# The Royal Society of Edinburgh

## Two-day Conference
## organised by Sir Michael Atiyah, University of Edinburgh and Professor Semir Zeki, University College London

## *The Science of Beauty*

Tuesday 10 & Wednesday 11 November 2015

Report by Matthew Shelley

*Speakers from the forefront of fields including mathematics, physics, neuroscience, art and psychology explored the experience of beauty. Over two days, they considered what beauty from sensory sources such as music and art has in common with beauty from cognitive ones such as mathematics or from moral sources. Sir David Attenborough also considered whether some animals make judgments for aesthetic reasons.*

The audience and speakers were welcomed by Dame Jocelyn Bell Burnell, President of the Royal Society of Edinburgh, who described the event as one that embraced many of the RSE's areas of interest such as science, arts and the humanities.

### *Day 1*

### *The Role of Beauty in Mathematics*

**Sir Michael Atiyah, University of Edinburgh**

As the introductory speaker, Sir Michael focused on geometry and evoked the words of great philosophers to make the case that mathematics is not only beautiful, but helps us to understand the world. Starting with the equilateral triangle, which he said is the most symmetrical figure in geometry, he then moved from two to three dimensions and the tetrahedron now replaced the triangle.

He then moved to biology and explained that most viruses take the form of an icosahedron (which can be created by repeatedly doubling tetrahedrons). Some have sharp points for defence, while others have flat faces and are designed to escape. Professor Atiyah said this is fundamental as "the most important things in life, whatever you are, whether you are a football player or a virus, are to be able to deter attackers or get away if necessary."

Sir Michael looked at how mathematical theory advanced over the centuries and the challenge of solving equations. The Norwegian Niels Abel and Frenchman Evariste Galois (a radical whose notes from the night before his assassination helped found the theory of groups on which modern algebra is based) realised that equations of degree 5 or more could not be solved by just $\sqrt{\ }, \sqrt[3]{\ }, \sqrt[5]{\ }$ .

Sir Michael went on to look at what can be done with shapes of increasing complexity. Archimedes (described as "maybe the greatest mathematician of all time") made use of regular polygons to calculate $\pi$ to increasing levels of accuracy. These days, he added, related ideas have a whole new use as the basis of modern coding theory and are key to effective data encryption.

He then turned to Gödel's incompleteness theorems and their impact on mathematical thought, logic and philosophy in the 20th Century, and also to the work of Bertrand Russell. This included Russell's appreciation of Pythagoras' recognition that the foundation of music is mathematics – and that we do not need to appeal to gods and the supernatural to understand the world, but to numbers.

Sir Michael concluded with a series of quotations including:

- Pythagoras: "Numbers rule the Universe."
- Plato: "God is a geometer."
- Karl Weierstrass: "It is not possible to be a complete mathematician and not have the soul of a poet."
- G.H. Hardy: "Beauty is the first test: there is no permanent place in the world for ugly mathematics."
- Hermann Weyl: "My work has always tried to unite the true with the beautiful and when I had to choose one or the other, I usually chose the beautiful."
- Bertrand Russell: "Mathematics, rightly viewed, possesses not only truth, but supreme beauty…"

**Questions**

Asked whether computers could be programmed to recognise beauty in mathematics, he said that appreciation of beauty lives somewhere in the mind. At present it is beyond the reach of computers.

***Neural Correlates of the Experience of Beauty, Including Mathematical Beauty***

**Professor Semir Zeki, University College London**

Far from being peripheral, Professor Zeki sees the issue of beauty as important. This is, in part, because "we all seek beauty almost 24 hours a day, whether it is in our homes, in our pastimes or in our work …"

One of the brain's primary functions is the acquisition of knowledge – making sense of the information it receives from the world. It does so both sensorially (as in vision) or cognitively (as in mathematics). But to obtain knowledge about the world, the brain has to stabilise the world because the signals reaching it from the world are never the same from moment to moment. The brain has, therefore, to impose some order on that ever-changing picture.

