Author(s): Lähdesmäki, Tuuli

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Universalist and Particularist Discourses on the Intersection of Reality, Truth and Beauty

Tuuli Lähdesmäki

Abstract
The history of the Western civilisation can be seen as a continuum of epistemological battles and alliances between two modes of grasping and describing the world. According to these conflicting views, the world has been grasped either through particular or universal explanations. These two views have formed a dualistic scholarly context which has directed philosophers, artists, and scientists to discuss whether the world and its diverse phenomena can be perceived and explained through the universal laws of mathematics and science or rather as culture-bound narrations and symbols; whether the world is best represented using the language of mathematical formulas and equations or that of the arts. The conflicting views of perceiving and explaining the world can be determined as two epistemes between which various issues, such as the nature of knowledge and the notions of reality, truth, and beauty, are intertwined and in which they are differently comprehended. Despite their differences, the epistemes share a common conceptual realm; some of the terms, words, and concepts are used in both. This common realm stems from the vocabulary of aesthetics. Mathematicians and scientists often refer to the aesthetic qualities of geometry, mathematical formulas, and scientific theories using the terms and expressions artists and art critics employ when they evaluate artistic objects and visuality. The concept of beauty is discussed in both epistemes but in a different sense. Based on a literature review, the chapter discusses how the notions of reality, truth, and beauty are intertwined in these two epistemes; how the notions are argued for and justified.

Key Words: Arts, beauty, culture, discourse, episteme, geometry, mathematics, reality, science, truth.

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1. Beauty in Making Sense of the World

The essence of beauty has interested man throughout the history of civilisation. Beauty is a timeless concept; it is a driving force of cultural production and creative thinking and a source for diverse emotions ranging from pleasure to exhilaration. In addition to being a timeless concept penetrating all cultures, the notion of beauty is profoundly historical. The focuses, definitions, and contents of beauty have changed through the course of time. On the one hand, beauty has been perceived as a profoundly human quality; it has been discussed in relation to diverse human activities and cultural phenomenon from the smallest decorative details to broad cultural entities, and from concrete objects to conceptual

abstractions. On the other hand, beauty has been related to the fundamental structures of the world and existence; it is something that exceeds the materiality of objects and the cultural dimension of phenomena.

Since antiquity, man has aimed to reach the essence of beauty, find its fundamental elements, and define its terms and prerequisites. However, these attempts indicate that any commonly accepted, universal, overall, or final definition seems to be impossible to formulate. Beauty is a concept that eludes definition. Thus, instead of aiming to define the concept of beauty or understand what beauty really is, it is more interesting to investigate how beauty has been discussed within diverse cognitive frameworks. In these frameworks, beauty is understood and given meanings to in different ways; beauty as an idea, a concept, and an experience is intertwined with the different modes of perceiving and explaining the world and its structures. Discussions on beauty reveal how man grasps the epistemological and ontological nature of reality.

Since the birth of civilisation, mathematics and arts have been essential instruments with which man has discerned, constituted, and reflected reality and aimed to explain, take over, and control the world. Mathematics and arts form two cognitive modes of perceiving, making sense, and representing the world. They include their own modes of communication used to reveal the alleged structures and qualities of reality and nature. Throughout the history of man, they have contributed to the practices of manifesting, illustrating, and representing the world both intrinsic and extrinsic to human beings. Both mathematics and arts are conceptual and symbolic languages which humans have used in their attempts to depict both their empirical perceptions and imaginings and to create beautiful objects and environments. Both languages provide representations of the visible and non-visible phenomena. In neither case do these representations equal the idea of resemblance or likeness, but they may rely on likeness in some respect. The philosopher of science Bas C. van Fraassen calls this selective likeness.[1] According to him:

> Likeness in contextually selective fashion is important to scientific practice. The world, the world that our science is of, is the world depicted in science, and what is depicted there, is the content of its theoretical representations (…).[2]

The same can be said about arts; the world that art is of, is the world depicted in the language of art. Arts offer us cultural, artistic, and emblematic representations of the world. The languages of mathematics and arts are both based on cultural agreements and their interpretation requires a reader who is able to decode their messages. Reading the language of mathematics or of arts requires knowledge of these languages and a competence to decipher their content. Reading and decoding are cultural and human actions; they always take place within a cultural and

subjective context. How are these two languages used in discussing beauty? And how well do these two languages communicate with each other in these discussions?

The history of Western culture from antiquity to the present day can be seen as a continuum of epistemological battles and alliances between the cultural-emblematic and the mathematical-logical ethos of describing the world. These discursive battles can be traced back to the Platonic and Aristotelian traditions.[3] According to these two opposing views, the world can be grasped either through cultural, thus particular, or scientific, thus universal, explanations. Depending on the world view, only one of them has been perceived as revealing the mysteries of the world, manifesting human mind and reality, containing the truth, and explaining beauty. These two views have formed a dualistic scholarly context which has directed philosophers, artists, mathematicians, and scientists to discuss whether the world and its diverse phenomena can be explained and perceived through the universal laws of mathematics or rather as culture-bound narrations and symbols. Scholars and artists have pondered whether reality can be best represented using the language of mathematics or that of the arts and whether beauty is an objective and universal quality based on mathematics or a subjective sensation and a historically transforming cultural discourse.

This chapter discusses how the notions of reality, truth, and beauty form an interdependent nexus of meanings and how the concept of beauty is made sense of in different cognitive frameworks – in mathematics, science, and arts. In addition, the chapter brings to the fore how the views in these two cognitive frameworks are argued for and justified. The discussion in the chapter is based on a literature review on beauty in the fields of mathematics and arts in the Western world. In addition to recent literature on the topic, the discussion in the chapter rests on a study of conference proceedings of the Bridges Organization, which aims to promote connections between mathematics, science, arts, and culture.[4] The proceedings consist of scientific papers written by professional mathematicians, physicists, and scientists interested in arts and cultural phenomena and artists and researchers of art who share an interest in visuality based on geometry and mathematics. The literature is approached through a critical discourse analytic reading in order to perceive the variety of meaning-making strategies in the discussions on beauty. In addition, the aim of the approach is to emphasise the hierarchical relations between the different strategies and their reciprocal contest over the *right* notions.

