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GOLDEN RATIO AND FIBONACCI SEQUENCE: UNIVERSAL FOOTPRINTS OF THE GOLDEN FLOW

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ABSTRACT
Golden Ratio and *Fibonacci numbers* have attracted attention from mathematicians, artists, architects, sculptors and musicians for centuries. *Golden Ratio* was associated with Ancient Greek art and architecture, and named after Greek sculptor *Phidias* (4th and 5th Century BC). *Fibonacci sequence* which is closely related to *Golden Ratio* was discovered by an Italian mathematician *Leonardo Pisano Bigollo* (1170-1250) in 1202. Those two phenomena have created a considerably extensive literature but the studies mainly focused on documenting where we encounter them in human body, in nature, in plants, in animal kingdom, in art and architecture. *Golden Ratio* was also known as *Divine Proportion* since commonly observed in nature. Yet, there have been few arguments or attempts to explain real reasons behind the existence of these numbers in nature and in universe. This study documented literature and collected puzzling pieces from various fields such as ancient philosophers, Far East philosophies, Western philosophy, mysticism, economy, sociology, religious scriptures, botany, psychology, astronomy, physics, mathematics and evolutionary approaches. This study aimed to construct a philosophical theory based on a physics phenomenon that widely influenced many fields including art. The information evolved through literature was used to construct an explanation why *Golden Ratio* and *Fibonacci sequence* existed in the universe. Starting from *Heraclitus* (535-475 BC) of Ephesus, there have been claims that all existence is in a constant flow (Panta rhei) motion. This study suggested *Golden Ratio* and *Fibonacci numbers* as evidences of a constant universal flow motion which could further be supported by many empirical evidences from the literature.

Keywords: *Phi, Fibonacci numbers, Matthew principle, Pareto distribution.*

ALTIN ORAN VE FIBONACCI SAYILARI: ALTIN AKIŞIN EVRENSEL İZLERİ

ÖZ
Altın Oran ve *Fibonacci sayıları* yüzlerce yıldır matematikçilerin, ressamların, mimarların, heykeltıraşların ve müzisyenlerin ilgisini çekmiştir. Antik Yunan sanatıyla ilişkilendirilen *Altın Oran*, Yunanlı heykeltıraş *Phidias* (MÖ 4. ve 5. yy) 'ın adından dolayı *Phi* harfiyle sembolleştirilmiştir. *Altın Oran* ile yakından ilişkili bir diğer kavram olan *Fibonacci sayıları* ise İtalyan matematikçi *Leonardo Pisano Bigollo* (1170-1250) tarafından 1202'de keşfedildi. Bu iki olgu hakkında oldukça geniş bir alan yazın oluşmuştur, bu araştırmalar genellikle *Altın Oran* ve *Fibonacci sayılarına* insan vücudunda, doğada, bitkilerde, hayvanlar aleminde, sanat ve mimaride nasıl rastlanıldığını ortaya koyan çalışmalardır. *Altın Oran* sadece insan yapısı olgularda değil doğada da karşımıza çıkan bir olgu olduğundan *İlahi Oran* olarak da anılmıştır. Buna karşın, *Altın Oran* ve *Fibonacci sayılarına* doğada ve evrende neden rastlanıldığı ve bu sayıların varoluşunun arkasında yatan sebepler hakkında çok az

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tartışmalar ve açıklama girişimleri olmuştur. Bu araştırmada, alan yazına dayalı olarak yap-bozun parçalarını bir araya getirmek için düşünürlerden, Uzak Doğu felsefeleri, Batı felsefesi, tasavvuf, ekonomi, sosyoloji, kutsal metinler, botanik, psikoloji, astronomi, fizik, matematik ve evrimci yaklaşımlar gibi alanlardan parçalar toplanmıştır. Sanat ve pek çok alanı etkilemiş olan bir fizik konseptine dayalı olarak, varoluşsal sorular doğrultusunda bir teori yapılandırılması hedeflenmiştir. Antik Yunan düşünürü *Heraclitus* (MÖ 535-475)'dan başlayarak bütün kâinatın sürekli bir akış hareketi (Panta rhei) içinde olduğuna dair iddialar olmuştur. Bu araştırma, *Altın Oran* ve *Fibonacci sayılarının Heraclitus*'un iddia ettiği gibi bir akışın göstergeleri olabileceğini ve literatürde yer almakta olan pek çok araştırmanın bu iddiayı destekleyebilecek empirik deliller içerdiğini ortaya koymaktadır.

Anahtar Kelimeler: *Phi, Fibonacci sayıları, Matthew prensibi, Pareto dağılımı.*

INTRODUCTION

Greek letter Φ (φ, *phi*) is the first letter of legendary Ancient Greek sculptor *Phidias* (Died 430 BC), therefore it was offered by mathematician *Mark Barr*, to be used as the symbol of *Golden Ratio*, and has been used widely ever since. Various phrases in different languages have also been used alternately for *Golden Ratio*. Some of these phrases are: *Section d'Or (Fr.); Golden Section; Golden Mean; Golden Cut; Divine Section; Divine Proportion; Sectio Aurea (Lt.); Sezione Divina (It.).* It was indicated that *Golden Ratio* was discovered by Pythagoras and that it was through him that the true knowledge of this ratio began to be understood. "It is believed that the Greek Philosopher *Pythagoras* discovered the concept of harmony while listening to the different sounds produced as the blacksmiths' hammers hit their anvils" (Thapa & Thapa, 2018: 191). Markowsky (1992) makes a distinction between the terms "golden mean" and "golden ratio".

