

[C G; A T] EPITAHEDRON GENETICS - TOWARDS A VISUALIZATION OF GENETIC CODES VIA GENETIC MUSIC

Authors Renate Quehenberger, Independent Researcher, Ziegelofengasse 6, A-1040 Vienna,

Email: office@epitahedron.eu and

Benjamin Skepper, 1-15-10 DAC Building 2F, Shinkiba, Koto-ku Tokyo, 136-0082,

Email: contact@benjaminskepper.com

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Abstract

The scientific background and technical details for the visualization of the mathematics underlying genetic codes applied to musical scales shall be described. Genetic Music provides audible access to genetic structures which become visible based on the fundamental level of nature as permutations of space itself. Hydrogen bonds characteristically appear in quantities 2 and 3 in complementary pairs of nitrogenous bases [GACT] in DNA - and [GACU] in RNA. Since hydrogen is observed to expose the symmetries of the Penrose Patterns, visual access is achieved by means of a 3D representation of the Penrose kites and Darts, named epitahedron. Those pyramid-shaped polyhedra represent the numbers of hydrogen bonds (C=G=3, A=T=2) which generate musical equivalence between the genetic alphabet and the 7 notes of the Pythagorean scale, as well as further and distinct correlations with "Fibonacci Stage Genetic Music Scales" which shall also be described.

Please Genetic Music scales provide an audible access to genetic structures where hydrogen bonds with quantities 2 and 3 are characteristics of complementary letters of the genetic alphabet, the pairs of nitrogenous bases (C=G=3, A=T=2). Hydrogen is not only an element of the basic building blocks of the genetic codes and therefore used as the fundamental principle of Genetic Music, moreover it plays an important role in the composition of our Universe, where 93% hydrogen atoms exist among all kinds of atoms and the chemical influence of omnipresent hydrogen is the defining factor"[1]. The genetic matrix of the varying hydrogen bonds [3 2; 2 3](n) generates a musical equivalence between the genetic alphabet and a new system of Fibonacci Stages Genetic Music Scales. This audible access to abstract mathematical structures inspired the aim to visualize those musical notes by means of permuting hyperspace elements, named epitahedra [2]. Since they are the 3-dimensional representation of aperiodic tilings in the plane named Penrose kites and Darts patterns [3] epitahedra (E±) - two shapes convex (E+) and concave (E-) - can be regarded as unit cells of the 5-dimensional space and promise a glimpse of the patterns inherent in genetic codes.

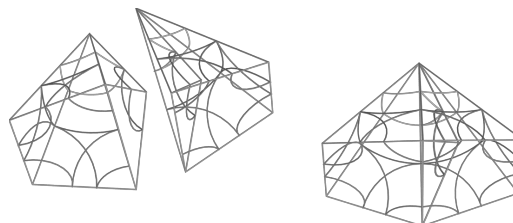
The connection to the Penrose Patterns, known as 2D slices of 5-dimensional space was given truly visionary by the Austrian physicist Erwin Schrödinger (1887-1961) known as the inventor of wave mechanics, who addressed the problems of genetics by looking at the phenomenon of life from the point of view of quantum physics and named living substances "aperiodic crystal" Schrödinger also coined the terms "code", "hereditary code-script" and "chromosome code" in his lecture series 1943, which became the basic vocabulary in Genetics[4]. This was 25 years prior to the discovery of those irregular patterns in the golden mean, by Roger Penrose whose equivalence in nature as real "aperiodic crystals" named Quasicrystals where discovered in 1984 [5].

Nowadays the accuracy of this term can be understood since hydrogen is observed to expose the symmetries of the Penrose Patterns [6] and hydrogen atoms are bonds in genetic molecules.

Visualization of Genetic Music

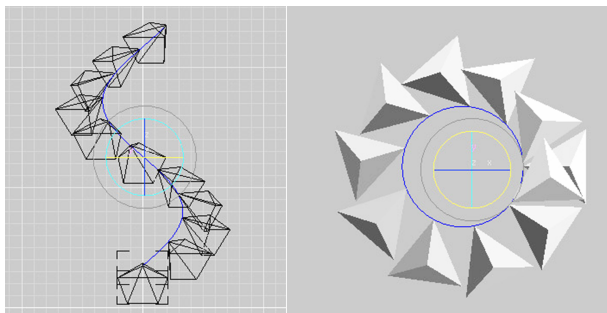
The visualization of genetic music notes is relying on characteristics of DNA geometry. The pentagonal symmetries provide the dynamics required to build a consistent, stable and uniform helical structure and also establishes why there should be consistently ten bases contained within a single turn of the helix. It seems notable that the shapes of epitahedra E+ and E- are fitting together and closing in three possible rotational positions, while one of them is forming a hexagonal basis (Fig. 1 right).