One way the brain helps interpret the world is through colour. There are no colours in the outside world; colours are, instead, created by the brain through its specialised systems. These systems are able to assign a constant colour to a surface, regardless of the continual changes in the wavelength-energy composition of the light reflected from it.

As a specialist in neuroaesthetics, Professor Zeki is concerned with what neural mechanisms are engaged when we experience beauty and not the nature of beauty itself. A key question is whether there are common neural mechanisms involved when

we experience beauty. The Professor outlined the results of experiments in which brain activity was monitored when people looked at pictures and listened to music. In each case, subjects had been asked to identify and rate musical excerpts and paintings according to whether they experienced them as beautiful or ugly.

The results showed that there is indeed a common mechanism in the brain where activity correlates with senses of beauty derived from all sources – visual, aural and even moral. It is located in the medial orbitofrontal cortex, a part of the emotional brain. Professor Zeki also asserted that aesthetic judgment can be quantified. Experiments showed that the more beautiful humans find something, the greater the blood flow in the areas of the brain that respond to beauty. The experience of ugliness triggers activity in other parts of the brain.

However, there are complicating factors. On the one hand, areas of the brain perform multiple functions; on the other, there are relationships between beauty and other qualities such as sublimity, which he said is unique, vast and involves "horror mingled with beauty, pleasure from displeasure, fear of something looked at from a safe distance …" The brain activity produced by something of a small scale regarded as beautiful turns out to be distinct from something sublime.

He then turned to the experience of mathematical beauty which, he said, "on the face of it offers an extreme example of the experience of beauty derived from culture and learning …" Experimentation has shown that the same areas of the brain which appear to respond to other forms of beauty become active when the mathematicians look at equations they find beautiful. The aesthetic experience derived from mathematical formulations is possibly due to the fact that they make sense to the logical deductive system of the brain. Hence, the beauty of a mathematical equation becomes a guide to its truth and validity, as Paul Dirac emphasised. "I think the winner in all this," he concluded: "is Keats, who said 'beauty is truth, truth beauty'."

**Questions**

The issue was raised of changes in concepts of beauty; for example, the initial rejection and later celebration of Impressionism by the Arts Establishment. Professor Zeki acknowledged that there is a cultural element in concepts of beauty, but added that if you want an instinctive reaction to beauty you do not go to experts, as "they know too much"; instead, you need to study, in the first instance, the reaction of ordinary people to what they find beautiful.

### *The Perception of Human Beauty*

**Professor Beatrice de Gelder, Maastricht University**

There is an intrinsic relationship between emotion and art, according to the Professor, though it may be more straightforward to be aware of it for music than for visual art. Nonetheless, she argued that a better understanding of bodily expressions of emotion "may allow us to build a bridge between art and neuroscience".

She then turned to the issue of how bodily expressions are processed by the brain. The standard view is that as soon as a brain receives information it assigns it to one or another object category, after which only "it deals with the various attributes". Professor de Gelder's own research suggests that the first response to an emotional bodily

expression is not in the areas of the brain that deal with categorisation but in areas that are for action, representation and emotion.

Professor de Gelder described experiments where subjects were shown images of bodily expressions, but using masking techniques that meant they were not consciously aware of them. This stopped their “very finely tuned conscious and conceptual judgment from kicking in”. Her tentative hypothesis is that the brain has a ventral object stream and a “dorsal, more action- and emotion-oriented perception stream” and they generate very different activities and feelings.

The Professor then discussed a study using paintings representing bodies. Researchers wanted to have comparable images of male and female beauty and chose pictures showing St Sebastian. In some cases, they showed pictures with the saint pierced by arrows, in others they removed them. There were significant differences in which areas of the brain were activated according to the genders of the viewer, the subject, and the presence or absence of arrows. Indeed, there was some activation of areas of the brain that normally respond to touch.