2. Aesthetics as a Common Vocabulary in Discussing Beauty

A. Two Epistemic Modes of Understanding

Contemporary linguists have defined different meaning-making modes and distinct strategies and practices of perceiving reality and its phenomena as discourses. Scholars have used the concept of discourse to refer to the specific and

restricted ways meanings are produced in and through certain kinds of social practices and uses of language. The concept of discourse has also been applied to explain broader societal structures which have an impact on various domains in societies and which are manifested in these domains in the similarity of strivings, values, ways of thinking, and actions of an era.[5] In this broader sense the concept of discourse is close to the sociological use of the concept of ideology[6] or the idea of an episteme, as discussed by Michel Foucault.[7] For Foucault, certain kinds of configurations of knowledge and the underlying assumptions regarding truth, good, and proper produce a kind of epistemological unconscious of an era, which encompasses not only science but a wider range of discourses in culture, education, politics, law, morality, etc. Several epistemes may co-exist simultaneously and their interaction produces complex power hierarchies and various systems of power-knowledge.[8]

Following Foucault´s conceptualisation, the cultural-emblematic and the mathematical-logical ethos can be determined as two distinct epistemes between which various issues, such as the nature of knowledge and the notions of reality, truth, and beauty are intertwined and within which they are comprehended differently, at least in the Western world. In both epistemes language – in a broad Barthesian sense[9] – produces its objects. The nature of knowledge, reality, truth, and beauty are given meanings in linguistic utterances, textual expressions, and pictorial or mathematical representations. Despite their epistemological differences, the epistemes share a common conceptual realm; certain terms, words, and concepts are used within both. This common realm stems from the vocabulary of aesthetics. Mathematicians, physicists, and scientists often refer to the aesthetic qualities of geometry, mathematical formulas, equations, and scientific theories using the terms and expressions artists and art critics employ when they evaluate artistic objects and diverse visual phenomena.[10] The concept of beauty is discussed in the fields of mathematics, physics, and arts. It, however, carries a different meaning in these fields. Thus, the investigation of the uses of language, modes of conceptualisation, and discursive meaning-making may reveal the epistemological and ontological differences between the cultural-emblematic and mathematical-logical epistemes. These differences are analysed and discussed as a universalist discourse and a particularist discourse in the sections four and five of this chapter.

B. Notions of Subjectivity and Objectivity in Aesthetics

Although the essence of beauty has been discussed by philosophers, artists, and scientists throughout the centuries, aesthetics was established in the Western academia as its own branch of philosophy only in the 18th century. The nature of beauty and its appreciation formed the core of the theoretical discussions in the newly established field. The birth of aesthetics as its own discipline transformed the theoretical focus in the discussions on beauty. Since antiquity, many philosophers, artists, and scientists have been interested in beauty as a quality of

beautiful objects and as an idea which could be defined and explained with certain objective and universal rules found in the objects perceived as beautiful. Along with the interest in objects and universal rules of beauty, several 18th century philosophers, such as David Hume, Edmund Burke, and Immanuel Kant, discussed beauty as a quality, competence, and a state of the subject (i.e. of a receiver or an appreciator of objects). In their treatises, beauty was approached through an experience of it and by emphasising the receiver's response. Thus, the focus of the theoretical discussions on beauty shifted from the creation of beauty and the recognition of its rules to the investigation of its reception and impact.[11] At the same time, the discussions on beauty were generally limited to the perceptible reality excluding the attempts to recognize beauty outside the sensory world.

Although the early theoreticians of the aesthetic were interested in the subject and subjectivity in the reception of beauty, the essence of beauty was still understood as a universal and generic quality. A classic of the theoretical treatises on the essence of beauty is Immanuel Kant´s study *Kritik der Urteilskraft*, published in 1790. In the study, Kant aims to solve the paradox of beauty introduced already by Hume: How can the judgement of beauty have universal validity although it is based on an emotion and a subjective feeling? According to Kant, there is no universal rule or generic term which would determine the nature of beauty or which could be used in categorizing objects as beautiful. However, the idea of beauty includes a universal character; the idea of the universality of beauty is related to the pleasure beauty produces in people. Kant explains how this pleasure is based on qualities that all humans share: imagination and understanding. In the pleasure produced by beauty, imagination and understanding are harmoniously present.[12]

Kant´s theories on beauty reflect the contradictions and contest of the cultural-emblematic and the mathematical-logical epistemes. These contradictions are included in the Kantian philosophy of beauty, although it attempts to find a solution to the contest of the epistemes by combining their arguments and theoretical points of departure.

The Kantian notions of beauty and aesthetic experience have had a broad impact on the discussions on beauty and the epistemological and ontological understanding of its essence. Kant´s interest in the subject and the perceivers´ experience as a *location* of beauty have been adopted in theoretical discussions on beauty in various disciplines. However, these discussions are usually produced as a response to the opposite view on beauty, which traces aesthetic pleasure to objective stimulus features *per se*.[13] In addition, Kant´s interest in the conditions of aesthetic judgement has had far-reaching consequences.

The disinterestedness of aesthetic judgement is a cornerstone of Kantian theory. According to it, aesthetic judgement (which forms the basis for aesthetic experience) requires a disinterested reception freed from any utilitarian or functional views, ideological, moral, or political interests, or a will to own the

viewed object. Disinterestedness demands detachedness of and distancing oneself from the perceived object and one´s personal interests.[14] As a result of Kantian theoretical notions, aesthetic perceptions and experiences based on disinterested reception have been interpreted as *pure* and as independent of and unconnected to any ideological, political or moral judgements. So called pure aesthetics have emphasised in particular the universal values in art and in the perception of beauty. Because of the influential legacy of Kantian philosophy, several aestheticians have until recently excluded diverse ideological, political, and moral issues and their influence on aesthetics from their field of inquiry.[15]

3. The Beauty of Mathematics

Although the epistemological and ontological points of view on the world differ greatly in the cultural-emblematic and the mathematical-logical epistemes, they share a common area of interest, in which their substances encounter and merge. This common area of interest can be located in the intersection of mathematics and arts: works of art, images, and visualizations which obey the structures based on geometry or mathematical sequences, formulas, equations, or algorithms. The encounter of mathematics and arts has inspired various scientists and artists throughout history. In several studies and treatises mathematics is even conceptualised as art and, respectively, art is being discussed as having its fundamental basis in mathematics. In these studies, the resemblance of mathematics and arts is validated by emphasising e.g., intuition, creativity, and realization as fundamental elements in both disciplines.[16] How are the ideas of beauty and the aesthetic experience discussed in the field of mathematics?

For mathematicians, the beauty of mathematics seems to be easy to perceive, but the content and composition of it is more difficult to explain. The Finnish mathematician Tuomas Hytönen described beauty of mathematics in a newspaper interview as follows:

> For me, mathematics is first and foremost an art. Problems are interesting because there is something beautiful in them. (…) First there are only miscellaneous perceptions, and then one finds a factor that explains it all. The unconnected issues turn out to form a picture – a whole. In other words, one finds the proper accuracy to explore an issue after which it appears clear.[17]

Recognizing and appreciating the beauty of mathematics seems to require knowledge and competence in mathematics. As the Finnish cosmologist Syksy Räsänen has noted, ‘It is difficult to communicate the beauty of mathematics to someone who cannot count. It is as difficult to communicate the emotion found in music, if you have only notes in your disposal, and the other person cannot read them.’[18] There are plenty of mathematicians who have emphasised the important

role of beauty in the subjective experience and enjoyment of doing mathematics. Mathematicians have described deriving aesthetic pleasure from mathematical research, pointing out the incomparable beauty and elegance of particular theorems, proofs, and theories.[19] Some mathematicians have even claimed that beauty acts as a guide in making mathematical discoveries and that beauty is an objective factor in establishing the validity and importance of mathematical results.[20] However, the idea of beauty in mathematics and the concept of mathematical beauty are vague: mathematicians have diverse views on their content and the concept of beauty gets various meanings.[21]

