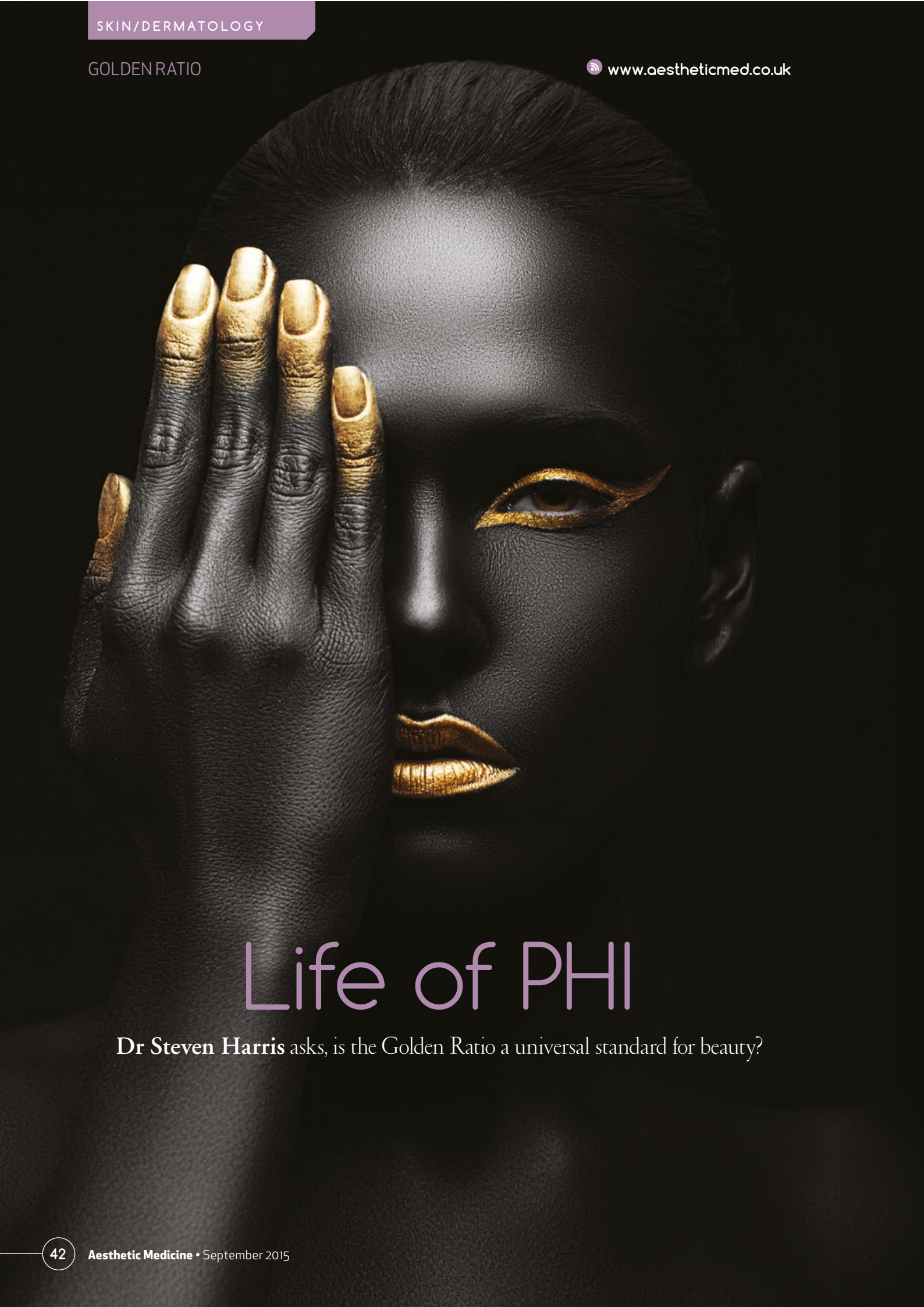

Life of PHI

Dr Steven Harris asks, is the Golden Ratio a universal standard for beauty?

According to astrophysicist Mario Livio, the Golden Ratio, or Phi, also known as the 'Divine Proportion', "has inspired thinkers of all disciplines like no other number in the history of mathematics."[1] Indeed, from the Parthenon statues of Ancient Greece to modern day aesthetic medicine, the Golden Ratio has been associated with all forms of beauty, both natural and man-made.