There has also been work on tactile body recognition which uses “tactile body expressions conveyed by 3D printing”. This showed a substantial overlap in the type of brain activity of people who actually touched the objects and those who were asked to imagine touching them. This, said the Professor, reinforces her suggestion that emotions are triggered by the dorsal stream and there is a period in which they are not formatted by the conceptual apparatus.

### Questions

Asked if there is a relationship between empathy and images showing people enduring pain, Professor de Gelder said that research in that area is limited. The images had not, though, triggered areas of the brain which deal with pain.

## *Beauty and Excellence in Scottish Philosophical Aesthetics*

### Professor Gordon Graham, Director of The Center for the Study of Scottish Philosophy, Princeton Theological Seminary

The science of beauty has, according to Professor Graham, received fresh stimulus as biologists and psychologists have turned their attention to the arts. It is not always appreciated, however, that questions being asked today about the psychological root of beauty or the relationship between evolution and art have historical precedent.

Aesthetics, said the Professor, is an 18$^{th}$ Century invention and Scotland took the lead with the work of people such as Francis Hutcheson. The debate he prompted about taste and beauty was one to which well-known figures such as David Hume, Thomas Reid and Adam Smith all contributed. At that point, aesthetics was not a freestanding subject but part of the wider science of mind. The purpose was not simply to understand human faculties, but to find ways they could be better used. The assumption was that the “taste” by which we appreciate beauty is one of our intellectual powers. The task of aesthetics, though it was not necessarily known by that name, was to arrive at general principles about the operations of the mind. Scientific observation would allow us to improve ourselves.

Immanuel Kant took a different view and believed that we must understand what constitutes beauty before we can understand the mind's response. Hume, by contrast, suggested a model in which there are universal principles of taste, but humans do not always grasp them because their faculties are insufficiently educated. He believed that the passage of time is the best test of the universality of good taste.

Hume's contemporary Thomas Reid, came up with a similar theory, but reversed key concepts. Where Hume claimed that feeling gives rise to opinion, Reid said it's the other way round and that we derive pleasure from things we judge beautiful. He recognised that beauty is so varied that it is difficult to determine what it is, or what beautiful objects have in common. Reid's solution was that the judgment of beauty reflects a delight in excellence. Professor Graham said: "Accordingly, the aim of a science of beauty must be to trace the structure of perfection. And Reid contends that it's the ability to do this which unites the critic and the artist."

While Reid offers the idea of aesthetics as a true science, because it is about the exercise of true reason, Hume can only encompass facts about psychological responses and never an account of the phenomena that cause the response. The Professor went on argue that if there can be an empirical science of beauty, then it is best conceived normatively, as was done by Reid, rather than psychologically, as done by Hume.

**Questions**

Asked about the concept of excellence and whether Reid came close to the rationalist concept of perfection, Professor Graham said that within this context the idea of excellence was one of "fittedness". It is possible to strive for perfection, he added, and achieve excellence.

### *Philosophical Approaches to Beauty in Mathematics*

**Dr Angela Breitenbach, Cambridge University**

Some of the world's greatest mathematicians have spoken of the centrality of aesthetic beauty in their work. According to Dr Breitenbach, this raises difficult questions; not least because mathematics is so abstract. "The question is whether beauty in mathematics is similar, or comparable to, beauty elsewhere such as in art or nature, which have a much more obvious sensory appeal," she said. Beyond that, there is the question of what it is that is beautiful.

Some experimentation has shown that the same areas of the brain are triggered by mathematical and other forms of beauty. But Dr Breitenbach raised the problem that these parts of the brain have a variety of functions, so it cannot be assumed that it is beauty that prompts the activity. Furthermore, just because people use the term 'beauty', this does not necessarily mean that the experience is genuinely aesthetic – there are other forms of pleasure.

Dr Breitenbach then turned to the debate between early modern rationalist philosophers and Kant. She then explored Kant's suggestion that beauty in mathematics is to do with the imaginative processes that lead to mathematical cognition. This differs from the rationalist idea that beauty is grounded in the sensory recognition of perfection; which suggests that the properties of beauty can be studied and, therefore, a science of beauty is possible.