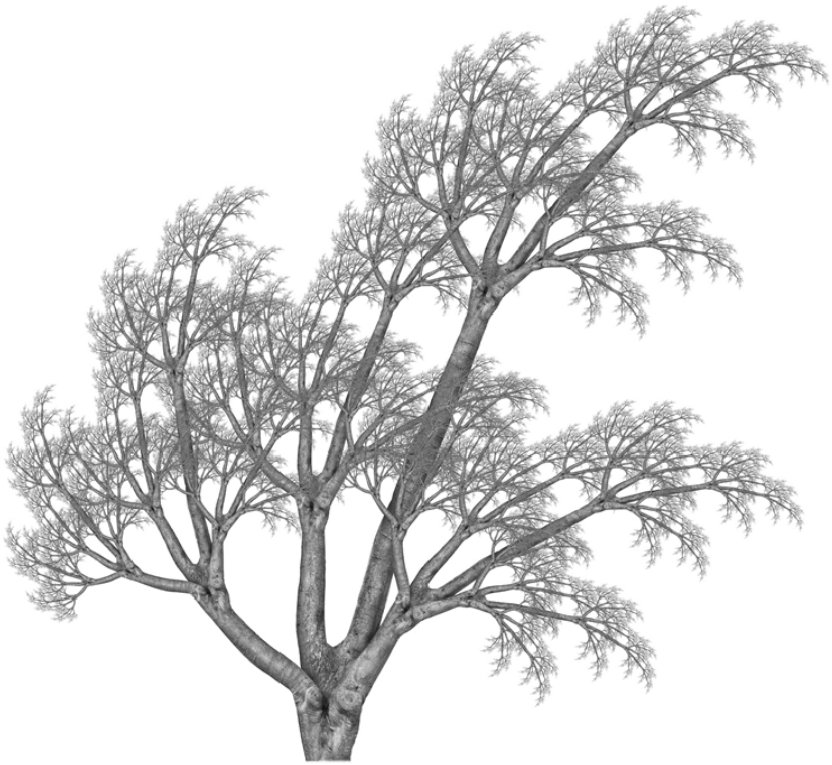

Image 1: Robert Fathauer, *Fractal Tree No. 6*, 2009, digital artwork constructed by graphically iterating a photographic building block created using photographs of a royal poinciana tree. © Robert Fathauer. Used with permission.

The philosopher of science James W. McAllister has aimed to classify the different approaches to the beauty of mathematics. He states that mathematical beauty can play both a subjective role in the experience of mathematicians and physicists and an objective role in the appraisal of mathematical results. In the latter case, beauty can be attributed to both the products and processes of mathematics, including proofs and theories.[22] But what kind of mathematical *products* do mathematicians consider beautiful? Many mathematicians have found beautiful those numbers that show either extreme simplicity or notable richness.[23] Simplicity and richness are, however, qualitative attributes, and dependent on interpretation. Other mathematical *products* that are often objects of aesthetic assessment are: fractals, diverse geometrical constructions (such as polygons, tilings, Platonic solids, and figures exhibiting the Golden Ratio), and symmetry (which can be manifested as regularity, pattern, proportion, or self-similarity).[24] What makes mathematical *products* beautiful?

The famous mathematician Godfrey H. Hardy has described mathematical theorems and proofs as beautiful when they exhibit the properties of seriousness, generality, depth, unexpectedness, inevitability, and economy. He claims that the beauty of a mathematical proof depends additionally on an element of surprise.[25] All these qualities are, however, difficult to objectively define; they are based on subjective experience and interpretation. As the mathematician and philosopher Gian-Carlo Rota has noted, 'One can find instances of very surprising [mathematical] results which no one has ever thought of classifying as beautiful.'[26]

McAllister has proposed an explanatory model of the aesthetic experience and a definition of mathematical beauty. He calls the model 'aesthetic induction' in order to emphasise the collective element of the scientific community in the formation of the aesthetic value of mathematical theories, processes, and products. He states:

> The aesthetic induction is the procedure by which scientists attribute weightings to aesthetic properties of theories. Scientists at a given time attach aesthetic value to an aesthetic property roughly in proportion to the degree of empirical success scored up to that time by the set of all past theories that exhibit the property. Thus, if a property is exhibited by a set of empirically very successful theories, scientists attach great aesthetic value to it and see theories that exhibit that property as beautiful.[27]

Empiricism, reasoning, rationality, and logic are often seamlessly related to the formation of the aesthetic experience and the notion of beauty in mathematics. Thus, the field of mathematics often relies on a Platonist notion of beauty; beauty has its grounds in intellectual insights into the fundamental structures of the universe. This kind of view opposes Kant´s notions of beauty and the aesthetic experience. Kantian notions of beauty do not leave much room for beauty in

mathematics, as in Kant´s view the judgements of beauty are essentially concerned with emotions and non-conceptual reception of objects.[28]

However, the beauty of mathematics can also be approached in a Kantian sense, as the philosopher Angela Breitenbach has suggested. She notes that 'the experience of beauty in mathematics is grounded not in an intellectual insight into particular properties of mathematical objects but in our felt awareness of the imaginative processes that lead to mathematical knowledge.'[29] From a Kantian point of view, the aesthetic experience of mathematical beauty consists of a non-conceptual and emotional response generated by the creative reasoning processes, rather than a rational insight into mind-independent truths.[30] Beauty in mathematics can be, thus, understood in terms of two different cognitive frameworks; either by relying on reason and logic as McAllister´s views indicate, or by emphasising the emotional and non-conceptual response as Breitenbach´s discussion brings out.

4. Mathematical-Logical Episteme: The Universalist Discourse on Reality, Truth and Beauty

A. Number and Order

The pre-Socratic philosophers already attempted to understand the world by searching for a single universal law which determines the world and structures all its qualities and phenomena. In their view, a universal law gives everything a certain form and form was closely related to the idea of beauty. Pythagoras was the first philosopher in the ancient Greece who unified diverse views on cosmology, mathematics, natural science, and aesthetics into a complete theory. According to his thinking, everything was based on numbers. Pythagorean views established an aesthetic-mathematical notion of the universe, in which every object and phenomena reflect a certain order based on mathematical laws which are the precondition of existence and beauty.[31]

Similar notion of the world also occurs in Plato´s texts. For him, beauty is an idea detached from the physical reality and only able to partially and incompletely reflect it. Beauty is not a physical quality that can be seen in the reality; it can be comprehended only through intellectual understanding which exceeds the sensory perception. However, Plato recognized some qualities which he believed all beautiful objects share. These qualities: order, right proportions, balance, and harmony, have their grounds in geometry and mathematics.[32] In addition, in Plato´s texts, the idea of beauty approaches the idea of good; what is good is also beautiful.[33] In fact, the Greek word for beautiful, *to kalon*, has a profoundly broad meaning; it also refers to pleasant, attractive, fine, functional, and good.

After antiquity, Pythagorean and Platonist traditions continued to influence the notions on the fundamental basis of the world. These notions regained popularity during the Renaissance. Various Renaissance artists, philosophers, and scientists, such as Leonardo da Vinci, Piero della Francesca, Leon Battista Alberti, and

Albrecht Dürer, studied the Platonic solids and other geometrical and mathematical models introduced and discussed by Greek philosophers.

