and in a virtually inverse ratio to that mentioned before. At any rate, if we stick to the 3:1 ratio between column drum diameter and depth, and the 9:1 ratio between column height and diameter, we end up with a 27:1 ratio between column height and drum depth. It should be remembered that temples and especially their columns signified the reaching up to the heavens from the Earth. If a single column drum represents the Earth, there would then be 27 earth sizes (thicknesses) between the base and top of the column, representing the distance (in elevation) between the earth and the heavens. This is an interesting parallel to the distance to the sun, i.e. the outermost element of Anaximander’s model in Figure 4, although the latter is a plan view and based on earth diameters.

*dipteros* temples where two peripheral colonnades surrounded the central chamber. In concept, this is similar to the inner and outer areas of Anaximander’s cosmos, i.e. a cosmos having depth.

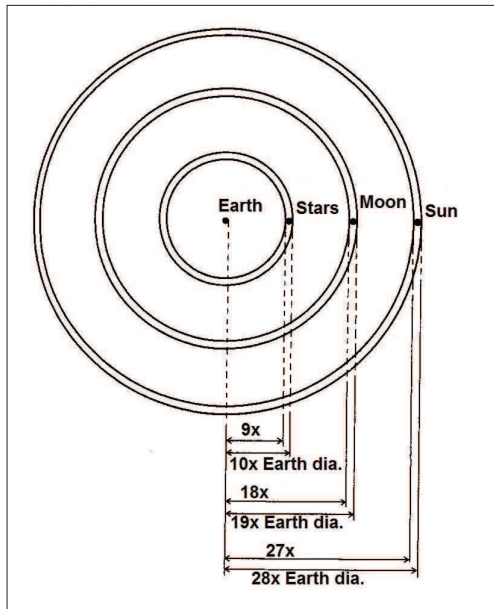


Figure 4: Anaximander’s cosmos visualised in plan, after Hahn (2001)

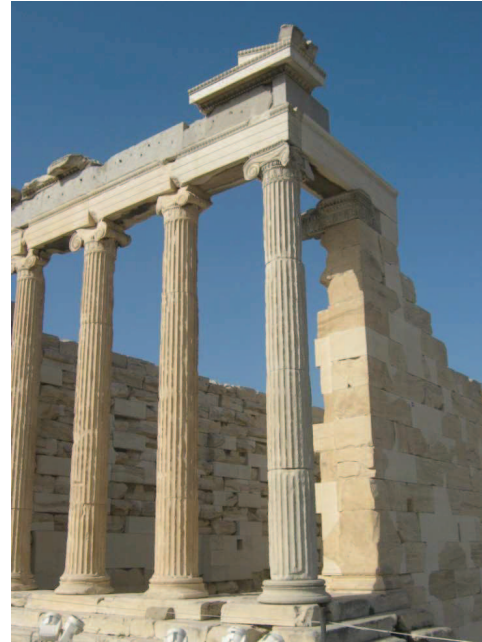


Figure 5: Slender Ionic columns of the Erechtheion at the Athens Acropolis

Therefore, although there is both poetic and architectural impetus for using the number 9, how did Anaximander arrive at the notion of ‘depth’ in space as reflected in Figure 4? Was there any observational analogy that corresponded to this notion? If we look at a typical temple plan view (Figure 6), there does not appear at first sight to be any similarity with Figure 4. A more reflective examination reveals however that there are inner and outer areas in the temples, especially in the monumental

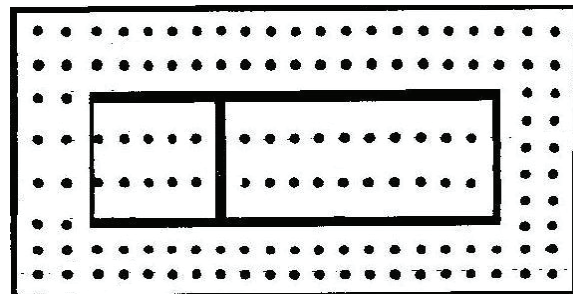


Figure 6: Plan view of a *dipteros* temple, after Hahn (2001)

