בס״ד

KABBALAH, GENETICS AND THE MUSIC OF THE SPHERES

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Abstract

In this paper, we describe shared attributes in Kabbalah, music, genetics and theoretical physics. Abraham Abulafia, 13th century founder of Prophetic Kabbalah, used the permutations of Hebrew letters, especially letters from the names of God, to augment spiritual awareness. He likened these permutations to ones generated by combinations of individual tones in music, anticipating identical permutations identified in improvisational exercises written for jazz musicians some 700 years later. These alphabetical and tonal permutations resemble arrangements of DNA bases in the genetic code, and thereby the subsequent DNA-governed arrangement of amino acids during protein synthesis. It has been reported that DNA base sequences can be used to generate tonal arrangements in musical compositions, and that musical scores can be found with sequences of notes that resemble closely the sequence of bases in particular genes. Inasmuch as music is mathematical, music and mathematics may be viewed as common underlying characteristics of Kabbalah and genetics. According to string theory, all subatomic particles can be viewed as vibrating strings, like the vibrating strings of musical instruments. In the same way that different modes of vibration produce different notes on a guitar string, for example, different modes of vibration account for the different subatomic particles identified in theoretical physics. Our study reveals interfaces between any of the four disciplines described here.

Key words

Abulafia, Kabbalah of permutations, Musical improvisation, Genetic code, DNA sequences in music, Music and string theory.

Introduction

Our study begins in 1285, the year in which Rabbi Abraham Abulafia completed the writing of his primary treatise called *Ohr Ha-Sekhel (Light of the Intellect).* This treatise dealt with Kabbalah, a mystical interpretation of the Torah, and especially, of the narrative of Creation.

Abulafia, a leading proponent of Jewish mysticism, was born in Saragossa, Moorish Spain (c.1240-c.1292). He was a devotee of the *Sefer Yetzirah (Book of Creation)* and the founder of Prophetic Kabbalah, concerned with the acquisition of prophetic abilities through meditation, permutation of Hebrew letters, and the visualization and chanting of divine names. Among his primary sources were the

writings of Rabbi Moshe ben Maimon (Maimonides) and those of Rabbi Eleazar ben Judah ben Kalonymus.

Maimonides (1135–1204) was born in Cordova, Spain. He is a preeminent scholar and teacher among the Jewish people, notable for his works, *Mishnah Torah (Reiteration of Torah)* and *Moreh ha-Nevuchim (Guide for the Perplexed).* Besides serving as a rabbi, Maimonides was a philosopher in the Aristotelian sense, an astronomer, and a renowned physician. In 1168, he became the personal physician of Saladin, the Sultan of Egypt.

Rabbi Eleazar (1176-1238) was born in Mainz, Germany. He was the head of the *Chasidei Ashkenaz,* a group of Jewish mystics living in 12th and 13th century Germany. Among his multitude of works, R' Eleazar wrote *Sefer Ha-shem* (*Book of the Name)* in which he outlined a system of permutations of Hebrew letters to facilitate imaginative meditation and prophecy, and thereby a connection to God.

The philosophical works of Maimonides were not, and are not, easy to understand, and Kabbalah was always transmitted in secrecy. Yet Abulafia synthesized both traditions and made them accessible to everyone. It was the first time anyone had ever taught Kabbalah in public.

Permutations in Kabbalah

The Torah teaches that God created the universe with Hebrew words, for example יהי אור *(Yehi ohr)* meaning *"Let there be light."* Abulafia and others therefore viewed Hebrew letters as the building blocks of creation. Abulafia knew that barring repetition, any four letters can be arranged in twenty-four different ways.