"Golden mean" was used in classical times to denote "the avoidance of excess in either direction". On the other hand, the term "golden mean" used to denote the golden ratio in different occasions. The confusion might have led people to conclude that "golden mean" was used in classical times to denote the golden ratio (p. 5).

Φφ

From *Leonardo Da Vinci* to *Le Corbusier*, many artists and architects knew *Golden Ratio*, they were influenced by it and they used *Golden Ratio* in their works throughout the ages. There were also claims that *Da Vinci* was used it in his masterpiece *La Gioconda*, Dutch painter *Mondrian*, and Spanish painter *Salvador Dali* also used *Golden Ratio* in their works. It was also used and observed in Ancient Greek and Roman Arts and throughout Renaissance. So, *Golden Ratio* and why it has been used passionately for thousands of years largely debated.

Italian mathematician *Luca Pacioli* (1445-1517) makes comparison between the incomprehensibility of God and the fact that the *Golden Ratio* is an irrational number. In his own words: "Just like God cannot be properly defined, nor can be understood through words, likewise our proportion cannot be ever designated by intelligible numbers, nor can it be expressed by any rational quantity, but always remains concealed and secret, and is called irrational by the mathematicians (Livio, 2008: 132). In essence, in a geometric shape, when longer edge divided by shorter edge is equal to 1.61803398875, it is considered as Golden Ratio and shown with φ (phi) in mathematics and art, as shown below in a Golden Triangle:

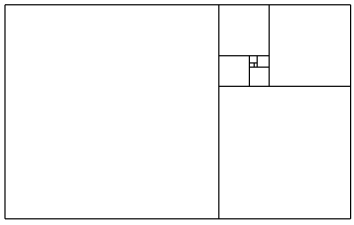

Figure 1. Golden rectangle

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Golden Ratio is a constant integer which is observed both in nature and also in human-created forms. It is claimed that the more a figure approximates this constant the more it gets closer to the universal human taste and preferences. However, it is still debated whether human aesthetical taste and preferences have such nature. *Fibonacci Sequential numbers* is examined under another section which is also a popular topic of discussion closely associated to *Golden Ratio.*

Observances of *Golden Ratio* is also not limited with human taste and preferences, in a study, psychometric data analyses and theoretical considerations revealed that the *Golden Ratio* underlies the clock cycle of brain waves (Weiss & Weiss, 2003). It was also confirmed in an empirical study in 2008 by a group of neurobiologists (Roopun et al., 2008). In 2010, the journal Science reported that the golden ratio is present at the atomic scale in the magnetic resonance of spins in cobalt niobate crystals (Nikolic et al., 2011: 8349). In a study (Yetkin, et al., 2014) it was shown that human heart beats in a ratio of 1.618, in addition electrocardiographical diastolic and systolic time intervals yielded a very close ratio to 1.618... Furthermore R–R/diastole ratio was 1.618 similar to the first described pattern by Euclid (p. 1459).

Figure 2. Pieces of the puzzle.

METHODOLOGY

This study aimed to construct a theory based on an unexplained natural phenomenon that widely influenced many fields including art. The question of why we encounter *Golden Ratio* in universe so often and in such a large scale is also considered an existential philosophical question. The current study discusses this phenomenon within their philosophical aspects based on empirical evidences laid out in the literature. The philosophical framework of this study is not qualitative but the theory construction approach may be rather comparable to grounded theory. Grounded theory is a qualitative research model that attempts to uncover the meanings behind qualitative data. Qualitative information may include social interactions, cultural ques and personal experiences (Merriam, 1998: 17). Gathered data is called grounded because they are grounded to either shared experiences or individual subjective experiences. Barney Glaser and Anselm Strauss suggested this research model in their 1967 book, *The Discovery of Grounded Theory* (Glaser & Strauss, 1967). The grounded theory approach has been used by researchers in various disciplines such as social sciences, art, economics and public health.

The inductive method in grounded theory approach allowed the analysis of data during the collection process. Grounded theory is a method of building theory from the ground up. Why do we consider it an interpretative method? Simply put, theories are organized meaning claims. The role of any theory is to make sense of what is happening in a particular setting" (Shank, 2002: 78). Over the years the two founders of grounded theory drifted away from each other, as they pursued different approaches to extending the ideas and methods of the original theory. While the grounded theory was evolving, Glaser felt that grounded theory was in danger of becoming too mechanical. His later work was based on his

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desire to make sure that the approach remained sensitive to the need to treat the creation of grounded theory as an organic, ongoing process. He rejected the use of rules for data gathering and manipulation in favor of procedures to keep the researcher open and aware of new possibilities of meaning within the emerging data record (Shank, 2002: 78-79).

Historical records and approaches related to *Golden Ratio* included both qualitative and quantitative data. Although, *Golden Ratio* and *Fibonacci numbers* required observations and rigorous math calculations to discover their nature; both phenomena have been also subject to philosophical discussions in art and science. Interpretations and inferences regarding the existence of these phenomena are depended on religious, theoretical and philosophical discourses throughout the ages. Qualitative data and interpretations constructed a rich scientific literature but they were insufficient somehow to explain their reasons of existence in nature and in universe. As we already know, "a piece of research could be valid if it were used to build theory, without the researcher having to go on and test that theory" (Shank, 2002: 78). This study used an inductive method to collect existing information based on interpretations and discourses which pointed out and shaped a new theoretical direction nevertheless.