Image 2: The Parthenon, Greece, constructed 447-438 BC. Several elements of the façade and the plan drawing in the temple approximate the Golden Ratio.
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The Greek and Renaissance aesthetic-mathematical notions, which tie the structure of the universe together with beauty, form the basis of the mathematical-logical episteme. In the discourses within the episteme, the language of geometry and mathematics are deemed universal, and the images and objects based on them carry fundamental universality. The discourses within the episteme relate the universality of geometry and mathematics to the idea of their beauty, and come to emphasise the idea of beauty as a universal quality. The interests in mathematics and geometry have also directed the reception and appreciation of art. Since antiquity, mathematicians, scientists, and philosophers have pointed out how, for example, the facades of architectural *masterpieces* and the compositions of excellent paintings obey the proportions of the Golden Ratio, the Fibonacci sequence, geometrical patterns, or other mathematical sequences. The beauty of these works of art has been located in the geometrical and mathematical principles

they follow and which are understood to imply the existence of universal aesthetics. Similarly, Western music has been considered to follow the Pythagorean arithmetic perception of harmony.[34]

In the discourses within the mathematical-logical episteme, the history of Western art can be perceived as a series of inventions in the use of geometry and mathematics in the artistic work. Styles, epochs, and works of art have been discussed as a reinvention of, rethinking of, or a return to geometry. The history of Western art has been seen as an evolution of the use of geometrical and mathematical rules developing from the use of pictorial foreshortening to the invention of perspective and ending up with modern art in which the artistic expression was finally reduced and transformed into the composition of pure geometric forms.[35] The development of computing programs and the possibilities they offer for creating graphic representations of algorithmic processes and various types of digital art and music form the latest phase in this evolution.[36] Because the discourses within the mathematical-logical episteme emphasise the universality of geometry and mathematics and the aesthetics related to them, the perception of beauty and the aesthetics of the geometrical and mathematical visualizations are not understood dependent on the cultural, historical, or individual contexts of their receivers. In the discourses, the aesthetics of geometrical and mathematical images are non-subjective and non-historical. Their aesthetic value is believed to remain the same throughout history and within different cultures.[37] As a consequence, visualizations and art that does not follow the geometrical and mathematical principles have occasionally been considered valueless, ugly, or incompetently executed. Due to these views, the visuality and mode of representation of various non-western, vernacular, and historical cultures have been labelled as primitive or undeveloped.

In the discourses within the mathematical-logical episteme, the geometrical and mathematical principles of visual phenomena relate them to the spheres of reason and logic which further increases their importance within the discourses of the episteme. In general, reason, logic, and the objectivity of perception are the determinants often related to science[38] and which determine the mathematical-logical episteme and its universalist discourses. The emphasis on reason and logic has also gendered these discourses as masculine.

In his work, Kant makes a clear distinction between beautiful and the sublime. Whereas, imagination and reason are harmoniously present in the experience of beauty, the experience of the sublime is based on a feeling of reason's superiority over imagination. For Kant, mathematics is not related to the realm of beauty, but it has a specific role in the experience of the sublime. In *Kritik der Urteilskraft* Kant outlines two different notions of the sublime: the mathematically sublime and the dynamically sublime.[39] In Kant´s theory, the mathematically sublime is related to the experience of magnitudes of either natural phenomena or human-made objects. For Kant, the experience of the sublime is a feeling of pleasure produced

by the superiority of reason, but it also involves a feeling of displeasure. In the case of the mathematically sublime, displeasure is aroused by the awareness of the inadequacy of human imagination.

B. In the Search for a Total Theory of the World

The fundamental point of departure in the universalist discourses of the mathematical-logical episteme is in the overall theories and total views of the world as being based on mathematical principles. The episteme relies on the belief/knowledge of the rationality of the world and its physical phenomena. In its views, the world and its structures are, thus, possible to understand, explain, and depict using mathematical formulas and patterns. 'We live in a universe of patterns', is how the mathematician Ian Stewart starts his book on mathematics and numbers as the elements that underlie everything.[40] Besides mathematics, geometry, and numbers in general, several scholars have perceived symmetry as the key to explaining the structure, function, and logic of diverse physical, social, and cultural phenomena.[41] In the discourses within the episteme, mathematical formulas and patterns are often discussed as the basis of the laws of nature that constitute the whole universe. Recent theories and innovations in science have strengthened the dominance and power of this kind of world view. The mathematician and computational musicologist Charalampos Saitis describes these recent developments as follows:

> With the establishment of fractal geometry and chaos theory it soon became clear that these are useful mathematical tools for describing nature. Scientists went on examining natural patterns and objects from a completely new angle, the results being more than just interesting. Irregularity, chaos, abrupt changes, discontinuity, self-similarity, scaling: all rule both the inner and outer beauty and harmony of nature and life. Trees, branches, leaves, the roots of a plant, cauliflowers, snowflakes, diamonds, coastlines, mountains, clouds, stars, the sky, galaxy clusters: fractal attractors describe visible natural shapes. The weather, the solar system, plate tectonics, turbulent fluids, population growth, economy: examples of chaotic dynamical systems. The brain and bronchial lobes are also examples of bodily structures with elements of self-similarity and scaling.[42]

In the discourses within the mathematical-logical episteme, images and objects that obey the laws of geometry and mathematics are at the same time considered to obey the natural laws of beauty.[43] The same views have also been applied to the beauty in humans. Human beauty has been explained e.g., by symmetry; several studies have indicated how facial symmetry is perceived attractive and beautiful in

different cultures, and it is, thus, believed to have a biological foundation.[44] In addition, human perception of visuality has been studied as biologically based. Even art historians have applied the biological world view to explain visual perceptions. For the art historian Ernst Gombrich, the reason why humans perceive visuality in a particular way stems from the *sense of order* that arises from a physical sense of direction and spatial awareness of the world. This innate *sense of order* leads to the anticipation and expectation of an order in visual images.[45] Because the *sense of order* is explained to be based on the physiological properties of all organisms, Gombrich suggests that the perception of this kind of visual effects is universal. When biology is used to explain the connections between mathematics and beauty, the evolutionist discourses are easily incorporated into the discussion. The appreciation of beauty based on geometrical or mathematical principles has been theorised as both having evolutionary grounds and influencing natural selection.[46]

In these discourses beauty, symmetry[47], geometry, and mathematics are connected to the idea of truth. In philosophy, the search for beauty and truth has often been complemented with the search of the good.[48] Beauty, truth, and the good form the fundamental trinity already discussed in the dialogues of Plato. On the one hand, the connection of beauty and truth is seen as forming the final goal of mathematics, while having, on the other hand, the role of an epiphenomenon: beauty and truth are taken as by-products of the laws of nature – as universal qualities that follow from mathematical principles.[49] The connection of beauty and truth and the interest in their interdependence has continued throughout the history of philosophy of Western science and arts. As the science writer K. C. Cole notes regarding this connection:

> (…) mathematics can (and does) frequently reveal surprising fundamental relationships – between cases and effects, for example, evidence and proof, truth and beauty. (…) In other words, the same properties that make a snowflake appealing underlie the laws that control the universe. Truth and beauty are two sides of a coin.[50]

C. Mysticism and Divinity in the Laws of Nature

Although reason, logic, and objectivity are key points in the mathematical-logical episteme, its idea of the fundamental laws of nature – which the whole universe is seen as being based upon and with which the diverse phenomena of reality can be explained – includes certain magic and mysticism. As Stewart notes with a reference to the famous lines on beauty and truth by the poet John Keats:

> Why does the universe seem to be so mathematical? Various answers have been proposed, but I find none of them very