This is expressed by the factorial: n! = n x (n – 1) x (n – 2) x 1 = 24, or 4! = 4 x 3 x 2 x 1 = 24. Examples are shown below for the English letters A-B-C-D and the corresponding Hebrew letters, א-ב-ג-ד *(aleph, beit, gimmel, dalet).*

ABCD	ABDC	ADBC	ADCB	ACDB	ACBD
BACD	BADC	BDCA	BDAC	BCAD	BCDA
CABD	CADB	CDAB	CDBA	CABD	CADB
DABC	DACB	DBCA	DBAC	DCBA	DCAB

אבגד	אבדג	אגדב	אגבד	אדבג	אדגב
בגדא	בגאד	בדאג	בדגא	באדג	באגד
גדאב	גדבא	גאבד	גאדב	גבדא	גבאד
דאבג	דאגב	דבגא	דבאג	דגאב	דגבא

These permutations illustrate the framework of Abulafia's method. But the method itself is not limited to any particular number or sequence of letters. It can be applied to individual words, or groups of letters, or to the entire alphabet, to derive creative awareness and a link to the Divine Intellect. Consider these three-letter words taken from the word *"Shalom."*

שלום

Shalom (Peace)

משל	שלם	שמו	לשם
Mashal	*Shalem*	*Shemo*	*Leshem*
Parable, Like	Complete, Whole	His Name	Precious Jewel

Abulafia might have construed these words as indicating that a person who emanates *complete peace* by meditating on *His Name* is *like* a *precious jewel.* Permutation of letters, especially letters from the names of God was a common Kabbalistic practice. The method becomes increasingly complex as letters are added. Consider the name of God, אלהים, (*Elohim),* which occurs in the first sentence of the Creation narrative (Gen. 1:1) and throughout Hebrew scripture. Barring repetition of a letter, this word has five letters which can be arranged in 120 ways (5! = 5 x 4 x 3 x 2 x 1 = 120).

By emphasizing permutation of Hebrew letters in conformity with R' Eleazar's studies, Abulafia was able to encode complex schemes within groups of elementary symbols. He believed that the methods of R' Eleazar and the rationalist approaches of Maimonides pointed to fundamental secrets of creation. We shall see that his permutations foreshadow analogous arrangements described more than 700 years later in music, genetics and theoretical physics.

In many ways, Abulafia was a synthesizer of intellectual traditions in Judaism, which he believed have applications for all peoples. He met with Christian and Muslim mystics to share his ideas and to retain channels of communication between Jews and the practitioners of other religious faiths.

He regarded the human intellect *(sekhel)* as a bond between God and human. He saw the intellect as a gift to all peoples, enabling in all peoples, the recognition

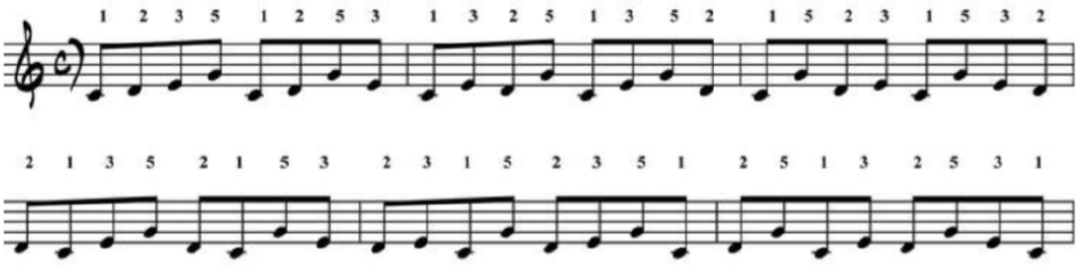
of universal truths. For Abulafia, enlightenment and the attainment of spiritual perfection were common human goals, not limited to a particular religious or national demographic.

He described a connection between letters and musical notes. Regarding music on a stringed instrument, he wrote: *". . . The strings touched with the right hand or the left hand vibrate, and the experience is sweet to the ears . . . The joy is renewed through the pleasure of the changing melodies, and it is impossible to renew it except through the process of combinations of sounds. The combination of letters proceeds similarly. One touches the first string, that is, analogically, the first letter, and the right hand passes . . . to second, third, fourth, or fifth strings, and from the fifth it proceeds to the others. In this process of permutations, new melodies emerge and vibrate to the ears, and then touch the heart. This is how the technique of letter combination operates . . ."* (Bokser, 1981; and see Idel, 1987; and Scholem, 1965).

Permutations in Modern Music

One of us (JC) designed the Universal Language Room, the central program of The Bridge Institute, dedicated to connecting people of diverse backgrounds through the medium of improvisational music. During his studies of musical improvisation, Jason discovered a system of permutations in modern music that matches perfectly the system of Abulafia.