Figure 3. Finding the correct pieces.

Bringing Pieces Together: Evolutionary Perspective

Studies in the literature mainly focused on where and how it is observed in nature. Besides belief-based explanations, there also have been attempts to bring an explanation for the existence of Golden Ratio phenomenon, but it is still usually considered as a mystery. Adrian Bejan, an academic at Duke University, claimed to have found why human aesthetical preferences oriented towards such an equation. According to Bejan, human eyes track, perceive and identify visual phenomena faster when they are structured based on *Golden Ratio* and the reason why we encounter this ratio on animals and in nature is that they are evolved together as a whole (Bejan, 2009: 101 and 103).

Humans scan the world on a two-dimensional screen approximated by a rectangle with the shape L/H~ 3/2. We scan the long dimension faster than the vertical dimension, in such a way that to scan long and fast takes the same time as to scan short and slow. This is the best flowing configuration for images from plane to brain, and it manifests itself frequently in human-made shapes that give the impression that they were 'designed' according to the golden ratio (Bejan, 2009: 101).

We un-consciously, promptly and effectively direct our gaze towards and prefer visuals and objects fitted to *Golden Ratio. Golden Ratio* is the proper ratio for a reading paragraph, we un-consciously perceive and apply this intuitive regulation whenever possible. McVeigh (2009) explains *Golden Ratio* based on an evolutionary perspective that our visual and perceptive processes evolved during the longest period of our evolutionary history in the African savannahs. From Ancient Greek to Renaissance, many artists and architects including Da Vinci, used Golden Ratio effectively in their paintings, sculptures and designs, they specifically preferred a certain proportion of Golden Rectangle.

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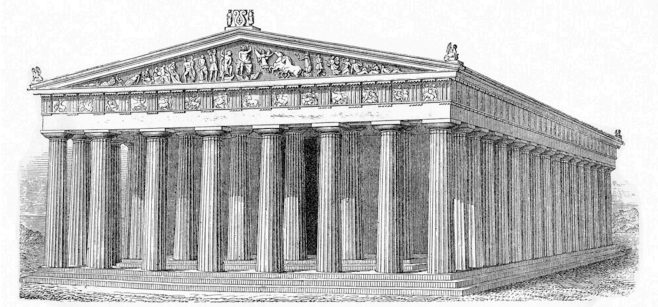

Figure 4. Parthenon, 432 BC, Athens

Source: URL-4

Da Vinci's famous painting *La Gioconda* (Mona Lisa) and *Parthenon* in Athens are often related to *Golden Ratio*. Some argue that *Golden Ratio* on the facade of *Parthenon* is coincidental, nevertheless, *Golden Ratio* is the best proportion to be perceived by human brain whether it is intentional or coincidental (McVeigh, 2009). Markowsky (1992) claimed that existence of *Golden Ratio* on *Parthenon* is not correct and popular opinions stem from measuring miscalculations (p. 9). In our evolutionary process, we attentively scanned, searched, perceived and explored possible dangers in nature and it was an intense and exhausting experience. So, we needed less demanding and efficient ways of this experience. For instance, animals genetically hardwired to feel good when they find food, shelter and mate. On the other hand, we, humans are hardwired to feel pleasure when we see something marked with *Golden Ratio*; furthermore, we identify it as attractive.

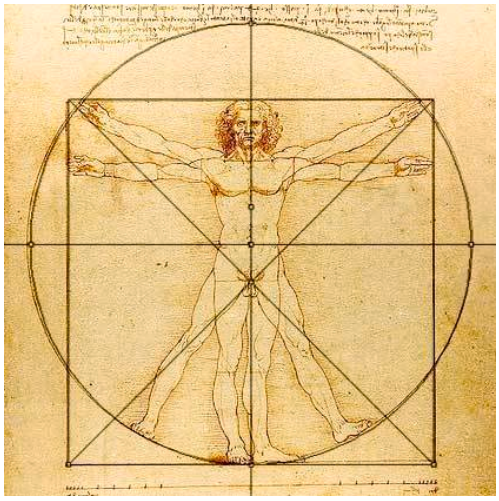

Figure 5. Leonardo Da Vinci, Vitruvian man.

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Adrian Bejan (2009), developed a new law of physics in 1996, governing the design of matter as it moves through air and water. He believes this "law of construct" governs systems that evolve in time, from cars in traffic to blood in the circulation, to how vision develops. Vision and cognition evolved together, he said. "Cognition is the name of the construct-based evolution of the brain's architecture, every minute and every moment," Bejan said. "This is the phenomenon of thinking, knowing, and then thinking again more efficiently. Getting smarter is the law of construct in action" (Bejan, 2009: 101).

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Bejan developed an argument to explain why so many things are designed and constructed around a universal number, and he suggested that everything evolved together. Animals' vision for example, may have evolved a certain horizontal ratio to scan nature effectively, and this ratio is 1.618. His argument may seem plausible in evolutionary aspects of nature in many ways, but Bejan's theory is still unable to explain why all other living organisms effectively followed this number but not another number. *Golden ratio* is observed in many natural and living phenomena, not only in organisms that evolved together. Furthermore, golden ratio is not unique to our planet, it is also observed in the physics of universe and in the physics of galaxies as well, so it must be a governing law of universe. The question remains "why is it this particular number?"