Kant did not accept that recognising mathematical objects as having a perfection is an experience of beauty. Dr Breitenbach said: “It is one thing to cognise perfection in an object and it’s another to experience it as beautiful.” As the experience of beauty is a feeling, it is important to be clear about what the feelings are. This, according to Dr Breitenbach, does not deny that there is beauty in mathematics. The argument is that it lies elsewhere, in the imaginative creative activity of the mathematician or the student of mathematics. This means there can be no ultimate principles about what makes an object beautiful. There can, however, be a critique of the intellectual process at work in making aesthetic judgments.

Dr Breitenbach believes that Kant’s arguments have relevance today. Even if we do not accept Kant’s idea that all mathematics is synthetic *a priori,* we can still regard mathematical beauty as consisting in a response that is generated by our own intellectual processes.

In conclusion, she said that anyone looking at mathematical beauty must distinguish between aesthetic and hedonic feelings. She also added a note of caution that aesthetic judgment may lead us astray. A sense of beauty may make us feel we are on the right track for truth – but this could be wrong. Beauty is not always a reliable guide.

### Questions

Challenged on whether it is possible to distinguish between aesthetic experience and pleasure, Dr Breitenbach said that we do, as a matter of fact, distinguish between the aesthetic and other types of pleasure and that, in many contexts, we regard the distinction as important.

## *Literature and Empirical Aesthetics*

### Professor Winfried Menninghaus, Director, Max Planck Institute for Empirical Aesthetics, Frankfurt

The beauty of language is less well investigated than visual or musical beauty, according to Professor Menninghaus.

The Professor presented the results of a study that manipulated the shortness, rhyme and metre of proverbs. Subjects gave higher beauty ratings to the material featuring rhyme, metre and brevitas. They also found it more persuasive, even though it was sometimes less easy to understand. This challenges psycholinguistic theory, which predicts that ease of understanding correlates highly and causally with beauty attributions. Obviously, beauty of language can go along with reduced levels of semantic comprehensibility. However, “if the three rhetorical target features (shortness, metre and rhyme) join forces, they are perceived as being both most beautiful and most persuasive, even though they are least comprehensible,” said Professor Menninghaus.

According to the Professor, this result is in keeping with Plato’s idea that you “purchase beauty and believe its truth”. It appears that beauty, “strikingness” and power of persuasion are all enhanced by poetic language, even while comprehensibility is diminished.

He went on to describe further work examining what people find more or less emotionally moving – whether negatively, such as the funeral of a loved one, or

positively, such as the birth of a child. This work has resulted in the creation of an entire psychological construct attempting to show what it is to be moved.

Professor Menninghaus then outlined research in which subjects were presented with a mixture of moving, lyrical and melodious poems, then shown amended texts where the metre, rhyme and other key poetic characteristics had been removed. The results showed that the presence of these characteristics clearly intensifies the emotional response.

Summing up, he said that the beauty of language, as driven by features such as rhyme and metre, strongly affects emotional responses and cognitive processing.

**Questions**

Looking at which great writers generates a strong emotional response, Professor Menninghaus said he has done considerable work on Shakespeare and his writing typically scores very highly on a measure for parallelistic patterning.

***Beauty in the Animal World***

**Sir David Attenborough**

Sir David said he would address the question of whether animals have an aesthetic sense and, on occasion, take decisions based entirely on qualities that have no practical value. He began by considering the perception of visual beauty; human beings certainly discern it in birds. But do birds themselves also do so?

The 19th Century explorer, Alfred Russel Wallace, was the first European to witness the mating displays of birds of paradise. He thought it absurd to suggest that females were selecting particular males because their plumes were brighter or more spectacular than those of their rivals. Darwin, however, argued that the huge train of the male peacock has evolved for precisely that reason.

That this can happen is shown even more clearly by male bowerbirds. They have relatively plain plumage and seek to impress females by gathering inanimate objects such as berries, flowers, snail shells or brightly coloured pebbles and display them in special nest-like constructions called bowers.