In his book, *Melodic Structures,* Jerry Bergonzi, a teacher at Boston's New England Conservatory of Music, describes improvisation based on four-note permutations, an example of which is shown in the figure below (Bergonzi, 1992). This figure shows only twelve of the twenty-four possible arrangements of the four notes selected: C - E - G - D without repetition of a note in any group.



Apart from their duplicating the permutation of letters in Kabbalah, we note that the musical lines pictured above were written to help train musicians in improvisation. It should be emphasized that musical improvisation, fundamental to jazz, blues, and other forms, involves *spontaneous composition* of a series of notes that follows a particular harmonic pattern or chord line. By definition, no two improvisations are the same, even those based on the same melody and played by the same musician.

Imagine a pianist performing *"Somewhere Over the Rainbow."* She plays the song in a way that is immediately recognizable. She follows this with an improvised melody created over the original chord line — improvisation — creation *de novo.* The melody is new, but it fits. The permutations above are therefore significant because they can be used by students and teachers to facilitate the generation of novel musical lines.

The Universality of Music

Two "Voyager" spacecraft were launched in 1977 to photograph the outer planets before continuing their travels into deep space. Each carries an identical golden record containing maps, images, voice messages, mathematics and twenty-seven pieces of music intended as a greeting to any alien life form they might encounter. The musical tracks consist of pieces from countries around the world — pieces as diverse as the first movement of *Bach's Brandenburg Concerto No.2* played by the Munich Bach Orchestra, *Johnny B. Goode* played by Chuck Berry and *Raga, Jaat Kahan Ho* sung by Kesarbai Kerkar of India.

The piece that opens the Sounds of Earth section of the golden records is called the *Music of the Spheres.* This "computer music" produced by composer, Laurie Spiegel, represents the transposing orbital speeds of planets Mercury, Venus, Earth, Mars, and Jupiter, according to the calculations of 17th century astronomer Johannes Kepler.

The Voyager spacecraft are still flying. At present they are more than 15 billion miles from Earth and still transmitting though some of their systems are no longer functional.

The Four Letters of DNA

The initials DNA stand for *deoxyribonucleic acid,* which is composed of four chemical building blocks or *bases — adenine, thymine, guanine* and *cytosine*. Scientists who study DNA like to call the bases by their initials: A - T - G - C.

Accordingly, DNA can be portrayed as a long string of letters laid out end-to-end in seemingly random order, as in A-A-A-T-G-C-G-C-G-C-T-T-A-A and so on. But the order is not random, for the letters spell out the genetic code, which governs the destiny of every living thing, and indeed, every living cell. The DNA code contains all the information needed to make and maintain a living organism. The code determines whether the organism will be a cucumber or a cat, a whale or a snail, an oak tree or a human; if human, whether it will have brown skin or pink, blue eyes or green, whether it will be tall or small, healthy or sick, quick-witted or slow. All this with just four letters.

How is that possible? How can all the information needed for the life of an animal or plant be contained in an alphabet containing only four letters? The answer is, DNA governs the production of *proteins* — large chemical compounds with specific functions. Just as DNA chains of four smaller units called bases, protein chains consist of twenty smaller units called *amino acids*. The order of DNA bases determines the order of amino acids, and the order of amino acids determines the shape and function of the protein — where it fits, how it works, what it does.

There are different kinds of proteins. Examples are: antibodies, which protect us from bacteria and viruses; enzymes, which control chemical reactions in cells; hormones, which govern the activity of particular tissues; and building blocks in skin and muscle. For every protein chain, there is a corresponding sequence of DNA letters, called a *gene.* Gene length varies from about 200 bases to more than two million bases. The average human gene is about 3,000 bases long. The total number of human protein-coding genes is around 20,000-25,000.

Each DNA letter is important. Loss or gain or substitution of a single letter or group of letters, called *mutation,* can lead to a protein without function. This can cause severe disability (e.g. muscular dystrophy), cancer (e.g. childhood retinoblastoma), or even death (e.g. Tay Sachs disease).

