Culture, the Silver Mean and Nuclear Pore Complexes

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ABSTRACT

The Golden Mean (or Golden Ratio) is well known for its appearance of beauty in art and beyond. The closely related Silver Mean less so. Yet it is important in art, architecture and religion. The Silver Mean and octagons are linked, with octagons possessing various properties based around the Silver Mean. Nuclear Pore Complexes are octagonal protein complexes linking the nucleus and cytoplasm in eukaryotic cells. They cluster in both tetragonal and hexagonal aggregates. Hexagonal clustering of octagonal subunits should be geometrically forbidden. Thus, here, is an instance of a protein quasicrystal. I suggest that the octagonal Nuclear Pore Complexes are part of a universal fractal which results in the Silver Mean being expressed in its various forms in human culture.

Key Words: Consciousness, Fractal, Golden Ratio, Nuclear Pore Complex, Quasicrystal, Silver Ratio

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Introduction

Towards a Universal Fractal

"the font, a diapered square, supported on eight engaged columns arranged octagonally, and having both caps and bases"

An aperiodic tiling is a non-periodic tiling that does not contain arbitrarily large periodic patches. A set of tiles is aperiodic if copies of these tiles can form only non-periodic tilings the tilings discovered by Roger Penrose are the best-known aperiodic tilings (Gardner, 1997). Aperiodic tilings serve as mathematical models for quasicrystals, physical solids that were discovered in 1982 by Dan Shechtman who subsequently won the Nobel prize in 2011 (Schechtman *et al.,* 1984). However, the specific local structure of these materials is still poorly understood. For example, whether quantum non-locality is required for their formation.

The idea that the presence of the Golden Mean in biological systems, and its presence in various man-made materials, may have similar etiology was first raised in 2001(Bolliger *et al.,* 2001). Previously I have suggested that protein complexes may form quasicrystals with 5-fold local rotational symmetry (in the case of animal neurotransmitter receptors and embryonic plant ribosomes) or 13-fold local rotational symmetry (in the case of ubiquitous microtubules) (Gardiner, 2015). These biological quasicrystals differ from those described in other aperiodic physical systems in that they form a regular hexagonal tiling with a component of arbitrary rotational status at each vertex. The arbitrary rotational status enables each protein quibit to take any value in the quasicrystalline quantum computer. 5-fold quasicrystals are closely related to the Golden Mean, which occurs in numerous permutations within them. The Golden Mean is thought to play a role in consciousness, due to it appearing as beautiful in numerous cultures. It is associated with the Divine (Yalta *et al*., 2016). The Silver Mean is closely related to the Golden Mean, as their names suggest.

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The Golden Mean is a/b when it equals a+b/a. The Silver Mean is a/b when it equals 2a+b/a. The Golden Mean is the irrational number $(1+\sqrt{5})/2$ while the Silver Mean is $(2+\sqrt{8})/2$. The Silver Mean is associated with the octagon. For example, the rectangle formed with two opposite sides of a regular octagon is in the Silver Mean.

A value tantalisingly close to the Silver Mean (2.38 as opposed to 2.41) is found in the cell area: perimeter ratios of mature epidermal cells of *Arabidopsis thaliana* (Staff *et al.,* 2012). The great American architect Frank Lloyd Wright was fascinated by Japanese design and the Silver Mean and indeed the study of his home at Oak Park is octagonal. In Christian culture the baptismal font is often octagonal, with the number 8 associated with resurrection, regeneration and rebirth, while churches in Ethiopia often form an octagon (Figure 1a).

Figure 1. Church of Archangel Raphael, Addis Ababa (a), and Temple of the Silver Pavilion, Kyoto (b)

The Silver Mean is seen as beautiful in Eastern Cultures, particularly Japanese culture (Figure 1b). In Islamic art the octagon is often used in tiling and in Arabic an octagonal glyph sometimes concludes a chapter. Much as a STOP sign demands attention.