Bringing Pieces Together: Panta Rhei and Matthew Effect

Pre-Socratic period philosopher *Heraclitus* (535-475 BC) believed that everything in universe is part of a universal flow (*Panta rhei:* Everything flows), everything is part of a constant flow movement; therefore, you cannot bath in the same river twice, since neither river is the same river, nor you are the same person. According to *Spinoza*, universe is a big single system in which everything moves together as part of a flow. The idea that everything flows is observed in *Taoism*, in *Zen* philosophy, and also in *Rumi*'s philosophy and mysticism. According to this idea, the universe from the minuscule simplest forms and subatomic particles to the motions of galaxies moves constantly as a whole single system. This constant flow motion could be observed everywhere from plants' structures to animals, and human anatomy and proportions. Water flow motion and its pattern is an example. We usually tend to expect and observe flow motion in liquids but not in solids. However, the flow motion *Heraclitus* pointed is not limited with water and liquids, solid objects such as snail's shell or shape of a pinecone also show clear signs of a universal flow motion. The geometry and mechanics of this flow motion is structured based on *Fibonacci Sequence*, and this systemic sequence is a number system somehow related to *Golden Ratio*. If everything in nature and in universe is structured and governed based on a single flow pattern and geometry, could it be a sign of a universal harmony and everything is a whole uniform system moving together? Ian Afflect, a physicist at University of British Columbia, reported in his article that *Golden Ratio* had been spotted in a magnetic compound (Afflect, 2010: 1-2). It is not surprising, if we are all moving in uniformity through the space through a certain motion which has a *Fibonacci Spiral* pattern, all particles and energy fields are also expected to behave within this uniformity.

Figure 6. *Fibonacci spiral* motion is observed in a galaxy photograph taken by Hubble telescope.

Source: URL-6

Matthew Effect of accumulated advantage is first coined in the literature by American sociologist *Robert K. Merton* in 1968. *Matthew Effect* takes its name from a verse in the *New Testament* (Matthew 25:29). The Bible verse verbatim is "For to him who has will more be given; and from him who has not, even what he has will be taken away." (Matthew 25:29). In sociology it was interpreted as the existing advantages will bring more advantages; in economy it was translated as the rich get richer and the poor

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get poorer. On the other hand, there is another phenomenon about the distribution of wealth in a society or the distribution of labor in a company. *Pareto Distribution* is also called 80/20 rule, for instance, in a given company 80 percent of the job is done by the 20 percent of workers. A similar principle, *Price's Law* says that 50% of work at a company is done by a small number of people. Specifically, it says that 50% of work is done by the square root of the number of employees (Peterson, 2019, May 27). Economists sometimes call *Pareto Distribution* as *Matthew Principle*. Peterson (2020, June 4) mentions that 85 richest people in the world have more money than the bottom two billion people that is a *Pareto Distribution* phenomenon. Peterson suggests that contrary to common belief it is not a product of capitalism, it is a natural law, no matter what society you study, you observe a similar *Pareto Distribution* of wealth.

You get a *Pareto Distribution* of number of records recorded; you get a *Pareto Distribution* of songs written or goals scored, any creative product has that characteristic. It is partly because as you start to become more successful, people offer you more and more opportunities; paradoxically, as you start to fail people move away from you and you plummet. Unfortunately, there is always a landscape of inequality and we do not have a plausible solution for this inequality. Maybe you could modify a *Pareto Distribution* of wealth, but we don't know how to do it without disrupting the system so completely that it collapses, which is what happened in the *Soviet Union* and in *Maoist China*. Those systems, in principle, were trying to adjust inequality but the cure was far worse than the disease. Another thing is that we don't know technically how much inequality there has to be to generate wealth, but we do know that it is inevitable and we don't know how to regulate it (Peterson, 2020, June 4).

"For to him who has will more be given;
and from him who has not, even what he has will be taken away."
(Matthew 25:29).

With its common interpretation, this verse does not seem so egalitarian and does not seem consistent with Christian values. So, what might this verse exactly mean? Jordan Peterson brings an alternative existential explanation to this Bible verse. According to Peterson (2020, June 4), when things are going backward in life, we should take incremental successive steps forward until we accumulate and gain a momentum instead of chasing big objectives which might bring hopelessness.

If everything in life is connected to everything else and those things are all part of a universal flow; we may allegorize that flow to a bathtub of water flowing through the drain as a whirlpool. A little hay grain is floating steadily at the far end of the vortex, and this little hay grain has to wait long time until it gains momentum with the flowing water. We could compare this hay grain to someone young and inexperienced. He will need to read, study, learn skills and struggle until he moves himself and gains momentum. However, it may take a while until enough advantage is accumulated to move himself, all the labor and hard work may just be a little touch for the little hay grain while it is still far away from the vortex, nevertheless each and every touch will bring it a little closer. Although, at the beginning all the struggle and patience may seem pointless and futile, they will eventually pay off; they are actually little touches that bring him closer to the flow.