In spite of its truly amazing mathematical properties, the Golden Ratio has also been the subject of a great deal of controversy, with many disputing its historical role in both the arts and the sciences. The passionate debate continues about whether artists like Da Vinci and Michelangelo applied the ratio to create their masterpieces and whether the Golden Ratio may in fact be applied as a universal standard for beauty including the human face.

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THE NATURE OF PHI

The Golden Ratio, Phi φ or Φ divides a line into two parts; one bigger (a) 61.8% and one smaller (b) 38.2% where

$$\frac{a+b}{a} = \frac{a}{b} \stackrel{\text{def}}{=} \varphi,$$

Its value, also known as the golden number, is:

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.6180339887....$$

The golden number is also known as an "irrational number" because like π, the non-terminating decimal constantly changes and so cannot be represented as a quotient of two integers. It is also the only number in mathematics that, when subtracted by units (1.0), yields its own reciprocal (0.6180339887....)[2]

The Golden Ratio may be represented as a linear relationship (Figure 1), a golden rectangle (Figure 2), or a curve known as the Fibonacci Spiral (Figure 3)

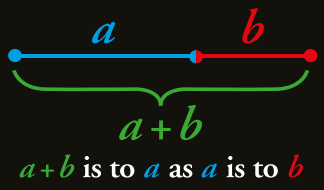


Figure 1: The linear relationship

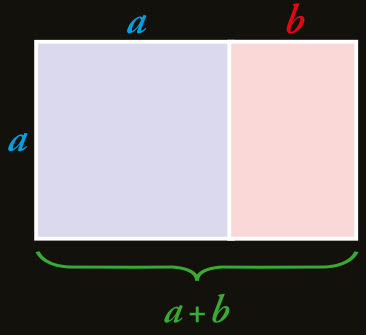
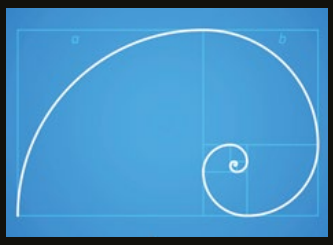


Figure 2: The golden rectangle with longer side ***a*** and shorter side ***b***, when placed adjacent to a square with sides of length ***a***, will produce a similar golden rectangle with longer side ***a + b*** and shorter side ***a***

Figure 3: A Fibonacci Spiral



THE HISTORY OF PHI

Phi is named after the Greek sculptor Phidias who used the Golden Ratio in his infamous Parthenon statues nearly 2,500 years ago (Figure 4).

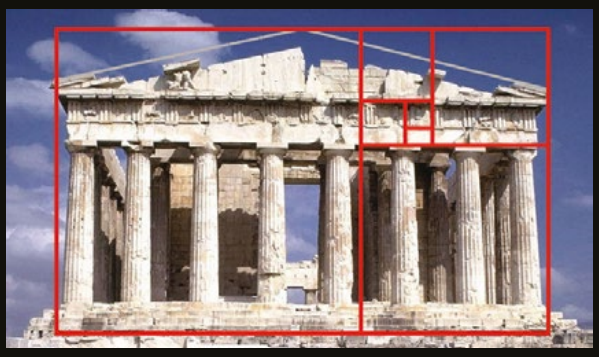


Figure 4: The Parthenon, demarcated by the Golden Ratio

However, it was the "father of Geometry" Eulicid in his greatly influential book, Elements (300BC) who first defined the Golden Ratio as a linear relationship.