Nor is aesthetic selection on visual grounds confined to birds. It also occurs among insects, spiders, even fish. The male of a small Japanese species of pufferfish spends days constructing a complex flower-like pattern several metres across in the sand of the sea floor to persuade a female to mate with him and lay her eggs in its centre.

Sounds too can be used in courtship displays. The female greater reed warbler, on arrival in Europe in spring, will tour a reed bed and choose to mate with the male whose song can be demonstrated, numerically, to contain the most complexity. Male lyre birds in Australia not only produce complex songs, but complicate them still further by including imitations of the songs of other species and of other sounds, such as those of camera shutters and chain saws, which they hear in the forest.

*A* few birds, such as the South American manakins, are not only brightly coloured and vocally gifted, but also add complex dancing to their displays. In the most extreme *case,* several subordinate males collaborate with a dominant male and work as a team to perform complex dance routines – though only the senior male will copulate

with a visiting female.

The recognition of an aesthetic sense, first proposed by Darwin, fell out of fashion in the 20th Century, as biologists concentrated on the genetic aspects of the evolutionary process. Plumes of birds, it was suggested, are selected by females, since they indicate a pre-eminent physiological vigour that would make the male concerned a preferable mate. Vigorous health may well explain why evolution proceeds at speed to produce such spectacular plumage, but it can hardly be knowingly identified by a female as a reason for selecting her mate.

Such examples as these surely make the case that the aesthetic sense, which some have argued is one of the qualities that lifts mankind above the rest of the living world, is not, in truth restricted to humanity.

## Questions

Asked if fitness and aesthetic explanations for mate selection were mutually exclusive, Sir David agreed that they were not necessarily so. Some male birds clearly seek to impress prospective mates by demonstration of their merits as parents in practical ways. A male tern, during courtship, brings offering of fish to a female. A male eagle indulges in athletic aerobatics which demonstrate his abilities as a hunter. Such actions are clearly of value to those species where both parents collaborate to rear young. But birds of paradise, and other birds mentioned, are polygamous. The females build a nest and rear the young entirely by themselves. They are not, therefore, choosing partners for practical reasons, but do so by assessing displays – visual, audible or choreographic – of prospective partners who will contribute nothing to producing the next generation, except conception.

## *Day 2*

### *Beauty in Physics and Mathematics*

**Professor Robbert Dijkgraaf, Director and Leon Levy Professor, Institute for Advanced Study, Princeton**

Physics and mathematics are very different and so, consequently, are their concepts of beauty, according to Professor Dijkgraaf. While physics may be expressed in mathematical language, it is about the explanation of physical phenomena.

In mathematics, the idea of beauty as a goal remains strong, but in physics it has gone through different phases. However, he quoted particle physicist Richard Feynman as saying that without knowing mathematics, it is difficult to appreciate the deepest beauty of nature – as this is the language in which it is naturally expressed.

Turning to the relationship between truth and beauty, Professor Dijkgraaf asserted that mathematics and physics have different approaches to truth. Mathematics can pursue absolute precision, whereas every theory in physics must have a degree of approximation and be flexible enough to adapt to our changing state of knowledge.

Sometimes the change can seemingly bring the loss of beauty – but the result can be an even greater one. When Kepler tried to explain the movement of the planets, he realised they were not going in circles but ellipses. While he felt that the loss of the perfection of circles involved bringing a “horse cart of manure” into physics, it was to replace a much larger one. And as our understanding of the Universe has evolved further, much more beautiful mathematics has been revealed.

Even within mathematics there are, according to Professor Dijkgraaf, different appreciations of beauty. For some, beauty is in the generalisable, for others, in the exceptional. In physics the idea of beauty may not bear much relation to what is considered beautiful in everyday life. One of the great beauties of physics lies in its equations, especially concise ones, for their capacity to explain huge ideas and bring different worlds together. The left and right hand sides will give two perspectives on the same phenomena.