"Those who flow as life flows know they need no other force."
—Lao Tzu

During this long and demanding course of time, every book read, everything learned, all new experiences, all the labor and hard work will continue accumulating advantages as incremental pushes. Eventually, after a long period of time, the hay grain will get closer to the circular waves of vortex, and will start to move gradually, and eventually will get faster and faster. When it gets closer to the center of vortex, it will take longer leaps much more quickly. Eventually, all the labor, effort and hard work will bring results. When the hay grain is moving rapidly as it gets closer to the vortex, someone from

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outside might observe and think how lucky the hay grain is. Nevertheless, its speed and quick move is not because of luck but years of labor, work and effort. *Matthew Effect* is the successive results of these accumulated advantages as explained allegorically. This principle suggests that no effort will be left unpaid. If they quit their efforts, while they are at great distance to the vortex, they will lose what they have; but, when they get closer to the center of vortex all their efforts and hard works will pay back exponentially. The power behind Hegel's dialectic approach to explain history may possibly be *Matthew Principle*. According to *Matthew Principle*, accumulated negative influences and positive influences will create historical up and down events that will eventually create trends and then dialectic progresses.

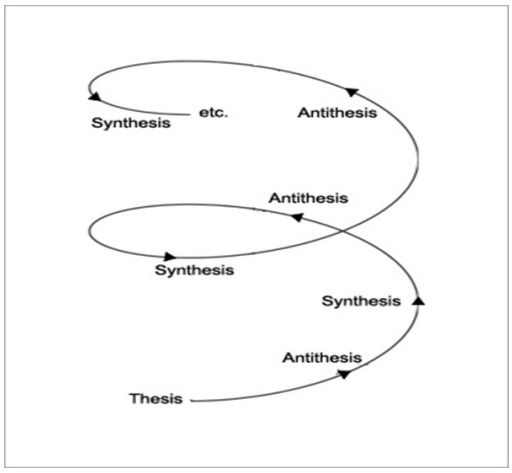

Figure 7. Dialectic progress and historical flow according to Hegel.

Figure 8. The flow in Vincent Van Gogh's Starry Night.

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Why Do We Incline Toward Beauty?

A management expert, Gary Hamel described great design as, "you know it when you see it", and you want it, too: brain scan studies reveal that the sight of an attractive product can trigger the part of the

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motor cerebellum that governs hand movement. Instinctively, we reach out for attractive things; beauty literally moves us (Hosey, 2013). Why does good design or beauty attract us? German researchers found in 2012 that just glancing at shades of green can boost creativity and motivation (Lichtenfeld, Elliot, Maier and Pekrun, 2012). It is not surprising from an evolutionary perspective that we associate green shades with life, nourishment and vegetation. Hosey (2013) also reported that window views of landscapes can speed patient recovery in hospitals, aid learning in classrooms and spur productivity in the workplace. We could also get the same effect with photographs and artworks.

We also experience similar results through geometric forms based on *Golden Ratio*. This almost magical number approximates a ratio of 5/8. We observe this ratio in many famous artworks, *Stradivarius* violins, TV panels and even in the first-generation iPods. Human perception and aesthetical preferences may show a universal inclination for similar geometric patterns featuring *Golden Ratio*. From snowflakes to leaf growing patterns of plants, snail shells to riverways, patterns featuring repetition of geometric forms based on *Golden Ratio* are also observed very often in nature (Fibonacci Sequence). "When a square is subtracted from a golden rectangle, what remains is another golden rectangle, and so on and so on, what it results is an infinite spiral also known as Fibonacci Spiral" (Hosey, 2013). In recent years, physicists have found that people invariably prefer a certain mathematical density of fractals, not too thick, not too sparse. This particular pattern echoes the shapes of trees, specifically the acacia tree, on the African savanna, the geography our longest evolutionary history took place (Hosey, 2013). Evolutionary explanations may show our genetically hardwired leaning and preferences toward *Fibonacci sequence* or *Golden Ratio*, but they still are unable to explain why at the first place the nature is configured around these numbers?

"Jackson Pollock canvases now known to conform to the optimal fractal density (about 1.3 on a scale of 1 to 2 from void to solid)" (Hosey, 2013). Could Pollock's paintings result from his intuitive evolutionary instincts our species share universally? Lance Hosey pointed that "we respond so dramatically to this pattern that it can reduce stress levels by as much as 60 percent". This perspective is also consistent with Dutton (2009)'s evolutionary theory of beauty, what we find beauty and how we respond to it is genetically hardwired in our brain and senses throughout our evolutionary history. On the other hand, based on his examples Livio (2008: 180-183) claimed that human preferences actually showed no inclination toward Golden Ratio.

Golden Ratio: Evolution or Sacred Geometry?

Golden Ratio has been also called as *Divine Proportion* in Europe throughout history, a sacred geometry seen in artworks, in architecture and in nature. Interestingly, it is also observed in many plants and even in human body proportions. If it is not a human construct, why is it a common pattern in nature? Could it be coincidental? Many people, especially Christians in Europe thought that it was a signature of God, his expression, a sacred number behind God's creation, evidence that everything is created by God. Another interpretation offers an evolutionary perspective and it suggests that *Golden Ratio* is a result of evolution. According to Darwinian Theory not only human species but all living beings went through a long and slow evolutionary process, they went through natural and sexual selection processes and eventually have come to their forms, evolution is also a living process and organisms are all still evolving.