Permutations of the Genetic Code

All life on Earth is governed by a genetic code consisting of three letter DNA words called *codons.* Examples of codons are ATG, ATC, GAC, TCA etc. With the exception noted below, each codon specifies an amino acid. Given that there are four letters in the DNA alphabet and three letter words, there are 64 possible codons, including codons with repeated letters like ATA or GGG (four letters at each of three points in the codon is expressed mathematically as 4 x 4 x 4 = 64).

That means there are 64 different codons for 20 amino acids — in other words, 64 permutations. It means more than one codon can specify an amino acid (actually, sixty-one of the codons specify amino acids; the other three are stop signals that mark the end of growing amino acid chains). The base permutations of genetics, like the letter permutations of Kabbalah and the tonal permutations of music, thereby involve the ordering of uncomplicated symbols that encode more complicated information.

Replication

In the early 1950's geneticists discovered that DNA occurs in the form of a double helix — two chains of bases wrapped around each other in a spiral and connected to each other by weak chemical bonds (Watson and Crick, 1953).

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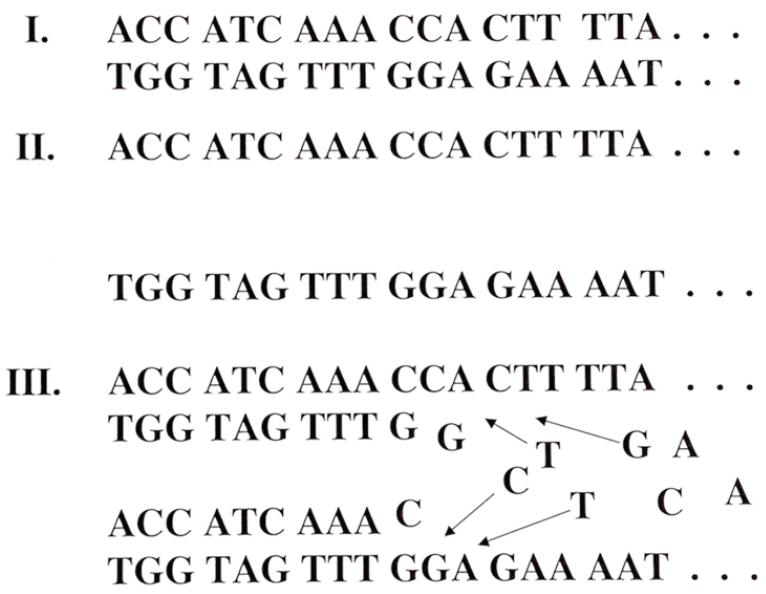
Within the double helix, it's remarkable that A pairs with T, and G pairs with C, because that immediately suggests a way that DNA can reproduce itself. It can *replicate.* The helix unwinds and the old chains serve as templates for the new ones.

In the figure below, Section I shows paired sequences of DNA letters in a double helix. In Section II, the paired sequences are separated. In Section III, new bases are added, forming two copies of the original paired sequences.



To reiterate, A pairs with T and G pairs with C, and thereby the genetic code is conserved in the new double helices. The newly made spirals will have the same sequence of letters as the original double helix. That's why we look like our parents. We inherited their genetic codes.

DNA Music

Genetic sequences can be transcribed directly into musical scores by use of scales consisting of four notes. And these are melodic if somewhat repetitive. But the connection between DNA and music goes beyond that simple relationship. Susumu Ohno, a friend and colleague of one of us (SW) was a pioneering scientist whose work in the late 1980's led to a direct connection between genetic codes and musical notes. Among his original ideas was the notion that just as DNA can replicate, so too can individual genes within DNA chains (Ohno, 1970), and so too can sequences of letters within DNA genes. He called this *repetitious recurrence.*

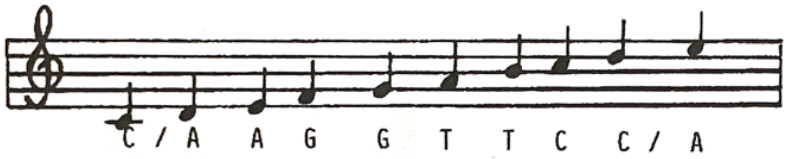
Together with his wife, Ohno shocked the genetics community with a paper entitled: "*The all pervasive principle of repetitious recurrence governs not only*

coding sequence construction but also human endeavor in musical composition." That was in 1986 — in a genetics journal! The Ohno's were saying that sequences of DNA letters *"could be transformed into musical scores"* and vice versa. This idea was based on the fact that certain sequences of letters within genes are repetitions of primordial sequences of letters found in ancestral genes.