In 1202, the Italian mathematician Leonardo Fibonacci introduced his sequence of numbers in his book Liber Abaci, where each number is the sum of the two preceeding ones (1,2,3,5,8,13,21...). But it was not until 400 years later when the famous German mathematician and astronomer, Johannes Kepler, proved that the Golden Ratio is the limit of the ratio of consecutive Fibonacci numbers. Kepler, who was also a keen astrologer, was captivated by the mystical side of the Golden Ratio; his writings on the topic have been described as a mixture of good mathematics and magic.[3]

The Italian mathematician Luca Pacioli was the first to name the Golden Ratio as the Divine Proportion in his treatise De Divina Proportionale, published in 15091. At the time of publication Pacioli stated *"It seems to me that the proper title for this treatise must be Divine Proportion. This is because there are very many similar attributes which I find in our proportion - all befitting God himself – which is the subject of our very useful discourse... just like God cannot be properly defined, nor can be understood through words, likewise this proportion of ours cannot ever be designated through intelligible numbers, nor can it be expressed through any rational quantity, but always remains occult and secret, and is called irrational by the mathematicians."*

THE GOLDEN RATIO IN NATURE

The German psychologist Adolf Zeising, who had a keen interest in mathematics and philosophy, was the first to describe the > Golden

Ratio in the arrangements of leaves, branches and stems of plants. He later found the same in the proportions of chemical compounds, the geometry of crystals, the skeletal structure of animals as well as human proportions. In 1854, Zeisling described the Golden Ratio operating as a universal law "in which is contained the ground-principle of all formative striving for beauty and completeness in the realms of both nature and art, and which permeates, as a paramount spiritual ideal, all structures, forms and proportions, whether cosmic or individual, organic or inorganic, acoustic or optical; which finds its fullest realisation, however, in the human form."[4] While there are a number of examples to support Zeisling's universal law, the vast majority of natural phenomena such as coastlines, trees, clouds, mountain ranges, rivers and star clusters appear to be completely independent of the Golden Ratio.

THE GOLDEN RATIO IN ART

Leonardo da Vinci, who was a close personal friend and student of Pacioli, drew the illustrations in De Divina Proportione, but there is no recorded evidence that Da Vinci was consciously applying the Divine Proportion to his works, either earlier in The Annunciation (1472-1473), or later in the Mona Lisa (1503-1506). The Vitruvian Man is often connected with the Golden Ratio, but the proportions of the figure do not actually match it and the text only mentions whole number ratios.[5]

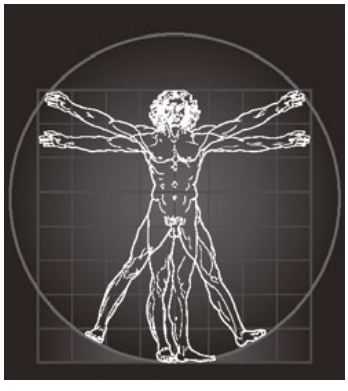


Figure 5: The Vitruvian Man by Leonardo da Vinci

Many other works of art have been associated with the Golden Ratio such as Botticelli's renditions of The Annunciation (1485-1493). Michelangelo's Creation of Adam from 1510 has God's finger touching Adam's finger at the precise Golden Ratio point of the width of the area in which they are framed. Whether or not Botticelli, Michelangelo, or others were consciously using the Golden Ratio is not actually known.

Still, there can be little doubt that the surrealist Salvador Dali consciously applied the Golden Ratio to his Sacrament of the Last Supper from 1955. The dimensions of the painting are those of the Golden Rectangle. A huge dodecahedron (polyhedron with 12 flat faces) is suspended above and behind an image of Jesus and dominates the composition. The dodecahedron described by Plato as a solid "which god used for embroidering the constellations on the whole heaven," is intimately related to the Golden Ratio.[1]

THE GOLDEN RATIO IN AESTHETIC MEDICINE

The geometrical figures with the closest relationship to the Golden Ratio and the human face are the pentagon and pentagram, where each intersection of edges sections other edges in the Golden Ratio (Figure 6). The Fibonacci Spiral may also be applied to the face (Figure 7).

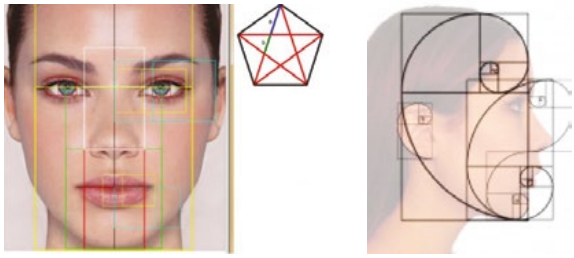


Figure 6 & 7: The Golden Ratio in an attractive face

The earliest experiments looking at the Golden Ratio and physical attractiveness were conducted by the German physicist and psychologist Gustav Fechner in the 1860s. Fechner presented rectangles varying in size to his subjects who were then asked to select the one most pleasing in appearance. The results showed an average toward the golden rectangle