Adrian Bejan suggested that animals' vision have evolved a certain horizontal ratio to scan nature effectively, and this ratio is 1.618 (Bejan, 2009). Bejan's theory is still unable to explain why all other living organisms effectively followed this number but not another number. The evolutionary argument that living organisms evolved together so that they are oriented around a certain ratio may seem plausible at some point but it is still unable to explain real causes behind the *Golden Ratio* phenomenon. Because *Golden Ratio* and *Fibonacci sequence* are observed in the planetary systems and galaxies, and seem rather universal. Evolutionary approaches try to explain human choices, aesthetical taste and preferences based on natural and sexual selection processes oriented toward *survival* and *replication*. Our ancestors'

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choices and preferences were epigenetically inherited when they were useful in natural and sexual selection processes, in another word they were inherited when they provided *survival* or *replication* value for our species in the long run. This epigenetic inheritance explains our certain preferences and tastes that we wouldn't be able to explain otherwise. For example, within this evolutionary understanding, we were able to explain why green color enhanced our creative impulses (Lichtenfeld, Elliot, Maier and Pekrun, 2012).

However, evolutionary approaches in regard to *Golden Ratio*, do not usually take gravity into consideration. When we examine plants, we see that growing is a vertical motion against horizontal structure of earth. We observe that many cultures for that reason associate death with horizontal orientation and life with vertical orientation. A plant sprouting from a seed shows a powerful vertical directional move upward against the power of gravity. While the plant grows rapidly at the beginning, then gravitational force slows it down gradually. Without the existence of gravitation, plants would have grown upward or maybe into uncertain directions for perhaps tens and hundreds of meters, but with the pulling force of gravitation, growing heights reach to their optimal limits which also may be thought to be their evolutionary limits. If examined we can see that internodes on plants and tree branches get shorter while they grow. Usually, each internode after the previous one gets gradually shorter on plant trunks and branches. According to Fibonacci, these internodes show growing distances on a plant branch and they follow a certain fractional geometry which is called *Fibonacci sequence*. This structural development can be observed on internode distances, number of branches, leaf numbers and orientations. This structural orientation provides also optimal sun exposure for the leaves. Seed arrangement on sunflowers follows a golden spiral pattern as claimed to "optimize the number of seeds in a limited space" (Hemenway, 2005, as cited in Ioasa, Morone, & Paolucci, 2018).

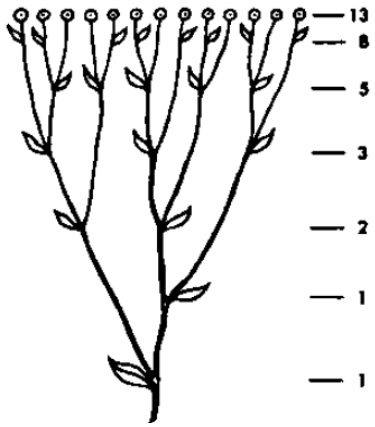

Figure 9. Structural growth geometry of a plant based on Fibonacci sequence.

Fibonacci Sequence (Fibonacci Numbers)

Golden Ratio and *Fibonacci Numbers* are closely related concepts. *Fibonacci Numbers* are sequential numbers with specific mathematical characteristics. Fibonacci, also known as *Leonardo Pisano Bigollo* (1170-1250) who discovered these sequential numbers in 1202 was an Italian mathematician. *Fibonacci sequence* includes the numbers below:

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, ...

Mathematical formula for *Fibonacci sequence also includes Golden Ratio:*

$$F(n) = \frac{\varphi^n - (1-\varphi)^n}{\sqrt{5}} = \frac{\varphi^n - (-\varphi)^{-n}}{\sqrt{5}}.$$

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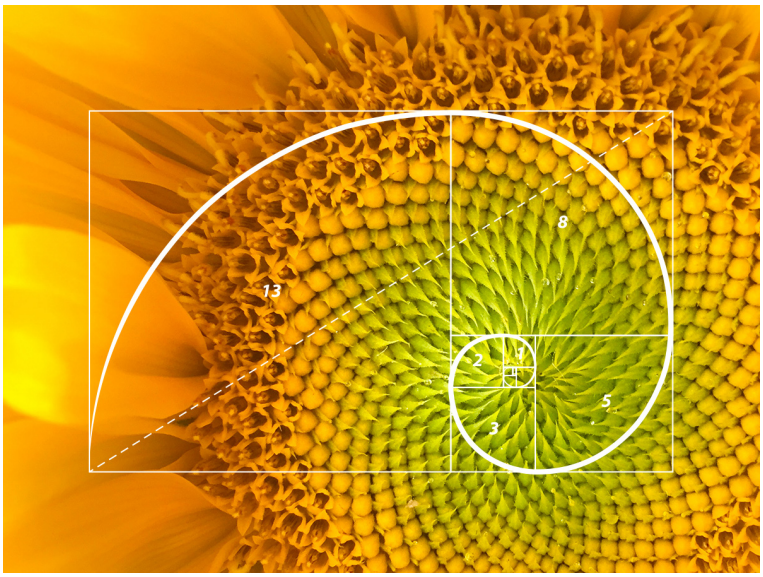