> convincing. The symmetrical relation between mathematical ideas and the physical world, like the symmetry between our sense of beauty and the most profoundly important mathematical forms, is a deep and possibly unsolvable mystery. None of us can say why beauty is truth, and truth beauty. We can only contemplate the infinite complexity of the relationship.[51]

In the history of science, the *laws* of nature and the mathematical structures of the world have often been discussed as if they were a mystery with a divine dimension.[52] Contemporary mathematicians have also brought to the fore the divinity of mathematics. In the title of his book, astrophysicist Mario Livio asks, 'Is God a Mathematician?', thereby referring to

> a mystery with which some of the most original minds have struggled for centuries – the apparent omnipresence and omnipotent powers of mathematics. These are the type of characteristics one normally associates only with a deity.[53]

The perception of these omnipotent powers of mathematics may be difficult to comprehend and it therefore seems to be very human to explain the perception with the presence of a higher power. These kinds of explanations are, in fact, contradictory to the episteme´s rationalist, objectivist, and scientific world view, considered to be based on the *pure* laws of nature. Discussions in which the universalist discourses of the mathematical-logical episteme are broadened (and also criticized) with the notion of divine powers as a fundamental force behind the so-called laws of nature are common in certain scientific circles. In these views, nature, life, and the structure of the universe are so complex that they cannot be explained using only mathematics or scientific theories such as natural selection or evolution. Thus, these complex phenomena have been explained e.g., with the theory of intelligent design – a term created by the creationist movement in the United States.

In general, the discussions on the connections of divinity and beauty have a long tradition in the Western history of philosophy. For centuries, art, nature, and the cosmos have been used as instruments of contemplation in the attempts of gaining an insight into divine beauty.

5. Cultural-Emblematic Episteme: The Particularist Discourse on Reality, Truth and Beauty

A. Experience, Emotion, and Cultural Construction

Against the ideas of the mathematical-logical episteme, images and art – including imageries that follow mathematical formulas and geometrical patterns – can be understood, and explained as cultural representations and artistic emblems

that transmit diverse cultural meanings to different receivers. Particularly, the scholars in humanities, such as historians, art historians, ethnologists, anthropologists, and also ethno-mathematicians, have emphasised the cultural, social, and historical contexts both in the production and reception of images. These notions rely on the world view of the cultural-emblematic episteme within which universal laws do not explain the meanings of reality and in which reason and logic are believed to be unable to reveal any fundamental truths. In the discourses within the episteme, different truths are cultural formations and, thus, historically transforming constructions. In these discourses, mathematical formulas and mathematical explanations of the world are also cultural, and the ideas of intrinsic beauty and the universal explanatory power of symmetry, geometrical patterns, and mathematical proportions, such as the Golden Ratio, can also be perceived as cultural constructions.[54]

The notions of the universality and objectivity of beauty were questioned already in antiquity. Beauty was also perceived as a relational quality depending on the contexts and impacts the objects and works of art produce. According to Aristotle, appropriateness – the ability to fulfil an aim and an expected function – was one dimension of beauty.[55] In addition, during antiquity and the Middle Ages, several philosophers and theologians emphasised qualities such as coherence and brightness as the core elements of beauty. Discussions on these qualities inevitably related a subjective perspective to the notion of beauty, because the conditions for coherence and brightness were difficult to define objectively. The rise of visual arts and the change of the position of an artist during the Renaissance strengthened the subjective notion of beauty. Beauty was understood as a quality which could be created and recognized with a non-rational intuition. In addition, the idea of taste became important in the reception and recognition of beauty. Although taste – whether innate or trained – was perceived as a quality of the subject, it could however still be determined as either good or bad.

Besides the artistic and cultural upturn during the Renaissance, the rise of empiricism as a philosophy of science influenced the transformation of the notion of beauty.[56] Interest in empirical perceptions and experiences as the point of view from which to explore the world and its phenomena shifted the focus in the discussions on beauty from objectivity, non-sensibility, rationality, and universality to subjectivity, experience, intuition, and context. At the same time, the realm of discussing beauty narrowed down. It became a topic discussed by focusing the theoretical interests in senses, perception, experience, taste, and aesthetic pleasure. In addition, philosophers aimed to explain the composition of beauty and define its essence by dividing it to various sub-categories or by emphasising several parallel concepts. These interests and aims recur e.g., in the texts of Kant, as described above.

Discourses within the cultural-emblematic episteme stress the subjects and their emotions and cultural positions in the reception and sense-making of art and

images. Instead of the non-sensible, the discourses highlight the intuitive, emotional, and affective nature of receiving beauty. These kinds of qualities are often related to femininity or gendered as female. Thus, the point of view of gender can be interpreted as intertwined with and structuring the distinction between the epistemes and their discourses.

In the discourses within the cultural-emblematic episteme, not only the experience of beauty but also the perception as such can be understood subjective, contextual, and culturally and socially relative. Whereas, Gombrich suggested that the perception of visuality is universal due to the physiological properties of all humans, archaeologist Ellen Swift highlights that:

> (…) not only meaning, but also perception itself, is culturally dependent; that the way in which the brain recognizes what the eye sees is culturally constituted and thus that what one person 'sees' may not correspond exactly to what another person 'sees', particularly if they are from different cultural backgrounds.[57]

According to this view, perception is a cultural practice, which includes the ideas of historicity, cultural agreement, and social construction.[58] In general, since the end of the 20th century, social constructionism as a philosophy of science has taken root and even reached a dominant position in diverse branches within the humanities. It emphasises reality and the knowledge of it as constructions produced in language, human interaction, and social practices.[59] In the production of meanings, culture is often perceived as the context within which the interaction takes place and which frames social practices. Thus, in the social constructivist views, various phenomena are defined as being culturally constructed. The recent discourses of the cultural-emblematic episteme emphasise beauty as a cultural construction and as being defined and receiving meanings in and through various cultural practices and discourses. Various critical and feminist studies on female beauty and beauty ideals have relied on social constructionist views; the ideals of beauty vary among different cultures and new ideals are easily created in the cultural and social interaction in and between cultures.[60]

Within the cultural-emblematic episteme, the notions of beauty and aesthetics are understood to be culturally bound conceptualisations and experiences based on conventions and shared cultural and social habits produced and learned in and through social and cultural reproduction. In this kind of epistemological frame, the idea of Kantian disinterested aesthetic judgement of objects and art seems impossible. The aesthetic judgements are always produced by subjects who cannot disengage from their cultural and social contexts.[61] Thus, feminist aesthetics have emphasised how the aesthetic judgement is – unlike in *pure* Kantian aesthetics – always intertwined with diverse ideological, political, moral, and cultural notions and how the notions of the universality of beauty, art, and aesthetic value are, in

fact, particularist discourses.[62] In the field of art history, the changes in artistic expressions, aesthetics ideals, and styles have been explained by transforming historical and cultural schemas based on learning and on previous experiences.[63] Form and content are inseparable in aesthetic order, as Ruth Lorand emphasises in her chapter in this book.[64]