Thus, any theory that posits a role for the Golden Mean in consciousness must also include the Silver Mean as an important component. Similar to the Penrose Tiling the Ammann-Beenker octagonal tiling uses only two tiles to tile the plane, with the Silver Mean underpinning this. Here I present an octagonal biological quasicrystal tiling by Nuclear Pore Complexes.

Nuclear Pore Complexes are large aqueous channels that penetrate the nuclear envelope, connecting the nuclear interior with the cytoplasm and are highly dynamic multiprotein assemblies involved in diverse cellular processes ranging from the organization of the cytoskeleton to gene expression (D'Angelo and Hetzer 2008). They are large assemblies of ~60–125 MDa in mammals and ~40–60 MDa in yeast, consisting of ~30 different proteins, known as nucleoporins, or nups, and invariably form an octagonal tube-like structure (Figure 2).

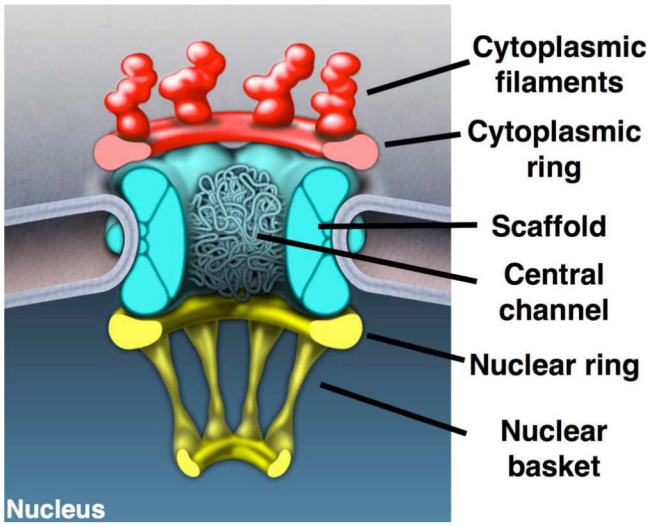

Figure 2. Nuclear pore, side view showing octagonal form (D'Angelo and Hetzer 2008)

Despite its nearly ubiquitous occurrence in eukaryotes, and the presence in prokaryotes of a similar protein complex (Sagulenko *et al.,* 2016), it is not known why NPCs are this shape. Various ideas have been floated. Perhaps the eightfold symmetry maximizes the bending stiffness of each of the eight NPC spokes (Wolf and Mofrad 2008)?

In oocytes of the amphibian *Necturus* (Akey 1989) and plant cells (Thair and Wardrop 1971) nuclear pores form both tetragonal and hexagonal arrays (Figure 3).

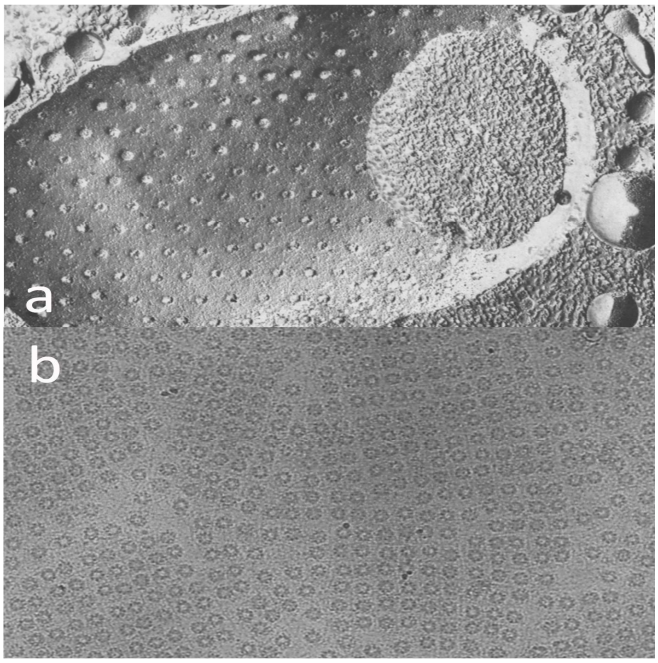

Figure 3. a. Freeze-etch replica of plant cell nucleus showing hexagonal nuclear pore arrangement (Thair and Wardrop 1971).
b. A low magnification electron micrograph of a detergent-stripped and spread nuclear envelope from Necturus (amphibian). The NPCs form arrays as the result of their interactions with the periodic lamina (Akey 1989).