"For example," wrote the Ohno's, *"the adaptive immune system of (all) vertebrates has apparently evolved by plagiarizing one ancestral gene."*

We noted above that a gene is a sequence of DNA letters that encodes an amino acid chain in a protein. In their paper, the Ohno's found musical correlates in DNA sequences of a human gene that encodes a protein called PGK (phosphoglycerate kinase). PGK is an enzyme that helps produce energy. They noted that enzymes like this have existed from a time shortly after the establishment of life on Earth. That's why the amino acid sequence of the human PGK enzyme resembles the amino acid sequence of the related enzyme in baker's yeast. And that's why the two enzymes are almost identical in their three-dimensional forms, despite the vast genetic distance between humans and yeast. Repetitious recurrence.

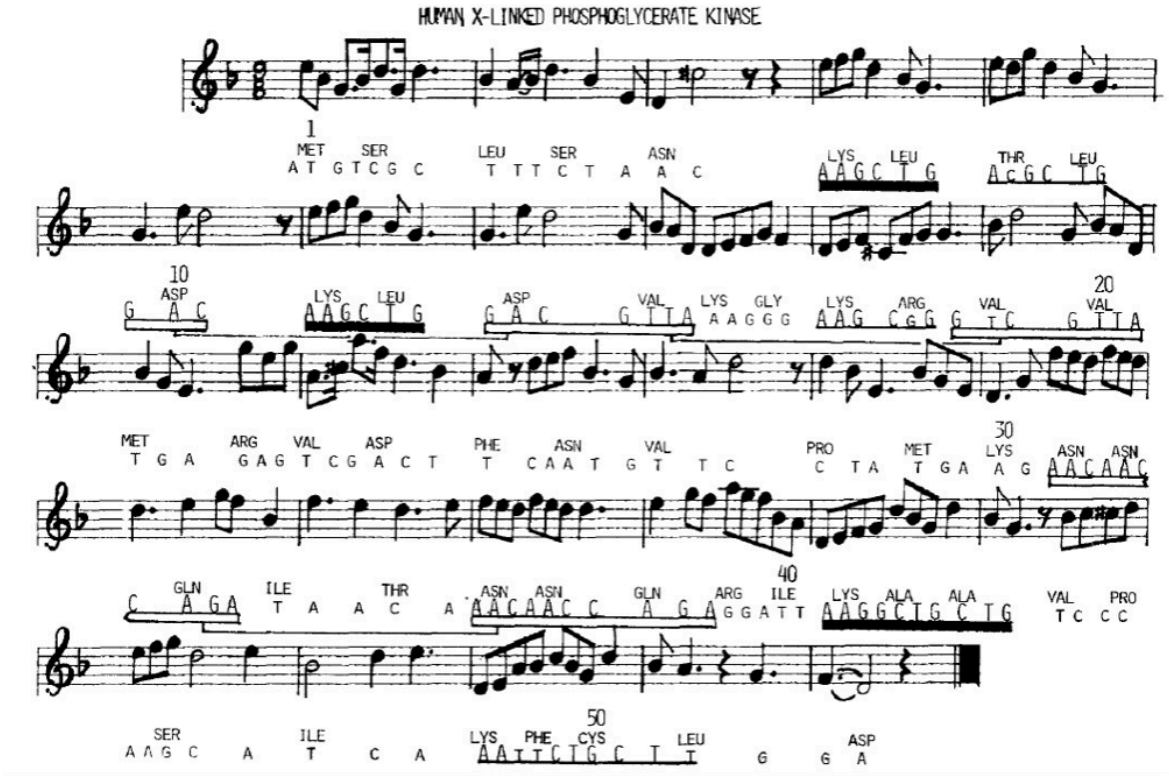
How do we make music from DNA sequences? Because there are eight notes in a musical scale and four bases in DNA, Ohno and Ohno (1986) developed this "inviolate" format for converting genetic sequences to musical sequences.