B. Context and Contest of Aesthetic Judgements

In the Western history of art, artists have often wanted to break the artistic conventions and the dominating ideals of beauty, and in doing so they have aimed to change the conception of art itself. Therefore, the definitions of the ideas of good and beautiful art have been, and still are, a matter of contest. In the field of art, the so-called gate-keepers (acknowledged experts, established art critics, workers in art museums and galleries, art historians, etc.), either intentionally or unintentionally, determine and define what is art, and what kinds of expressions are taken to be aesthetic. Agents in the field of art do not unanimously agree on these definitions, quite the contrary. Sociologists of art, such as Pierre Bourdieu, have emphasised how the fields of art and culture are founded on a continuous battle on meanings and positions out of which these meanings can be produced.[65]

In mathematics the concept of beauty can also be perceived as discursively and socially determined. Mathematical beauty and artistic beauty are both cultural constructions, as the physicist Daniel J. Goldstein has stated.[66] New mathematical theories and artistic innovations become objects of beauty only after new generations are educated in them. In both fields, the sensations of beauty require familiarity with the conventions of the field. As Rota notes, 'Appreciation of mathematical beauty requires familiarity with a mathematical theory, which is arrived at, at the cost of time, effort, exercise, and *Sitzfleisch* rather than by training in beauty appreciation'.[67]

How have the scholars within the cultural-emblematic episteme approached, interpreted, and given meanings to works of art, images, and visualizations which have their basis in geometry or mathematics? The structure, proportions, regularity, and order received and recognized in the works of art and other visual objects have been interpreted as having diverse emblematic, symbolic, artistic, religious, and social meanings. Scholars, particularly art historians and historians, have also discussed the narrative dimension of these images and works of art. In general, all kind of visuality includes a narrative function. The status of objects and images as art and the meanings of such concepts as beauty and aesthetic value are produced through and in narrative practices, as Rosina Martucci's chapter in this book emphasises.[68] Mathematics and geometry in art and images have also been explored in relation to theories of style, fashion, perception, and affect. In all these points of view, the meanings of mathematical and geometrical images have been emphasised as socio-cultural. The interpretation of these meanings has been

perceived as context-dependent; the change of context may negate the meaning of the image.[69]

Several scholars in humanities have also been interested in the performative meaning and functions of images based on geometry and mathematics. Creating mathematical images, such as geometrical line drawings known as *kolams* in southern India and parts of the Far East, often includes a performative ritual which connects the image to a particular spiritual world view or a system of knowledge. In the case of *kolams*, the drawing ritual in which a line circling around a grid pattern of dots drawn with a chalk or with rice powder on the ground in front of the house, aims to bestow prosperity and good fortune upon the residents. The drawing ritual as such is a meditative process which creates a connection to the spiritual world.[70] Scholars have also indicated how mathematical and geometrical images could have functioned as ritual spaces which have further strengthened their symbolic and performative meanings, as in the case of labyrinth tiling on the floors of various medieval churches in Europe. A labyrinth – being a Christian symbol of the path of the soul through life, or more precisely, a symbol of a pilgrimage to Jerusalem – could serve in the churches as the physical stage for medieval clergy dances performed during Easter[71] and later for pilgrimage rituals practised by monks and pilgrims.[72] According to the discourses within the cultural-emblematic episteme, images and meanings are intertwined with a certain cultural and historical system of knowledge, interpretational frame, and aesthetic ideal, which determine the production, interpretation, and use of geometrical and mathematical imagery.

6. From Inter-Disciplinarity to Distinguished Disciplines: Epistemic Transformations in the Academia

The mathematical-logical and cultural-emblematic epistemes and their different modes of explaining the world and its phenomena have often been described as being opposite to each other. Similarly, the fields of science and art are often considered as two incompatible modes of grasping the world; they are seen as objective or subjective, as theoretical or practical, and as appealing to either reason or emotions. However, throughout history these two modes have been intertwined in various ways. Since antiquity, several scholars and artists have fruitfully aimed to merge these modes and create interdisciplinary explanations of the world by combining the views of the two epistemes. The interdependence and interaction between the mathematical-logical and the cultural-emblematic world views culminated in Renaissance scholarship, theoretical treatises, and artistic practice. In the Renaissance, geometry and mathematical proportions were adopted as underlying principles e.g., in the theory of perspective, architectural concepts, definitions of musical harmonies, and ideals of bodily beauty. Several scholars have discussed and highlighted the continuity of the affinity between mathematical

and artistic ethos in the Western world from the Renaissance to the emergence of artistic modernism in the 19th century.[73]

However, in the academia and scholarly practices, the cultural-emblematic and mathematical-logical epistemes can also be interpreted as gradually diverging after the Renaissance. The development of modern science and academia with distinct disciplines had an impact on their specialization and the deepening focus of their fields of enquiry. As a consequence, the core questions, methods, and epistemological and ontological understanding in different disciplines were distinguished and the interaction and dialogue between them narrowed down. Similarly, the arts developed into its own field with its own criteria of evaluation, special value systems, expertise, and connoisseurship. The field of art, its agents, practices, and knowledge was institutionalized as its own system of values. Because of this, acting in the realm of arts required a special competence and an acknowledged position within its hierarchy.

In addition to emphasising the affinity of mathematics, geometry, and arts in the Western world, the relations of the cultural-emblematic and the mathematical-logical epistemes can be, thus, presented as a collision or a dis-encounter. On the one hand, the differences between the epistemes have caused disinterest towards the world views and modes of thinking inherent to the other episteme. On the other hand, the agents in science and arts have fostered epistemic thinking in their own disciplines, and, thus, created even stronger differences and juxtapositions between the epistemes.

7. Conclusions

The concept of beauty is profoundly flexible and its focuses, theoretical frames, and uses have changed throughout the centuries and varied in different discourses within science and arts. The contradictions and contests between different discourses and the historical transformations of them have reflected the dynamics and power relations of differences in epistemic thinking and perceptions of the world. The two opposing modes of perceiving and explaining the world and its phenomena have been described in this chapter as mathematical-logical and cultural-emblematic epistemes. Whereas, the discourses of the mathematical-logical episteme emphasise: total theories, one truth, laws of nature, science, objectivity, non-sensibility, rationality, and universality, the discourses of the cultural-emblematic episteme rely on: contextuality, historicity, multiple truths, cultural constructedness, arts, subjectivity, experiential, intuitiveness, and particularism. Despite their differences, the epistemes share a common realm of interest – beauty and aesthetics.

As the chapter has indicated, the concepts of beauty, aesthetic value, and aesthetic experience are discussed in the fields of mathematics, science, and arts. In the discourses of the two epistemes, these concepts are approached in a different sense. In the mathematical-logical episteme, form, order, and mathematical laws

are considered to be closely related to the idea of beauty. In the discourses of the episteme, beauty is not, however, only a physical quality that can be seen in reality; it has to be comprehended through intellectual understanding which exceeds sensory perception. The mathematical-logical episteme emphasises the idea of beauty as a universal quality which is not dependent on the cultural, historical, or individual contexts of people. Through the emphasis of universalism, the discourses of the episteme relate beauty to the laws of nature and the idea of truth.

Within the cultural-emblematic episteme, the notion of beauty is understood as a culturally bound and discursive concept based on conventions and shared cultural and social habits produced and learned in and through social and cultural reproduction. Beauty is perceived as a relational quality depending on the contexts and impacts the objects and works of art produce. Instead of the non-sensible and rational, the discourses of the cultural-emblematic episteme highlight the intuitive, emotional, and affective nature of receiving beauty. In the discourses, not only the experience of beauty but also the perception as such is often understood as subjective, contextual, and culturally and socially relative.