Figure 10. Fibonacci spiral on sunflower

Source: URL-10

In *Fibonacci sequence*, starting from the beginning if a number is divided by the previous number the resulting fraction approximates the *Golden Ratio* and if we continue it gets incrementally closer to *Golden Ratio* every time; and finally, the *Golden Ratio* signifies the limit number in *Fibonacci sequence* as shown on the formula:

$$\lim_{n\to\infty} \frac{F(n+1)}{F(n)} = \varphi.$$

The *Fibonacci Spiral* below is getting closer to the *Golden Spiral*. A *Golden Spiral* is a logarithmic spiral with a growth factor of *Golden Ratio*. That is a *Golden Spiral* gets wider by a factor of φ (Phi) for every quarter turn it makes. *Golden Ratio* and its derivatives provide wide opportunities; therefore, it attracted attention of not only mathematicians but also artists and architects, provided inspiration for artists throughout the history. It was reported that

The distribution of coronary arteries reveals a morphological spread that follows Fibonacci series of 2,3,5,8, and 13. The arteries are distributed sequentially not only to closely resemble phyllotaxis seen elsewhere in nature but also to reveal an underlying association with the *Golden Ratio*. Studying data from 36 mammalian species has shown that the association of cardiac diameters by the sum of the diameters of all 13 branches across these species is in the order of the Golden Ratio's 1.618. It has also been reported that diseased atherosclerotic lesions in coronary arteries follow a Fibonacci distribution (Thüroff, Hort & Lichti, 1984).

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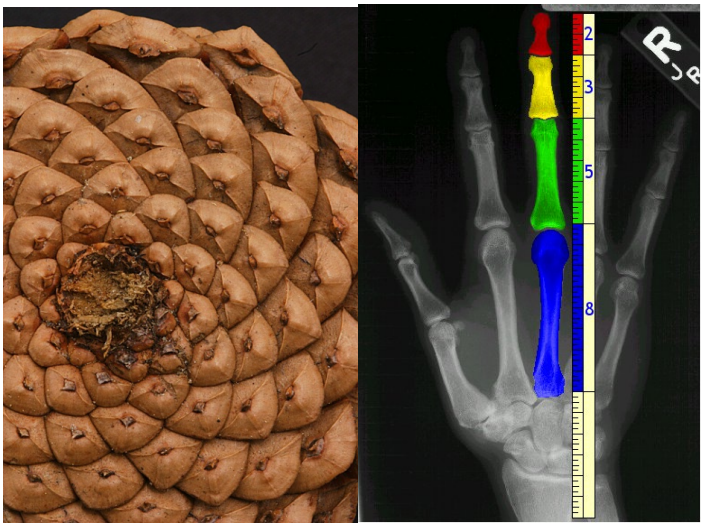

Figure 11 and 12. A pinecone with Fibonacci spiral and Fibonacci numbers on human hand.

Source: URL-11-12.

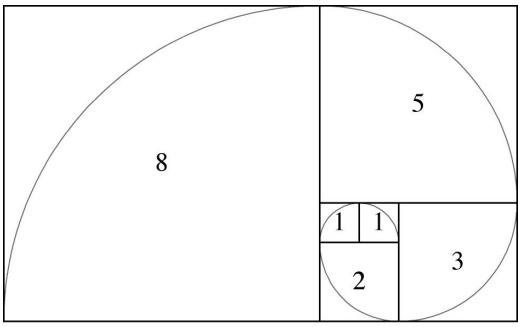

Figure 13. Fibonacci Spiral

Italian mathematician *Luca Pacioli* (1445-1517) published his work *Divina Proportione* (İlahi Oran) in Venice in 1509. *Pacioli* states that:

Just as God conferred being to the entire cosmos through the fifth essence, represented by the *dodecahedron*, so does the *Golden Ratio* confer being to the *dodecahedron*, since one cannot construct the *dodecahedron* without the *Golden Ratio*. He adds that it is impossible to compare the other four *Platonic solids* (representing earth, water, air, and fire) to each other without the *Golden Ratio* (Livio, 2008: 132).

Golden Ratio was only known by the mathematicians until *Pacioli* wrote his book. Finally, with *Pacioli*'s book, the *Golden Ratio* started to become available to artists in theoretical treatises that were not overly mathematical, that they could actually use (Livio, 2008: 136). Later, Kepler discovered that "the ratio of consecutive *Fibonacci numbers* converges to the *Golden Ratio*" (Livio, 2008: 152). *Kepler* thought that God used the *Golden Ratio* as a tool while creating the universe. *Kepler* was also aware of the appearance of the *Golden Ratio* and *Fibonacci numbers* in the petal arrangements of flowers (Livio, 2008: 154). Livio claimed that artists did not know, therefore it was not possible for the artists to follow the *Golden Ratio* until Pacioli published his book in 1509 (Livio, 2008: 162).

According to Mario Livio (2008), there have been hypes about the *Golden Ratio* and most of the tales are just irrational speculations. He also pointed out that *Mona Lisa* painting has been the subject of so

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many contradicting scholarly and popular speculations that it would be impossible to reach any conclusions; therefore, Livio suggested that it is just another speculation that *Golden Ratio* is found in the dimensions of a rectangle around *Mona Lisa*'s face (p. 162). In the recent years, there have been attempts to quantify facial beauty into *Golden Ratio* (Prokopakis et al. 2013). It should be remembered that *Golden Ratio* is meaningful when it is a part of *Fibonacci* sequential structure in nature, but using simple variations of *Golden Rectangles or Golden Triangles* may not succeed attraction as expected and they could be seen as marketing strategies, how it is observed in nature should be understood first instead. Markowsky (1992) explained misconceptions about *Golden Ratio* and noted conscious or unconscious miscalculations of Golden Ratio on objects. "He explained that measurements of real objects can only be approximations".