Other studies found a hexagonal nuclear pore complex tiling in the midgut epithelia of *Dystiscus marginalis*, an insect (Andries 1983), and a hexagonal packing of Nuclear Pore Complexes in male germline cells (Fawcett and Chemes 1979).

Now the tetragonal arrays may be explained as a truncated square tiling which is a semiregular tiling by regular polygons of the Euclidean plane with one square and two octagons on each vertex (Figure 4).

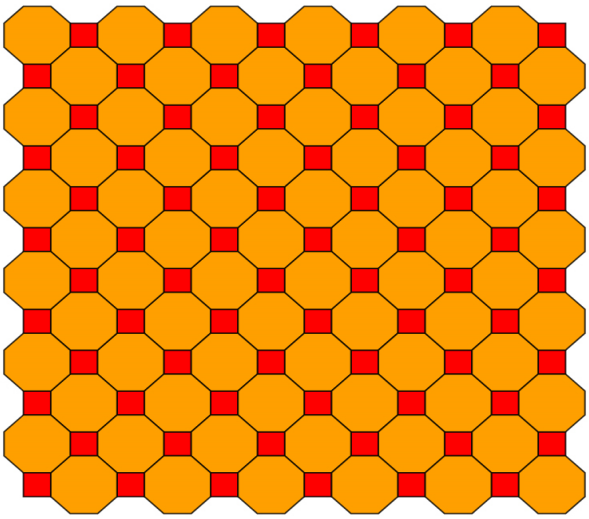

Figure 4. A semiregular tiling by regular polygons of the Euclidean plane with one square and two octagons on each vertex

This is the only edge-to-edge tiling by regular convex polygons which contains an octagon. But there is no known tiling that has octagonal components in a hexagonal lattice. Thus, here, as previously with pentagonal neurotransmitter receptor complexes and plant ribosomes and 13-mer microtubules I suggest that we are looking at aperiodic tilings and biological quasicrystals, this time formed around octagons.

Are these octagonal quasicrystals important for consciousness, as I have proposed for pentagonal (Golden) and tridecagonal (microtubule) quasicrystals? In the mammalian brain there are quite sparse nuclear pore complexes in rat cerebellar cortex (Garcia-Segura *et al.,* 1989). Thus, here it may not be possible to discern any underlying tiling. Certainly, the Nuclear Pore Complex is involved in nucleus-cytoplasm transport of macromolecules in the neuron and plays a key role in neurodegenerative diseases including Huntington's (Grima *et al.,* 2017), Alzheimer's (Sheffield *et al.,* 2006) and amyotropic lateral sclerosis (Taylor 2017) and is thus of medical significance. Indeed, Huntington's and Alzheimer's can be seen, in part, as diseases of consciousness. The microtubule-associated protein Adenomatous Polyposis Coli interacts with the Nuclear Pore Complex (Collin *et al.,* 2008). This protein is also implicated in schizophrenia (Onouchi *et al.,* 2014), perhaps another link between a disorder of consciousness and the Nuclear Pore Complex? Finally, it should be noted that the Nuclear Pore Complex is important during development with one component, Sec13, necessary for retinal development (Niu *et al.,* 2014).

We live in a holographic, fractal universe. Richard Dawkins has proposed in "The Extended Phenotype" that physical alterations to the environment by biological entities should be viewed as of the same ilk as the physical form of te biological entity itself. Thus, the expression of the octagon and Silver Mean in human culture (not forgetting its potential presence in plants) is as intrinsic to ourselves as our eyes or hands. Where do they arise? They cannot just magically appear. I suggest that one (or maybe more) iterations down in the human fractal Nuclear Pore Complexes pass the Silver Mean upward towards the building of churches or the close of an Arabic chapter. And below the Complexes in the fractal lies a mystery.

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