Discussing the “deepest concept of modern physics” the Professor said that if you look at physical phenomena at different scales, the phenomena themselves are different. Even the laws of nature change according to the scale at which you observe them. If you ask physicists where the greatest beauty is found, some will see it at smaller scales, whereas others would find it at the largest. Moving to modern particle physics Professor Dijkgraaf said it satisfies the requirements of being beautiful, with simple equations and elegant mathematics which explain much about the world around us.

Mathematics has exceptional rigour, while physics demands a capacity for intuition, and the two are not always easy to reconcile. It may be the case that we can only understand physical reality through a series of overlapping partial explanations – each with beautiful mathematics. However, it is possible that the beauties within mathematics and physics can be reconciled and united, if it turns out that there is a single, overarching language with which we can understand the Universe, with a single underlying mathematical structure.

### Questions

The question was raised of whether string theory is an entirely intellectual construct. Professor Dijkgraaf agreed that theoretical physics is always a step ahead of observation, but that there is always an interaction with experiments. Radical advances involve a combination of new thinking and experimentation.

### *The Neurobiology of Aesthetic Judgments*

**Dr Tomohiro Ishizu, University College London**

The experience of beauty has often been regarded as subjective, so Dr Ishizu said his central theme was whether it could be studied by neuroscience.

Thanks to the development of technologies such as MRI, it is now possible to measure brain activity. As the subjective experience we have of beauty is a product of the brain and must have a neural basis, it can be objectively measured. As science is based on fact and measurement, this means that beauty can be the subject of scientific study.

Dr Ishizu went on to discuss how the brain works when we experience beauty, the systems within the brain that make aesthetic judgments and, finally, the distinction between inherited and acquired concepts in our visual perception.

First, he looked at the common neural conditions which allow us to experience beauty in diverse sources. Using functional MRI scanning, it was shown that blood flow increases in the same areas of the brain when people experience paintings and pieces of music they rate as beautiful. This demonstrates that the experience and the judgment are closely related.

However, Dr Ishizu argued that there is a distinction between perceptual and aesthetic judgments. This is backed up by experimentation which looked at which parts of the brain are active when people are asked to judge beauty in a pair of paintings and then asked to say which of the two paintings of the same pair is brightest.

Dr Ishizu has also used paintings by Francis Bacon to look at the brain's responses to ugliness. These showed that different areas are triggered than for beauty, including the motor cortex that is generally associated with action. He speculated that this is because the brain wishes to protect a person from ugliness. It also demonstrates that two different forms of subjective experience can be distinguished by brain activity.

He went on to suggest that there are templates in the human mind that help determine what we see as beautiful in natural objects. These are not present for artefacts. This could mean we have both inherited and acquired responses. Indications from ongoing experimentation also suggest that there are significant differences in brain responses to things such as faces, for which we have templates, and artificial objects, for which we have learned responses.

In conclusion, Dr Ishizu emphasised that study is at an early stage and has still to resolve major issues over areas such as correlation and causation. While there are many problems to be addressed, he believes we can now study beauty scientifically.

### Questions

Questioned about whether ideas of beauty vary between people (perhaps serial killers would be different from others?) Dr Ishizu said there were clear distinctions between what people found beautiful. The brain's responses to something that an individual did judge as beautiful were, however, similar.

### *The Neurobiology of Beauty, as Related to Symmetry*

**Dr Cinzia Di Dio, University Cattolica Milan**

Dr Di Dio described research into the brain's responses to beauty that were designed to filter out as many potential sources of distraction as possible. Rather than using paintings, where colour and background may have an influence, it used classical sculptures depicting people. Subjects were shown photographs, in some of which changes had been made to the proportions. The results established a clear link between aesthetic evaluation and modification, with people showing a strong preference for the originals.

When people observed the images of the sculptures, it was found that areas of the brain were triggered that normally become active when we perform an action, or watch others taking action. Dr Di Dio suggested that humans do not just view sculptures with their visual brain "but somehow we are involved … we resonate with the movement expressed in an artwork".