The philosophical discussions on beauty and aesthetic theories include views in which the discourses of the two epistemes encounter. For example, Kant´s theories on the essence of beauty merge and utilize ideas from both epistemes. Although beauty is approached in his texts as a subjective experience, the judgement of beauty is still understood as having universal basis. The recent developments in the academia have aimed to produce bridges between the cultural-emblematic and the mathematical-logical epistemes. During the past decades, multidisciplinary, cross-disciplinary, and interdisciplinary approaches have been emphasised in natural, social, and human sciences. However, the epistemes still exist and influence the theories and practices in science and arts and the interdisciplinary dialogue between them.

In order to understand the world and its phenomena in depth and to produce new insights of their complexity, the interdisciplinary dialogue between sciences and arts is needed. Bringing together different modes of perceiving, grasping, and explaining phenomena may lead to the fruitful interaction of different disciplines and their specific knowledge. As a result of a successful dialogue between different – or even opposing – epistemological and ontological views, the paradigms in science and arts are reshaped and revised, creating fruitful grounds for the emerge of new paradigms. Interdisciplinary dialogue is a lifeline for the regeneration of science and arts.

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Notes

[1] Bas C. van Fraassen, *Scientific Representation* (Oxford: Clarendon, 2008), 7.
[2] Ibid., 9.
[3] Although the Platonic and Aristotelian traditions differ from each other in many ways, they still share similar notions regarding the essence of beauty. Both Plato and Aristotle emphasise mathematics, order, symmetry, and proportions as elements of beauty. According to their views, beauty is located to the form rather than content and perceived as an idea rather than manifested in materiality. However, Aristotle distinguishes between beauty and the good – Aristotle, *Methaphysics*, trans. George Cyril Armstrong and Hugh Tredennick (London: William Heinemann, 1933), 1078a-b – and recognizes various beauty ideals in man: people can be beautiful in different ways – Aristotle, *Rhetoric*, trans. John Henry Freese (London: William Heinemann, 1926), 1361b.
[4] The US-based international Bridges Organization was established in 1998. Since then it has annually organized conferences and hosted diverse art-math workshops and art exhibitions as a part of the conferences. See the home page of the organization: http://www.bridgesmathart.org.
[5] Teun A. van Dijk, 'The Study of Discourse,' *Discourse as Structure and Process. Discourse Studies: A Multidisciplinary Introduction Volume 1*, ed. Teun A. van Dijk (London: Sage Publications, 1997), 1-34.
[6] Stuart Hall, 'The West and the Rest: Discourse and Power,' *Formations of Modernity*, ed. Stuart Hall and Bram Gieben (Cambridge: Polity, 1992), 275-320; Alastair Pennycook, 'Incommensurable Discourse?' *Applied Linguistics* 15.2 (1994): 127.
[7] Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Pantheon Books, 1970).
[8] Michel Foucault, *Power/Knowledge. Selected Interviews and Other Writings, 1972–1977* (New York: Pantheon Books, 1980), 194-198.
[9] Roland Barthes, 'Texte (théorie du),' *Encyclopaedia Universalis* 15 (Paris: Encyclopaedia Universalis, 1973), 1013-1017.
[10] Daniel J. Goldstein, 'Beauty in Art and Mathematics: A Common Neural Substrate or the Limits of Language?' *Renaissance Banff*, eds. Reza Sarhangi and Robert V. Moody. Conference proceeding of Bridges: Mathematical Connections in Art, Music, and Science held 31 Jul-3 Aug in Alberta, Canada (Phoenix: Tessellations Publishing, 2005), 93-100.
[11] Umberto Eco, 'Ylevyys,' *Kauneuden historia*, eds. Girolamo De Michele and Umberto Eco, trans. Pekka Tuomisto (Helsinki: WSOY, 2008), 275.
[12] Immanuel Kant, *Critique of Judgement*, trans. James Creed Meredith (Oxford: Clarendon Press, 1952), 29-30.

[13] Rolf Reber, Norbert Schwarz and Piotr Winkielman, 'Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience?' *Personality and Social Psychology Review* 8.4 (2004): 364.
[14] Kant, *Critique of Judgement*, 42-44.
[15] Pauline von Bonsdorff and Anita Seppä, 'Johdanto,' *Kauneuden sukupuoli. Näkökulmia feministiseen estetiikkaan*, eds. Pauline von Bonsdorff and Anita Seppä (Helsinki: Gaudeamus, 2002), 9-10.
[16] Michele Emmer, 'Visual Mathematics: Mathematics and Art,' *The Visual Mind II*, ed. Michele Emmer (Cambridge: MIT Press, 2005), 59-90.
[17] Kerttu Piirto, 'Kauneuden etsijä,' *Helsingin Sanomat/Nyt*, 17 March, 2011: 29.
[18] Katri Kallionpää, 'Galaksit tanssivat talvisirkuksessa,' *Helsingin Sanomat*, 30 October, 2013, B: 1.
[19] Angela Breitenbach, 'Beauty in Proofs. Kant on Aesthetics in Mathematics,' *European Journal of Philosophy* (2013):1-23, Article first published online: 16 April 2013, viewed 12 October 2013, http://www2.phil.cam.ac.uk/teaching_staff/breitenbach/Breitenbach_BeautyProofs.pdf.
[20] James W. McAllister, 'Mathematical Beauty and the Evolution of the Standards of Mathematical Proof,' *The Visual Mind II*, ed. Michele Emmer (Cambridge: MIT Press, 2005), 15.
[21] Emmer, 'Visual Mathematics,' 66.
[22] McAllister, 'Mathematical Beauty,' 15-18.
[23] Ibid., 17.
[24] Ibid.
[25] Godfrey H. Hardy, *A Mathematician´s Apology* (Cambridge: Cambridge University Press, 1967).
[26] Gian-Carlo Rota, 'The Phenomenology of Mathematical Beauty,' *The Visual Mind II*, eds. Michele Emmer (Cambridge: MIT Press, 2005), 4.
[27] McAllister, 'Mathematical Beauty,' 28.
[28] Breitenbach, 'Beauty in Proofs. Kant on Aesthetics in Mathematics', 1.
[29] Ibid., 2.
[30] Ibid., 23.
[31] Umberto Eco, 'Kauneus sopusuhtaisuutena ja harmoniana,' *Kauneuden historia*, eds. Girolamo De Michele and Umberto Eco, trans. Pekka Tuomisto (Helsinki: WSOY, 2008), 63.
[32] Plato, *Timaeus*, trans. Donald J. Zeyl (Indianapolis: Hackett Publishing, 2000), 53e-56c.
[33] Plato, *The Symposium*, trans. Margaret C. Howatson (Cambridge: Cambridge University Press, 2008), 211d-212b.