They noted that a *"primordial building block"* in the human gene that encodes PGK is the base sequence, A A G G C T G C T G. That sequence and a related six-letter sequence, A A G C T G, are found repetitively in the gene. The base sequence was first described in Singer-Sam et al., (1983).

The development of the above scale and the strict logic behind it are beyond the scope of this article. But by using it, the Ohno's were able to assign alternative melodies to the A A G G C T G C T G sequence and a derivative, A A G C T G. They tested the melodies and selected ones that seemed most appropriate. Then they assigned an appropriate key and a time signature.

According to that method, they created a musical score based on the coding sequence for the PKG gene. Here is Figure 3 from their paper, showing correlation of musical notes and DNA bases at the beginning of the human PKG coding sequence. The primordial and secondary DNA sequences are underlined by thick black bars. The three-letter groups above the genetic sequence are abbreviations of the corresponding amino acids.



"Musical transformation of the first 52 codons of the human . . . phosphoglycerate kinase coding sequence . . . in D minor and with a time signature of 9/8. As the piece was written for the violin, only the treble clef musical score is given." From Ohno and Ohno (1986); reprinted by permission.

The Ohno's went on to say that *"repetitious recurrence is still the hallmark of musical composition."* They found another primordial building block sequence, C A A C C T C C C, and a secondary sequence, T A C G G T G, both from the mouse RNA polymerase gene, several times each, in Chopin's Nocturne, Opus 55! The Ohno's concluded, *"The resemblance between (DNA) coding base sequences and musical composition is indeed more than skin deep."*

Strings

Pythagoras of Samos (c.580 - c.495 BCE) is the Greek philosopher and mathematician best known for the theorem that bears his name.

1 - 2 - 3 - 4

Among his other ideas, Pythagoras taught that 1,2,3, and 4 are the most important numbers, because they add up to 10, the *"perfect number"* and the basis of all arithmetic and mathematics.

Pythagoras was among the first to make a connection between music and mathematics by noting that the frequency of vibrations on a stringed musical instrument depends on the length of the string. The longer the string, the fewer the vibrations when the string is plucked and the deeper the resulting tone. This is obvious when comparing the sounds produced by a string bass, cello and violin. Pythagoras observed that cutting the length of a musical string in half raises the tone by one octave. He showed that various intervals (fourths, fifths etc.) could be established by changing the lengths of strings in accordance with strict mathematical rules. Based on his studies, he taught that *the universe is ordered by arithmetic and music — mathematical ratios and harmonies* (Siegfried, 2023).

Pythagoras believed that the Earth is a sphere at the center of the universe. He believed that the various celestial bodies orbiting the Earth produce musical tones according to their speed of movement and their distance from the Earth, and that together, the tones produce harmonics, which he called the *"Music of the Spheres."* Surely the *Kosmos* of Pythagoras differs considerably from the cosmos we know today, yet the potential importance of music on a cosmic scale should not be underestimated.

Today, music is one way physicists can reconcile Einstein's *General Theory of Relativity* (concerned with gravity and massive structures like galaxies and black holes) with q*uantum physics* (concerned with subatomic particles like electrons and protons). At face value, relativity and quantum physics are incompatible because relativistic gravity doesn't fit into the quantum realm, but in the 1980s physicists developed s*tring theory,* which unifies both (Kaku, 2021).

We know that matter is composed of atoms, and we know that atoms consist of a nucleus containing neutrons and protons, with electrons in orbit around the nucleus. Neutrons and protons themselves consist of smaller particles called quarks, and electrons belong to a class of particles that includes muons and neutrinos. Physicists have described hundreds of different subatomic particles, but the great majority of these are unstable and very short-lived.

According to string theory, as defined by one of its proponents, Michio Kaku, Professor of Theoretical Physics at the City College of New York, all subatomic particles are infinitesimal one-dimensional strings arranged like tiny loops, vibrating in multidimensional space-time. *"The subatomic particles that we see in nature . . . are nothing but musical notes on a tiny vibrating string."* (Kaku, 2011; and see Kaku, 2021; and Greene, 2003). In other words, the different particles are really strings vibrating in different ways.

"*What is physics? Physics is nothing but the laws of harmony that you can write on vibrating strings. What is chemistry? Chemistry is nothing but the melodies that you can play on vibrating strings. What is the universe? The universe is a symphony of vibrating strings"* (Kaku, 2011; and see Kaku, 2021).