Surfaces of real objects are not perfectly flat. Furthermore, it is necessary to specify the precision of measurements and to realize that inaccuracies in measurements lead to greater inaccuracies in ratios. Thus, someone eager to find the golden ratio somewhere can alter two numbers by approximately 1% and alter their ratio by roughly 2% (Markowsky, 1992: 5).

Figure 14. Fibonacci spirals in nature.

Source: URL-14

CONCLUSION

There have been attempts to explain why we experience *Golden Ratio* phenomenon based on evolution. Bejan (2009) suggested that shapes with 3/2 length to height ratio appear to breath and flow (p. 99). He suggested that evolution around *Golden Ratio* was an efficient, effective and necessary course in the long evolutionary process. However, he does not explain why *Golden Ratio* was an efficient and effective course in the evolution and why each and every living organism, inorganic compounds and even the universe itself agreed on such a number. Adrian Bejan (2009) tries to explain various uses of *Golden Ratio* based on evolutionary principles. According to Bejan:

The evolution of writing, toward simplicity and universality (one alphabet), is one phenomenon of design generation. The evolution of languages, and the emergence of English as a global language, is another example. The evolution of book design, library design, currency design, photography, eyeglasses, dashboard and computer screen design is the same phenomenon of facilitating the flow of information between the page and the brain (Bejan, 2009: 99).

The literature about *Golden Ratio* and *Fibonacci sequence* is largely based on examples from nature, art and music. These phenomena attracted great attention ever since they were explored in the history. There have been many articles documenting *Golden Ratio* in nature and in man-made artifacts and art forms.

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However, there have not been many explanations regarding their origins and how these two phenomena originated and observed everywhere. One possible explanation associated them with evolutionary principles with some shortcomings. The oldest explanation about the existence of these phenomena associated them with divinity.

Although there have been attempts to explain existence of *Golden Ratio* by means of evolution, these attempts were only able to explain process how things evolved together in time. Evolutionary process started on earth starting millions of years ago; however, we also observe *Golden Ratio* and *Fibonacci sequence* in other parts of the universe. Therefore, it must be something besides our planet; it must be something within and beyond the borders of earth. Human perception is limited with our familiar classification of matter as solid, liquid and gas. We usually tend to think that flow motion is something rather uniquely related to liquid and gas. We perceive our world as solid objects, materials and substances within their spatial relationships. We also perceive negative space that is the remaining void without substances. *Classical Mechanics* which is the description of mechanical events those that involve forces acting on matter, using the laws of motion and gravitation formulated in the late seventeenth century by English physicist *Sir Isaac Newton* (1642–1727). Likewise, the common perception is that gravitational forces acting on matter and mass individually and separately as they are situated in the space. However, today we know that flowing motion does not uniquely belong to liquids, and we know that space does not consist of mass and void. In other words, everything is connected to everything else. Whether we realize or not everything is moving together as part of a flow motion. Newton's *Classical Mechanics* was a breakthrough in the history to understand mass, gravitational forces and motion. Therefore, the constant flow motion of the universe also must be closely related with these forces.

Furthermore, as we already know *Golden Ratio* and *Fibonacci sequence* are observed in nature and in many aspects of life. *Golden Ratio* underlies the clock cycle of brain waves (Weiss & Weiss, 2003), *Golden Ratio* is present at the atomic scale in the magnetic resonance of spins in cobalt niobate crystals (Nikolic et al., 2011: 8349). *Golden Ratio* had been spotted in a magnetic compound (Afflect, 2010: 1-2). Human heart beats in a ratio of 1.618, in addition electrocardiographical diastolic and systolic time intervals yielded a very close ratio to 1.618 (Yetkin, et al., 2014), furthermore R–R/diastole ratio was 1.618 similar to the first described pattern by Euclid (p. 1459). The flow motion that *Heraclitus* claimed is not limited to water and liquids, solid objects such as snail's shell or shape of a pinecone also show clear signs of a universal flow motion. The geometry and mechanics of this flow motion is clearly structured on *Fibonacci sequence*, and this systemic sequence is a number system somehow pointing to *Golden Ratio*.

On the other hand, many artists in the history utilized and imitated *Golden Ratio* in their works, they employed *Golden Ratio* sometimes as Golden Rectangle, Golden Triangle or sometimes used it in their compositions with expectations that their works would conform to viewers' aesthetical taste. All of these approaches were aesthetical quests aiming to reach beauty and grazia in art. These resolutions show that artists were fascinated by it but they did not have an idea why *Golden Ratio* phenomenon was part of nature and existence. The reality behind this number and Fibonacci sequence seems sophisticated. As previously explained, there have been historical claims and philosophical theories that universe is in a constant flow motion, everything is part of this flow and they must reciprocate the physical dynamics of this flow. *Classical Mechanics* and the laws of motion are fundamental to *Newtonian Physics*, and it seems that universal flow motion is also part of these universal laws of physics. If this is true and we better understand this universal flow motion, our perception of life and existence may also change consequentially.

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