

Pay attention to the sense.

Pay attention to the structure.

Verbs you can use instead of 'say'

The Hidden Maths in Great Art

By Marcus du Sautoy
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Marcus du Sautoy looks at how writers, painters and composers have obeyed laws of nature for centuries.

For many, this **would appear to be** synonymous with chalk and cheese. **One is the domain of emotional**

expression, passion and aesthetics. The other, **a world of steely logic, precision and truth.** And yet scratch the surface of these stereotypes and one discovers that **the two worlds have much more in common than one might expect.**

Any creative artist will tell you that the emotional resonance of a piece emerges out of the construction of the work and is rarely an ingredient fed in at the beginning of a composition. The composer Philip Glass **admits** that **he never deliberately programs** any emotional content in his work. He **believes** it's generated spontaneously as a result of all the processes that he employs. **"I find that the music almost always has** some emotional quality in it; it seems independent of my intentions." **The structure and internal logic of a piece is what drives** its composition.

Explain this idea with your own words. Use an AOK / WOK to give a concrete example.

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Elaborate on this point. Mention examples from different disciplines if possible.

Explain this idea with your own words. Mention examples to support your opinion.



Nadja Saidakova and Vladislav Marinov dance to music by Philip Glass at the Ballet Gala of the Berlin State Ballet in 2011. (Credit: Sueddeutsche Zeitung Photo/Alamy Stock Photo)

Mathematicians are storytellers. Our characters are numbers and geometries.

Perhaps more surprising is the role that emotions and passion play in the mathematics that we humans create. **Mathematics is far from being just** a list of all the true statements we can discover about number.

Mathematicians are storytellers. Our characters are numbers and geometries. Our narratives are the proofs we create about these characters. Not every story that it's possible to tell is worth telling.

I have spent many years as a mathematician working alongside artists and what has struck me is how similar our practices are. I have so often found artists drawn to structures that are the same ones I am interested in from a mathematical perspective. We may have different languages to navigate these structures but we both seem excited by the same patterns and frameworks. Often, we are both responding to structures that are already embedded in the natural world. As humans we have developed multiple languages to help us navigate our environment.

Explain this idea with your own words. Then explain how the meaning would differ if it had been stated as: "Mathematicians could be story tellers..."

What questions would be worth asking about these ideas?

Explain this idea with your own words. Use an AOK / WOK to give a concrete example.

A different beat

Music is probably the artistic discipline that traditionally has resonated most closely with the world of mathematics. As the German philosopher Gottfried Wilhelm Leibniz once **declared**: “Music is the pleasure the human mind experiences from counting without being aware that it is counting.” But this connection goes much deeper than that. The very notes that we **respond** to as harmonic have a mathematical underpinning, as Pythagoras famously discovered. And mathematical structures also **inform** the architecture of composition.

“Music is the pleasure the human mind experiences from counting without being aware that it is counting.” – Leibniz

Take the 20th-Century composer Messiaen’s Quartet for the End of Time. In this piece, **Messiaen creates an extraordinary sense of tension by employing** one of the most important sequences of numbers on the mathematical books: the primes. In the opening movement, Messiaen uses the indivisible numbers 17 and 29 to create a sense of never-ending time. If you look at the piano part, you’ll find a 17-note rhythmic sequence repeated over and over – but the chord sequence that is played on top of this rhythm

What questions would be worth asking about these ideas?

What questions could we ask to introduce a different perspective?

What AOK is used to explain this idea?
How do you know?

What questions would be worth asking to deepen the discussion about this topic?

consists of 29 chords. So as the 17-note rhythm starts for the second time, the chords are just coming up to about two-thirds of the way through its sequence. The effect of the choices of prime numbers 17 and 29 are that the rhythmic and chords sequences won't repeat themselves until 17 times 29 notes through the piece, by which time the movement has finished.

The intriguing thing for me is that the musician and the mathematician's attraction to primes to keep things out of synch can already be found in the natural world.

There is a species of cicada that lives in the forests in North America that has a very curious life cycle: the cicadas hide underground doing nothing for 17 years and then, in the 17th year, the insects emerge into the forest for a six-week party. At the end of the six weeks they all die and we have to wait another 17 years before the next generation emerges. This prime number life cycle is believed to be connected with its ability to keep the species out of synch with a predator that also appears periodically in the forest.