## THE HEAVENLY BODIES AS WHEELS OF FIRE

Anaximander dealt with cosmogony and meteorology too, reflecting the ancient Greek philosophers’ preoccupation with the primordial elements of earth, air, fire and water. In fact, the only surviving fragment of

writing directly attributable to him is about his theory of the *apeiron* or the ‘boundless’ that had no origin (Kahn, 1994). The cosmos was considered to have arisen from the boundless through a process of differentiation into the above primordial elements. Thus, the heavenly bodies were formed as wheels of fire surrounding the earth, separated from each other by moist air. As such, according to Aetius [I, 20.1; D-K 12A21], “Anaximander [says the sun] is a circle.....resembling a chariot wheel, having a hollow rim, full of fire”; and also that [II, 13.7; D-K 12A18], “Anaximander [says of the heavenly bodies that] they have the form of wheels, formed by compressed air and filled with fire, that exhale flames at one point through a mouth-like opening”.

We have here, analogies not from a temple or any of its components, but from other objects that form part of the ‘object world’ (Bucciarelli, 1994) of a temple. Anaximander would probably have seen wheels being used at temple construction sites, maybe not in chariots but in carts that would have been used to transport the heavy column drums and architraves from the quarries to the site. A reconstruction of a system attributed to the architect Metagenes for the construction of the temple of Artemis at Ephesus is described by Hahn (2001) and Coulton (1977); the rectangular prismatic architrave appears as the axis connecting two cylindrical wheels.

The flames exhaling from a mouth-like opening would have been seen in a bellow used for the metal working associated with the construction (Hahn, 2010). A reconstruction by Diels (1897) shows how such openings in the wheels of fire would enable light from the heavenly bodies to reach the Earth. It was probably assumed that the ‘denseness’ of the mists enclosing the moon and star wheels was progressively less than that of the mist surrounding the sun wheel; else, the light from the sun wheel opening would not have been able to penetrate the former. This would be acceptable because mists of progressively lower denseness would be sufficient to enclose the ‘lesser fires’ in the moon and star circles.

The ‘wheels of fire’ analogy also allows us to reconstruct a 3D view of Anaximander’s cosmos, to supplement the plan view in Figure 4. In order to do this, we need to digress to the seasonal sundial that he is credited with inventing, according to the doxography [Diogenes Laertes, II, 1-2: D-K 12A]: “Anaximander, the son of Praxiades, of Miletos, was first to discover the gnomon and set it up on the sundials of Sparta, according to what Favorinus says in Universal History, in order to mark the solstices and equinoxes, and also

he constructed markings to show the hours. He was the first to draw an outline of the earth and sea, and he also constructed a (celestial) model”. Hahn (2001) imagines the gnomon as a vertical pin at the centre of a stone disc. The minimum shadow lengths for a day would help to identify the zenith of the sun at various times of the year, for example, at the equinoxes and the summer and winter solstices. At the same time, the positions corresponding to sunrise and sunset at those times can also be marked on the disc. This will indicate that the plane of the sun’s path (i) is inclined to the vertical; and (ii) experiences a parallel shift from summer to winter solstice.

If we combine the above insights with a suitably inclined image of an architrave block fixed to two end wheels for transportation, we can imagine the two cart wheels to be the sun wheel’s positions at summer and winter solstice. This will help us to reconstruct a 3D model of Anaximander’s cosmos as done by Couprie (1995), of which Figure 7 gives the essential features. The entire cosmological model is a cylindrical one, with the sun wheel shifting along the axis on the outermost cylinder from summer to winter solstice.