[34] Charalampos Saitis, 'Fractal Art: Closer to Heaven? Modern Mathematics, the Art of Nature, and the Nature of Art,' *Bridges Donostia*, Conference proceeding of Bridges: Mathematical Connections in Art, Music, and Science held 24-27 Jul in San Sebastian, Spain, eds. Reza Sarhangi and Javier Barrallo (Phoenix: Tessellations Publishing, 2005), 369-376.
[35] See e.g., György Darvas, *Symmetry* (Basel: Birkhäuser, 2007).
[36] Saitis, 'Fractal Art: Closer to Heaven?' 369-376.
[37] Several artists interested in mathematics and geometry have also participated in the production of this discourse. See e.g., Emmer, 'Visual Mathematics: Mathematics and Art', 59-90.
[38] Darvas, *Symmetry*, 375.
[39] Kant, *Critique of Judgement*, 90-114.
[40] Ian Stewart, *Nature's Numbers: The Unreal Reality of Mathematics* (New York: Basic Books, 1995), 1.
[41] E.g., Joe Rosen, *Symmetry Rules. How Science and Nature Are Founded on Symmetry* (Berlin: Springer, 2008); Mario Livio, 'Symmetry: From Perception to the Laws of Nature,' *The Many Faces of Beauty*, ed. Vittorio Hösle (Notre Dame, Indiana: University of Notre Dame Press, 2013), 79-112; Ian Stewart, *Why Beauty is Truth: The History of Symmetry* (New York: Basic Books, 2007); K. C. Cole, *The Universe and the Teacup: The Mathematics of Truth and Beauty* (Orlando: A Harvest Book Harcourt, 1997), 174-176.
[42] Saitis, 'Fractal Art: Closer to Heaven?', 375.
[43] E.g., Heinz-Otto Peitgen and Peter H. Richter, *The Beauty of Fractals: Images of Complex Dynamical Systems* (Berlin: Springer, 1986); Przemyslaw Prusinkiewicz and Aristid Lindenmayer, *The Algorithmic Beauty of Plants* (Berlin: Springer, 1990); Gary W. Flake, *The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation* (Cambridge: MIT Press, 1998).
[44] E.g., Gillian Rhodes, Fiona Proffitt, Jonathon M. Grady and Alex Sumich, 'Facial Symmetry and the Perception of Beauty,' *Psychonomic Bulletin & Review* 5.4 (1998): 659-669; Karl Grammer and Randy Thornhill, 'Human (Homo sapiens) Facial Attractiveness and Sexual Selection: the Role of Symmetry and Averageness,' *Journal of Comparative Psychology* 108.3 (1994): 233-42.
[45] Ernst Gombrich, *The Sense of Order. A Study in the Psychology of Decorative Art* (Oxford: Phaidon, 1979), 3 and 216; see also Boussora Kenza, 'The Complex Experience of Beauty. Architecture, Man and Building Environment,' in this volume.
[46] Magnus Enquist and Anthony Arak, 'Symmetry, Beauty and Evolution,' *Nature* 372 (2002): 169-172.
[47] See particularly Stewart, *Why Beauty is Truth*.

[48] Darvas, *Symmetry*, 367.
[49] Darvas, *Symmetry*.
[50] Cole, *The Universe and the Teacup*, 4.
[51] Stewart, *Why Beauty is Truth*, xiii.
[52] Ian Stewart and Martin Golubitsky, *Fearful Symmetry: Is God a Geometer?* (Oxford: Blackwell Publishers, 1992); Mario Livio, *Is God a Mathematician?* (New York: Simon & Schuster, 2009).
[53] Livio, *Is God a Mathematician?*, 1.
[54] Mario Livio, *The Golden Ratio: The Story of Phi. The World´s Most Astonishing Number* (New York: Broadway Books, 2003).
[55] Aristotle, *Poetics*, trans. Malcolm Heath (London: Penguin, 1996).
[56] Arto Haapala and Ukri Pullinen, *Taide ja kauneus. Johdatus estetiikkaan* (Helsinki: Kirjapaja, 1998), 27.
[57] Ellen Swift, *Style and Function in Roman Decoration* (Abingdon: Ashgate, 2009), 12.
[58] See the discussion on the opposite views between the universalist and cultural notions on the nature of perception e.g., Jacques Ninio, *The Science of Illusions*, trans. Franklin Philip (Ithaca: Cornell University Press, 2001).
[59] Kenneth Gergen, 'The Social Constructionist Movement in Modern Psychology,' *American Psychologist* 40.3 (1985): 266-275; Jonathan Potter, *Representing Reality. Discourse, Rhetoric and Social Construction* (London: Sage, 1996).
[60] See studies on female beauty ideals and their differences in different cultures e.g., Katherine Frith, Ping Shaw, and Hong Cheng, 'The Construction of Beauty: A Cross-Cultural Analysis of Women's Magazine Advertising,' *Journal of Communication* 55.1 (2005): 56-70; Qinwei Xiea and Meng Zhanga, 'White or Tan? A Cross-Cultural Analysis of Skin Beauty Advertisements between China and the United States,' *Asian Journal of Communication* 23.5 (2013): 538-554; Kim L. Bissella and Jee Young Chung, 'Americanized Beauty? Predictors of Perceived Attractiveness from US and South Korean Participants Based on Media Exposure, Ethnicity, and Socio-Cultural Attitudes toward Ideal Beauty,' *Asian Journal of Communication* 19.2 (2009): 227-247.
[61] See e.g., Katy Deepwell, 'Beauty and Its Shadow: A Feminist Critique of Disinterestedness,' *Feminist Aesthetics and Philosophy of Art: The Power of Critical Visions and Creative Engagement*, ed. Lisa Ryan Musgrave (New York: Springer, forthcoming).
[62] von Bonsdorff and Seppä, 'Johdanto', 7-24.
[63] See e.g., Ernst Gombrich, *Art and Illusion: A Study in the Psychology of Pictorial Representation* (New York: Pantheon Books, 1960); Nelson Goodman, *Languages of Art* (Indianapolis: Hackett, 1976).

[64] Ruth Lorand, 'What is Beauty and Why Do We Need It?' in this volume.
[65] Pierre Bourdieu, *Distinction. A Social Critique of the Judgement of Taste* (Routledge: London, 1984).
[66] Goldstein, 'Beauty in Art and Mathematics,' 94.
[67] Rota, 'The Phenomenology of Mathematical Beauty,' 9.
[68] Rosina Martucci, 'The Analysis of Beauty. When Art Meets Literature: Giovanni Boccaccio and William Shakespeare through the Paintings of William Hogarth,' in this volume.
[69] Swift, *Style and Function in Roman Decoration*, 3; Ernst Gombrich, *The Sense of Order*.
[70] Vijaya Rettakudi Nagarajan, 'Threshols Designs Forehead Dots, and Menstruation Rituals: Exploring Time and Space in Tamil Kolams,' *Women's Lives, Women's Rituals in the Hindu Tradition*, ed. Trace Pintchman (Oxford: Oxford University Press, 2007), 85-106.
[71] Tessa Morrison, 'Labyrinthine Path of Pilgrimage,' *Peregrinations. Journal of Medieval Art and Architecture* 1.3 (2003): 1-7.
[72] Craig M. Wright, *The Maze and the Warrior: Symbols in Architecture, Theology, and Music* (Cambridge: Harvard University Press, 2001), 210.
[73] Martin Kemp, *The Science of Art. Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven: Yale University Press, 1990).

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Docent **Tuuli Lähdesmäki**, PhD, DSocSci, is an Academy Research Fellow at the Department of Art and Culture Studies, University of Jyväskylä, Finland. Her research focuses on discursive meaning-making processes in visual art and contemporary visual culture.