Mathematics

Each of the fields we have studied rests on an underpinning of mathematics.

Kabbalah: Hebrew letters are more than phonetic because each Hebrew letter is also a number. *Aleph* is the number 1, *beit* is 2, *gimmel* is 3 and so on. It follows that each word is also a number, which adds additional depth to the interpretation of Torah and Hebrew scripture in general. The letters of the creation account thus provide a numerical code of creation.

Music: Mathematics and music are closely interlaced, with tonality, scales, chords and rhythms based on numerical relationships. We said above that Pythagoras showed how octaves and other intervals could be obtained by changing the length and thereby the frequency of a vibrating string according to strict mathematical rules. The same is true for wind instruments, in which case the pitch of a note is determined by the length of a vibrating air column.

Genetics: Like any physical science, genetics relies on mathematics for statistical analysis of experimental data. Moreover, patterns of inheritance, in general, follow strict mathematical rules. Recently physicists, mathematicians and others in the United States and England used *number theory* (study of the attributes of whole numbers) to determine the likelihood that a particular point mutation, i.e. change of a single DNA letter, will affect a change in a physical trait of the affected organism (Mohanty et al. 2023).

String theory: As a science within the domain of theoretical physics, string theory is intimately bound up with mathematics, relying on mathematical equations for expression and analysis of its concepts and proposals. The relation between physics and mathematics is long-standing, originating in part with Newton's use of numbers and numerical equations to express his theses. The close relationship

between string theory and mathematics is based in part on the development of novel conjectures and novel structures calling for novel mathematics such as differential topology (the study of forms that do not change even when deformed — items like a flat square that can be shaped into a circle, but not a hollow sphere, for example).

Synopsis

In demonstrating that string length governs tonality in music, Pythagoras shows how mathematics and music are intimately bound, and it is not hard to see parallels with string theory according to which subatomic particles are one-dimensional strings in hyperspace vibrating like musical strings on a guitar. The mode of vibration of these one-dimensional strings determines what kind of particles they are — photons, electrons, quarks etc. — just as the mode of vibration of guitar strings (controlled by finger pressures) determines what kind of notes they produce.

An easy step forward to Genetics: The DNA code, which controls the fate of all life on Earth, can be used to generate music, and indeed, primordial DNA sequences can be correlated with note sequences in musical compositions. DNA as music. Music as DNA. We have seen that genetic diversity is a direct result of permutations of the DNA code. We noted 64 possible arrangements of the three-letter words (codons) with a four-letter alphabet. That simple scheme is what makes us different from one another, from a chimpanzee, a dandelion or a virus. The same scheme is found in the generation of three-letter groups (words) from the four-letter word "*shalom,"* שלום, described in the section above on *Permutations in Kabbalah.* What would Abulafia think of DNA permutations?

In conclusion, Abulafia finds links between musical tones and his alphabetical permutations, and we can see an interface between any two of the disciplines we have discussed. Letter sequences in Kabbalah can be likened to note sequences in music, and both can be likened to base sequences in the DNA code. We have already noted shared aspects between vibrational modes in stringed instruments and string theory.

As for string theory, we note that this conceptual approach to the reconciliation of Relativity and Quantum Physics suffers from a paucity of experimental evidence to confirm or falsify it (but see Feldman, 2025). Moreover, string theory calls for supernumerary dimensions beyond the four space-time dimensions of Einstein's relativity. We discuss it here for its potential cognates in music and genetics.

We have seen that string theory relates to Kabbalah and genetics through the common attribute of music. Thus, music may be viewed as a prime characteristic of Kabbalah, genetics and string theory, whereas mathematics is a more basic characteristic underlying all four disciplines.

Mathematics provides numerical insights for the interpretation of scripture in Kabbalah. Mathematics is central to the ordering of chords, intervals and rhythms in music. Mathematical guidelines determine the nature of inheritance in genetics. And mathematical equations govern the behavior of vibrating strings in string theory. As to the significance of the shared attributes we have described, further research will determine whether these attributes are more widespread among information-bearing systems or only a fortuitous observation allowing the creation of papers such as this one.

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