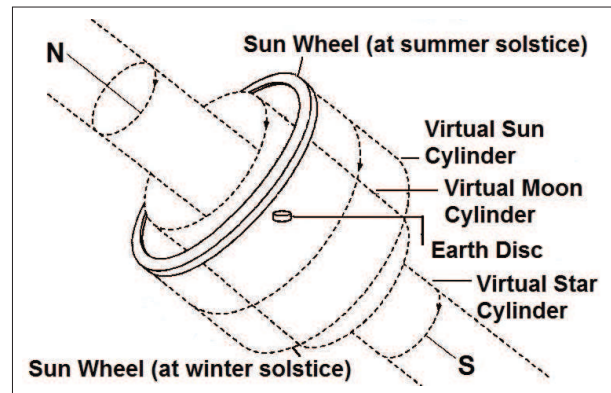


Figure 7: Reconstruction of Anaximander’s cosmos, after Couprie (1995)

Popper (1989b) critiques Anaximander for being misled by observation to propose a flat earth. However, if our reconstruction of Anaximander’s model is correct, he is nothing if not elegant, using cylinders for all the elements of his model, and elegance is highly prized in arriving at scientific theories (Polanyi, 1958). The column drum and hollow wheels of fire are cylinders, as is the ‘tube’ along which the parallel shift of the sun wheel takes place.

If we look at his plan views, they are all annuli of circles around a central focus. This is clearly seen in

Figure 4. In this context, it is interesting to note that the doxography [Agathemerus, I.1] credits Anaximander with the drawing of a terrestrial map too: “Anaximander the Milesian, a disciple of Thales, first dared to draw a map of the inhabited earth on a tablet.” Reconstructions of this (Hahn, 2001; Robinson, 1968) depict a circular earth with Greece at the centre, and three water bodies - namely, (i) the Mediterranean sea, (ii) the Black sea and river Phasis and (iii) the Nile river - radiating outwards to meet the ocean that is an annulus at the circumference. This annularity is reminiscent of *anathyrosis* in column drums (Figure 2) as well. In addition, annularity is also found in tree rings.

In fact, the tree (which is essentially cylindrical too) was the precursor of the temple column, with the temple itself replacing the sacred grove. We can then imagine a link, characterised by cylindrical shape and annular cross section, from trees to temple columns to the cosmos itself. This could be considered a sort of ‘hierarchical typology’. One of the most striking features of the mental model constructed by Anaximander is its geometric nature. This reinforces the link with the architects, who were also using applied geometry in their physical constructions, and strengthens the case for an architectural or structural analogy being employed by Anaximander for his cosmic model.

## THE DISCOVERY OF BUCKMINSTER-FULLERENE

We move now from the 6<sup>th</sup> century BC to the 20<sup>th</sup> century AD, where the discovery of a new allotrope of carbon took place in 1985. Harry Kroto, a British scientist was visiting the laboratory of an American colleague Rick Smalley, who had an apparatus that could vapourise graphite by laser irradiation and perform mass spectrographic analysis on the resulting vapour. They discovered a remarkably stable clustering of 60 carbon atoms but found it difficult to propose a structure for it – extrapolations of graphite sheet structures and tetrahedral diamond structures were not satisfactory.

The structure they finally proposed was inspired by the geodesic domes of the engineer *cum* architect Buckminster Fuller, causing them to name the molecule ‘Buckminsterfullerene’. The following is a quote from the article in the prestigious science journal *Nature*, announcing their discovery (Kroto *et al.*, 1985): “Thus a search was made for some other plausible structure which would satisfy all  $sp^2$  valences. Only a spheroidal structure appears likely to satisfy this criterion, and thus

Buckminster Fuller’s studies were consulted (see, for example, ref.7). An unusually beautiful (and probably unique) choice is the truncated icosahedron depicted in Figure 1”.

A truncated icosahedron is a spheroidal structure with 60 vertices and 32 faces, 12 of which are pentagonal and the rest hexagonal. A soccer ball also has such a structure (Figure 8). Aldersey-Williams’ (1995) description of the discovery of the molecule reveals that both Smalley and Kroto had independently visited the US Pavilion at the Expo ’67 in Montreal, which was in fact a geodesic dome by Buckminster Fuller. These large domes have more than 32 faces, but the important thing is that 12 of them must be pentagons, without which the spheroidal shape cannot be developed. Aldersey-Williams (1995) describes Smalley’s frustration when trying to construct a spheroidal shape using paper hexagons alone.