A tentative explanation is that there is a match between the sculpture and the brain's established notion of what a human body should be. The researchers think that aesthetic experience comes from the joint activation of cortical areas related to visual analysis and of the areas of the brain that provide emotional responses and those responsible for cognition.

A potential flaw in the work is that the responses might have been to the human body rather than to the objects as works of art. Further experiments were carried out comparing people's responses to images of sculptures and ones of professional football players in similar poses. From this, they found that the brain evaluates images of real humans differently from sculptures, responding more as it would if it was in a real-life engagement with the person in the photograph.

### Questions

Dr Di Dio was asked about the selection of subjects for her experiments, and why right-handed people were chosen. She said this was simply standard procedure to reduce potential variables.

### *The Beauty of Tears and the Tears of Beauty: Neurobiology of Sorrow*

**Professor Michael Trimble, Institute of Neurology, University College London**

We start to cry emotionally around the age of three months. Opening his talk with a video recording of a mother singing a lullaby to her baby who starts crying, Professor Trimble said that tears have a close relationship with mothers, their embraces and early experiences of music.

Emotional tears are triggered by many things, mostly autobiographical, especially loss, bereavement and pain. Several studies have shown that seeing someone crying has a strong impact on the behaviour of the observer, and evokes feelings of empathy. Tears are not so frequently represented in the arts, especially sculpture. However, removing tears from a painting showing someone crying renders the expression ambiguous. Professor Trimble showed several images of tears of beauty in paintings, especially from the Netherlands. Many were related to religious themes.

In art, tears are linked with beauty and eroticism. To emphasise these points, he quoted passages from Cervantes *Don Quixote*, the sad knight, who wept in pursuit of beauty he could never attain; from Dante's *Divine Comedy;* and from Goethe's *Werthe*r.

Professor Trimble and colleagues have researched crying in relation to the arts. Few people are moved to tears by architecture or paintings, but very many are moved by music and substantial numbers by novels. "Music is the art form that really does it," he said. The Professor asserted that we are feeling something very special when art brings us to tears and that it is beyond, and different from, our everyday emotions.

Turning to evolution, he said that the ability to cry emotionally emerged a long time before the first known human artworks. It is likely that emotional crying might have developed perhaps as long as 500,000 years ago, with the dawning of pre- *Homo sapiens* cultures, alongside capacities such as singing, dancing and the development of an emotionally-based proto-language.

In summary, Professor Trimble, said that while the face is very important to human beauty it is the eyes that probably have done most to enhance the development of compassion between individuals, closely linked with empathy and interpersonal bonding. He said "beauty may be in the eye of the beholder but there is even more beauty in the tears". Our ability to cry emotionally has done much to make us human.

### *Conversation Without Words*

**Professor Nicky Clayton, Cambridge University and**
**Mr Clive Wilkins, Artist in Residence, Cambridge University**

In a dynamic double act, the two speakers focused on the art of the ancient Greeks and what it tells us about our perception of beauty and the cognitive mechanisms we use to evaluate beauty and interpret its significance. Professor Clayton described the arrival of the Classical period of art as seeming "as if man's ability to describe and define our humanity had blossomed into something very special overnight".

A vital capacity for the development of art is the ability to plan and anticipate – to project the self in space and time. According to Mr Wilkins, it is as if the Greeks began to feel that the perfection they imagined in the gods was coming within their own grasp. As a result, they showed the ambition to depict the impossible, depicting themselves in the guise of the Gods they worshipped, in so heavy and weighty a substance as white marble, or heavy cast bronze.

Professor Clayton suggested that the ancient Greeks were recognising that beauty is not in the object but in the perception that an idea can be wonderful. The art of the period used mathematics and geometry in its efforts to describe the human form, and this was not the form as generally found in nature, but perfected.