Fig. 1. Epitahedra E+ and E- (left) and both joining together (right), cf. [2]



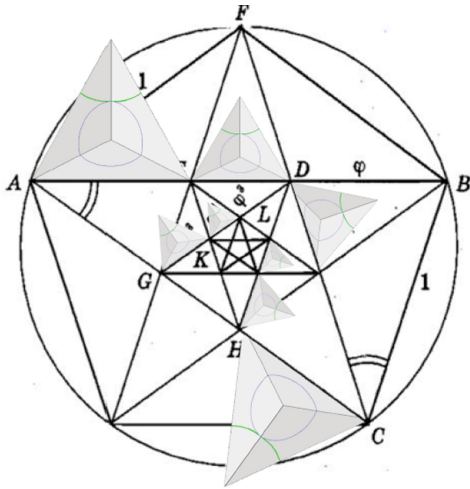
We arranged eleven epitahedra according to the geometry of genetics in a 32.7° rotation bp (right-handed A-DNA form basepair rotation) and mean 11 bp/turn [7] and derived the shape of the helix (Fig. 2a). There are two polyhedra overlapping in the top view of the helix when seen as a circle accordingly (Fig. 2b)

Fig. 2. Eleven epitahedra arranged as helix (left) and top view (right), artist: Oliver Thiele



The goal is a synchronic visualization grammar matching the acoustic patterns of the newly developed Genetics Music Scale by means of epitahedra. One feature is inspired by German mathematician August Ferdinand Möbius (1790 - 1868) who suggests a musical visualization by assigning the edges of a second order polytope to particular music notes [8]. Accordingly we assign each of the 7 faces of the epitahedron to a musical note. Those pyramid-shaped polyhedra are representing the numbers of hydrogen bonds. Secondly we use two sizes according to the frequencies of the "Fibonacci-stage scales" or "pentagram scales" hierarchy in Genetic Music. Those structures are connected with Fibonacci numbers, the golden section $\phi = (1 + \sqrt{5}) / 2 = 1.618...$ with the factor ϕ^2 , which exists in regular 5-stars (pentagram) as a ratio between sides of the

Fig. 3. Epitahedra arranged in the sizes Q, Q(2) and Q(3) according to Fig. 4 in [10]

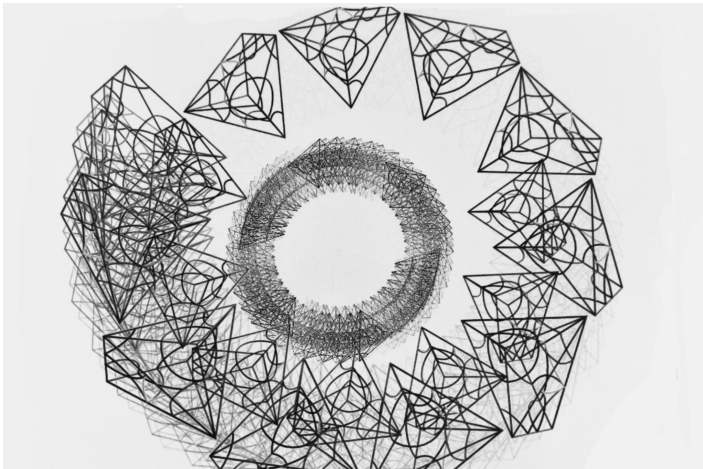


adjacent stars entered in each other [9] (cf. fig. 3) [10].

So the Kronecker family of quint genomatrices [3 2; 2 3] ⁽ⁿ⁾ below denoted as Q, determines the frequencies of musical notes carrying familiar names: do (C), re (D), mi (E), fa (F), sol (G), la (A), si (B) as follows :

	E(n) frequency	tone	visualization
Q = PHI	2 := 220	= a	(not used)
Q = PHI	3 := 330	= e1	(not used)
Q(2) = PHI ^2	4 := 440	= A1	4 E+
Q(2) = PHI ^2	6 := 660	= E2	6 E-
Q(2) = PHI ^2	9 := 990	= B2	9 E+
Q(3) = PHI ^3	8 := 87	= F	8 E-
Q(3) = PHI ^3	12 := 130	= C	12 E+
Q(3) = PHI ^3	18 := 196	= G	18 E-
Q(3) = PHI ^3	27 := 293	= D1	27 E+

Fig. 4. Epitahedra configurations visualizing nite D1, E2 and B2 (visuals: Hannes Mennewenger, Lichttapete)



Conclusion

These visualizations reflect that each gene and each part of DNA and RNA have their own genetic “melody of hydrogen bonds”, for which genetic music tools create audible understanding. From this challenge, the aim to create a visual representation was born. The epitahedron is our tool for the visualization of musical notes as permutations of hyperspace cells. Whereas normal sound waves are only creating a turbulence in the air, we want to visualize how music is creating a visual turbulence of space itself: the dancing hyperspace, as it is supposed to be performed in those higher-dimensional realms beyond the borders of our own cells.

Acknowledgements and Notes

Genetic Music was initially developed by a team of musicians and scientists at the Moscow State Conservatory, based on mathematical and genetic research conducted by bio-physicist Petoukhov, and supported by Ivan Stepanyan, from the Russian Academy of Sciences. Petoukhov first discovered that Fibonacci Stages scales are related with parametric characteristics of the molecular genetic system (molecules DNA). The Dean of the Composer Faculty of the Moscow State Conservatory Alexander Koblyakov, composer and biophysicist Ivan Soshinsky, and composer Michail Puchkov then spearheaded the quest to develop this new musical language.

References and Notes

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11. ad Fig.3, 3D Animated films of visualizations of musical notes were developed by R. Quehenberger with Oliver Thiele for the multimedia-performance entitled [C A; U G] ⁽ⁿ⁾ Epita Matrix Genetics, featuring Australian Japanese multi-media-artist, composer and electric cellist Benjamin Skepper and Austrian sound artist and violinist Mía Zabelka for the Symmetry Festival Vienna 2016.
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