Figure 8: Pentagons and hexagons in a soccer ball

It could be argued of course that geometry was the common basis for both the success of the geodesic dome and the existence of the buckminsterfullerene structure. Euler had proposed rules for polyhedra, including the truncated icosahedron, two centuries previously. It is also true that physical rules govern the efficiency of the spheroidal structures – especially for radial loading, but even approximately for vertical loading. Further, where buckminsterfullerene is concerned, the spherical structure is able to satisfy all the bonding capacities of the carbon atoms. However, despite or even because of these common geometric and physical roots, the fact remains that Smalley and Kroto were inspired by geodesic domes when proposing a model for the new molecule.

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## CONCLUDING DISCUSSION

Anaximander's model of the cosmos has been superseded. Nevertheless, his notions of free suspension and depth in space were revolutionary for his time and in some senses are still valid. At any rate, as Popper (1989b) would argue, the role of scientific theory is to present bold conjectures that must of course be subjected to critical testing; this is the evolutionary problem solving method used not only in science but in all of life (Popper, 1999). The structural model for buckminsterfullerene continues to be valid.

There are a number of interesting issues raised by the two examples above. First, although we are more familiar with the use of nature as a source of analogy for structural engineering, the reverse can be true at times too. Structures can indeed serve as analogies for proposing models of nature. It should be noted in passing that apart from this technological analogy for the cosmos, Greek science used socio-political and organismic ones too (Lloyd, 1966). Even Anaximander's own model has elements of these - for example, the differing distances to the heavenly bodies could reflect the hierarchical structure of the *polis*; and the wheels of fire with breathing holes, a universe that is alive in some sense.

Second, geometry (including proportion) and elegance (or even beauty) were important in both cases. It could be argued that the rules of proportion, such as 1:3 and 1:9, were the common basis for both the Greek temples and Anaximander's model of the cosmos; also that the principles of geometry (e.g. Euler's rules for polyhedra) or physics were the common basis for the structures of both the geodesic dome and the buckminsterfullerene molecule. Nevertheless, the literature describing the discovery of the models discussed above makes it clear that structural form did serve as inspiration for the positing of the models of nature. This is the argument advanced by enlightenment geologists as well, as described by Ksiazkiewicz (2015).

In any case, beauty, or at least elegance, is one of the goals of a scientific theory (Polanyi, 1958). Kepler for example, using analogy of sorts, conjectured that the distances to the sun from the planets ("the most excellent things created") could be related to certain regular solids ("Euclid's most excellent figures") (Polya, 1954). Although he was completely mistaken, it was probably his passion for elegance that led him to later discover that the orbits of the planets were (elegant) ellipses. It has also been demonstrated that aesthetically attractive

structural configurations are also the best with respect to materials usage and economy (Kulasuriya *et al.* 2002). Structural engineers often employ the maxim that a structure will not be 'right' unless it 'looks right'. This will apply of course, only to instances where structural form dominates (such as bridges), rather than to some postmodern buildings where the structural form is deliberately hidden.

Third, although Popper argues that scientific theories should be generated by bold conjecture rather than by observation, such conjectures probably rely on observational analogies. As argued here, even Anaximander's two most impressive conjectures of free suspension and depth in space could have resulted from analogical reflection on column drum equilibrium and column arrangement in temples, respectively.

Finally, the two examples we have considered describe an interplay between objects and ideas (Hahn, 2010). Do we get ideas from the objects that surround us, or do we get them by interacting with other ideas, all of which inhabit a separate Platonic space? In some ways this parallels the interplay between the mind and body too (Johnson, 1987; 2007). Does the mind arise from the body or is it independent of the body? A full exploration of these issues is clearly beyond the scope of this paper. However, Anaximander's idea of free suspension could be viewed as arising either out of observing an object (i.e. the column drums and their equilibrium due to relative location); or out of critiquing another idea, namely, Thales' proposition that the Earth was suspended on water; or even out of both.

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