Between the lines

While the abstract quality of music might make it a natural partner with mathematics, the other arts also provide fascinating examples of mathematical ideas bubbling away underneath the artist's output. The visual arts have an obvious connection to mathematics given

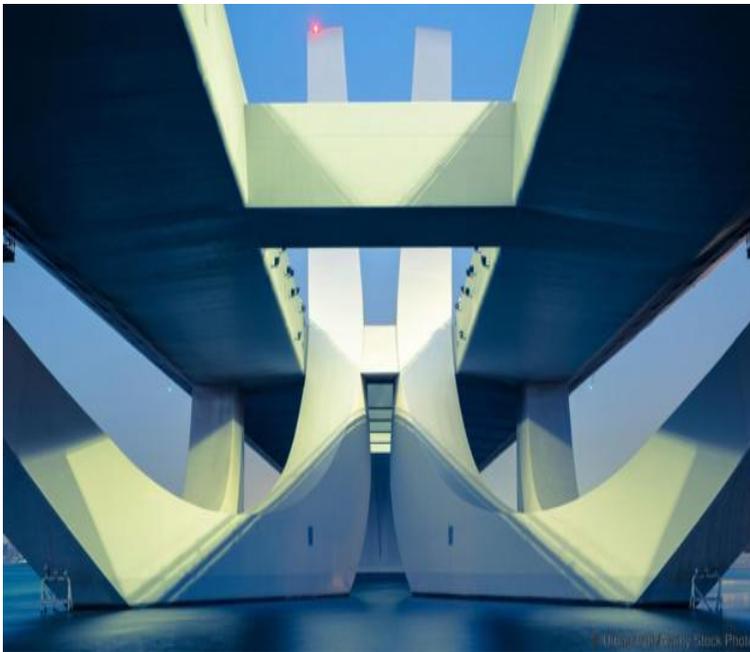
To what extent could this idea be considered an effective RLS? Explain.

What questions would be worth asking to knowledge in these ideas?

that every time you paint a line on a canvas or carve a surface from a sculpture, geometry is emerging.

Architecture has a very necessary connection with mathematics, which is what guarantees the building will make it from the drawing board to the city landscape.

But the shapes and forms that now populate the skyline are as informed by the aesthetic of mathematics as by its power to ensure the building doesn't fall down.



The Sheikh Zayed Bridge in Abu Dhabi by Zaha Hadid.
(Credit: Urbanmyth/Alamy Stock Photo)

For me, one of the most exciting revelations has been that even the art of the written word has mathematics hidden inside it. Poets, playwrights and novelists have all played around with exciting forms and patterns and frameworks that have mathematical shapes to them.

Do a quick research about the mathematics in:

- a) Alhambra (Granada, Spain)
- b) The Heydar Aliyev Cultural Centre, Baku.
- c) The roof of the British Museum, London
- d) The triangular wedges inside the Gherkin, London.

Explain this idea in at least two of the cases above.

In my radio series **The Secret Mathematicians**, I have explored the artistic practices of a whole range of composers, writers, architects and artists. Through their work I look at the range of mathematical ideas they have been drawn to, sometimes consciously but often quite unconsciously.

Philip Glass is fascinated by the power of

number to create rhythms that draw the listener into his meditative world, rhythms

that nature beats to. **The Argentinian writer**

Jorge Luis Borges strove to find an

explanation for the shape our finite universe

by writing *The Library of Babel*; and **Zaha**

Hadid's parametricism movement is

helping to seed our urban environment with

forms that are both mathematical and natural

at heart.

In my programme on visual art, I

investigate how Renaissance artists helped

mathematicians of the period rediscover

shapes first found by the ancient Greek

mathematician Archimedes – their

descriptions **had been lost over time, but**

they were uncovered through developments

Do quick research on Philip Glass' work and use an example to explain this idea.

Do quick research on Zaha Hadid's work and use an example to explain this idea.

CHALLENGE. Research about Borges' *The Library of Babel*, and explain the mathematics in this work.

Answer this question: how did Renaissance artists help mathematicians of the period rediscover shapes?

Explain the grammar in this statement: passive voice in past perfect vs passive voice in past tense.

in drawing.

I find a hyper-dimensional solid in one of Salvador Dalí's most famous works, Crucifixion (Corpus Hypercubus), and discover how Jackson Pollock was unconsciously tapping into geometric structures called fractals – shapes that mathematicians only discovered in the 20th Century. The US artist was a secret mathematician by virtue of his lack of balance and penchant for alcohol, using what mathematicians call a 'chaotic pendulum' when staggering around to create his drip paintings.

Anish Kapoor originally wanted to be an engineer but gave up after finding the maths too challenging. Yet his works reveal an extraordinary sensitivity to mathematical structures, shapes that are universal and not bound by cultural reference. His 2009 tower of spherical balls, called The Tall Tree and the Eye, created reflections that are fractal in nature, while his hyperbolic mirrors distort our environment to create a strange new perspective on the world. Kapoor's curved mirrors provide a lens to see the universe as it really is: curved, bent, where light is warped on its way through space and our intuition is turned inside out.

Marcus du Sautoy is the Simonyi Professor for the Public Understanding of Science and a Professor of Mathematics at the University of Oxford. He is author of The Number Mysteries (Harper Perennial).

Do research on the works compared in this paragraph and explain the comparison with your own words. Include 3 questions worth asking.

Do quick research on prof. Jo Boaler's mathematics work, and use some of her ideas to illustrate the idea in the first 5 lines.

What does The Tall Tree and the Eye look like? Do quick research this work of the artist mentioned, and explain the mathematics you have studied in school that you can see in it.