(with ratio 1.62). In his book Vorschule der Aesthetik, Fechner measured thousands of rectangular-shaped objects, from books to windows and claimed to have found the average ratio to be close to the Golden Ratio.[1]

Many psychologists have since repeated similar studies, though with often conflicting results. The Canadian psychologist Michael Godkewitch noted that individual preferences are not necessarily reflected in group averages. Furthermore, the British psychologist Chris McManus found individual preferences for ratios other than the Golden Ratio.[1]

In 1985, the psychologists Samuel and Ewy, found that three and six-month old infants had a preference for attractive over unattractive faces, suggesting a biological basis for individual preferences. A few years later in the 1990s the American psychologist Judith Langlois and her colleagues showed that young infants prefer attractive female faces in the same way that adults do and that these preferences were cross cultural. In fact, both infants and adults were found to have a preference for mathematically averaged faces (in the form of computer generated composites) independently of other factors such as youthfulness and symmetry. Indeed, the "law of averageness" is supported by evolution; people with average physical properties are more likely to survive than those with extreme physical properties and average features are also a greater indication of fertility.[6]

However, psychologist David Perret compiled composite photographs of European and Japanese faces and found that individual attractive faces were preferred to the composites. Furthermore, when computers were used to exaggerate the shape differences away from the average, those too were preferred. Perret noted that his beautiful faces had higher cheek bones, a thinner jaw, and larger eyes relative to the size of the face.

In 1994, Mark Lowey, an orthodontist from University College Hospital made detailed measurements of fashion models' faces. His assertion was that the reason we classify certain people as beautiful is because they come closer to Golden Ratio proportions in the face than the rest of the population and so it would appear that 'beauty is in the Phi of the beholder.'

In contrast, one of Lowey's co-workers, Dr Alfred Linney, used lasers to make precise measurements of the faces of top fashion models and could not find an ideal beautiful face. Instead, Linney and his team found that the features of models are just as varied as those of everyone else.[1]

Stephen Marquardt, the Californian maxillofacial surgeon, developed his Phi mask (also called the golden mask) from the golden ratio to represent the "ideal" facial archetype (Figure 8).[15] Many aesthetic doctors and surgeons have since used his mask as a template for beauty; at the same time, the Phi mask has attracted a fair amount of criticism. In developing his mask, Marquardt concentrated on female fashion models, many of whom tend to have masculinised facial features. In addition, the mask has been found to be ill-suited for non-European populations, especially sub-Saharan Africans and East Asians.[7]

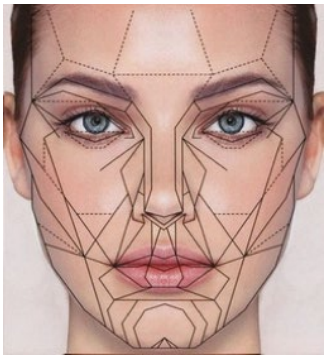


Figure 8: The Phi Mask

More recently, Professor Victor Johnston of the University of New Mexico, published results of a fascinating series of experiments, which linked perceptions of beauty to the effects of oestrogen and fertility. Volunteers were asked to rate the attractiveness of computer generated faces which were then combined to offer a second generation of faces, a third generation and so on. His results show a preference toward child-like features (a shorter distance from the eyes to the chin and fuller lips), but participants in the study still perceived the ideal face as being older, with an average age of 24.8 years. Interestingly, this is the time when oestrogen levels are highest and women are at their most fertile.[8]

IN SUMMARY

There can be little doubt that the Golden Ratio is a number like no other with truly amazing mathematical properties. The Golden Ratio has throughout history been associated with all forms of beauty, but has also attracted a significant amount of controversy surrounding its origin and its role as a universal standard for beauty. While the Golden Ratio certainly does appear in many natural phenomena, beautiful works of art and attractive faces, there are many instances where it is not present. Furthermore, it is often precisely the departure from such a "universal standard" which, for example, makes a painting appear so beautiful, or a face so attractive. **AM**

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