The Greeks also introduced *contrapposta*, one of the great artistic insights which added immeasurably to the capacity to depict beauty. While beauty has symmetry, Mr Wilkins said that “Perfect mathematical forms were all well and good. Beauty has symmetry but that is not necessarily enough to imply life or the plasticity of movement.” To breathe life into a form requires the suggestion of energy and movement. Greeks in their classical period realised that a delicate imbalance where stress appeared to be exerted across a form created a tension that held interest in the mind of the viewer, and this could be used to change and strengthen other areas of society, and even government.

Professor Clayton went on to argue that the Greeks understood not just that life is dynamic, but that “beauty needs to be ambiguous, in transition, caught in the moment”, and to illustrate the point the couple performed a stunning Argentine tango.

As Mr Wilkins explained, the Greeks also looked to the natural world for evidence that other creatures shared the gifts that humans had – and they found it among the corvids, the crow family. They believed such birds held the power of prophecy.

According to Professor Clayton, there is strong evidence that corvids can, like humans, anticipate and plan for the future. She described experiments in which Clark’s nutcrackers were sometimes put in cages where they had breakfast immediately the next morning and at other times put in cages where breakfast was later. They were also given access to extra food the night before. They rapidly learned the difference between cages and when they were in the “hungry” cages they made caches of food to ensure that breakfast was available first thing.

The speakers said that it is this capacity to anticipate and think beyond our immediate selves that is a fundamental building block of our creativity, because we have to imagine and plan. These, they said, are essential to our pursuit of beauty, as well as being the key traits which drive us as a species.

### Questions

A discussion took place on whether beauty is always contemplative, or whether the experience can be in action, like dancing. Professor Clayton and Mr Wilkins explained how tango, and other forms of dance, can be a meditative experience which transcends the present.

## *The Role of Art in Mathematics*

### Sir Roger Penrose, Emeritus Rouse Ball Professor of Mathematics at the Mathematical Institute of the University of Oxford and an Emeritus Fellow of Wadham College

Sir Roger focused on the synthesis of art and mathematics, especially in the work of M C Escher and his use of complex rotational and translational symmetry. A mathematician himself, Sir Roger has also used his skills artistically.

He went on to discuss the rules of symmetry, including that one, two, three, four and six are the only symmetries possible in crystal patterns (ones which repeat themselves). He then showed a pattern which was devised after Escher’s death, taking five-point symmetry almost to the point of infinity. Sir Roger said there are 17 ways to create symmetrical patterns that can entirely cover the plane – all of which were used in the Alhambra Palace in Granada. Escher was inspired by the Alhambra and went on to create his own ever-repeating patterns.

There has been interest over the years in the creation of symmetrical patterns which will only tile the plane in a non-repeating way. Raphael Robinson had attempted to find the smallest number of shapes that would make this possible and got it down from the hundreds to six. Sir Roger had then taken up the challenge and eventually reduced it to two.

The artistic use of complex patterns has been used as part of the development of the Oxford University's Andrew Wiles Building. The area in front of the mathematics building is tiled with a design devised by Sir Roger – in this case, he has created something that looks as if it is going to repeat itself but never does.

Sir Roger said he first became aware of Escher's work in 1954 and "was absolutely stunned", especially by his use of paradox. This included a painting where a boy is looking at a picture but is also in the picture. Some of Escher's best-known images, including of endless stairs, are based on the Penrose tribar created by Sir Roger and his father Lionel. Others show impossible buildings through the simultaneous use of multiple viewpoints.

Sir Roger showed a series of pictures by Escher and explained their mathematical features. He said the accuracy and detail of Escher's work is especially astonishing because he had no mathematical training and had to work everything out for himself.

In conclusion, Sir Roger said it took a long time for Escher to be accepted by the artistic community and he was often seen as an outsider. But his work has great value, not least because it uses high artistic skills to show something of the beauty of mathematics.

### Questions

Asked how he and Escher influenced each other Sir Roger said that the artist had a substantial impact on his work and had driven his own interest in tilings.

The Vote of Thanks was given by Sir Michael Atiyah OM PPRS PPRSE.