GOD IS BEAUTY

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PART TWO: Emmy Noether's Beautiful Theorem

Most mathematicians would agree that Albert Einstein's equation, 'E=mc2', to be beautiful. In fact, they would also agree that an equation needs to be simple and beautiful for it to be true. This seems strange at first, and "…most physicists still find it somewhat staggering" as quoted from Richard Feynman by Jim Holt in his book, *When Einstein Walked with Godel*, published in 2018. Feynman's remark was about the intimate connection between symmetry and conservation proven by Emmy Noether as "a most profound and ***beautiful*** thing."

"Emmy Noether was among the greatest pure mathematicians of the twentieth century," Jim Holtz writes.

> Born in Bavaria in 1882, she obtained a Ph.D. at Gottingen in 1907. Though the equal of such illustrious colleagues…she was, as a woman, barred from holding a full professorship, but she was allowed to give unpaid lectures as a *Privatodozent*. When the Nazis came to power in 1933, Noether, a Jew, was stripped of her semiofficial position at Gottingen. She fled to the United States, where she taught at Bryn Mawr and gave lectures at the Institute for Advanced Study in Princeton. In 1935, she died suddenly from an infection after an operation.

"Noerther's Equation connects symmetries of the abstract mathematical theories of matter to quantities that experimenters can measure," Public Domain. What

that means is that mathematical descriptions of nature can be tested in the real world – a crucial relationship between the abstract and the concrete. Otherwise, the mathematicians can dream up all sorts of formulas that may not necessarily have any meaning in the real world, and especially if they cannot be tested.

Generally, especially with abstract mathematics, physicists see mathematicians with their heads in the clouds. Only recently have both worked together, mathematician and physicists. Einstein almost pleaded with them to work together since he believed that both would profit in the long run for each other. It was really not until the end of the 20th century and the beginning of the 21st century that more cooperative work has been done, especially in particle physics between the disciplines. Even among the different fields, like astronomy and particle physics have more cooperation yielded results and more than enough work for the future in those fields.

James Clerk Maxwell, in response to Questionnaire by Francis Galton, 1870, "I always regarded mathematics as the method of obtaining the best shapes and dimensions of things; and this meant not only the most useful and economical, but chiefly the most harmonious and the most ***beautiful***." There is that word beautiful again used by one of the great mathematicians of his century. Ironically, he was initially a philosopher and country gentleman. His theory of electromagnetism was later encapsulated in the most important set of differential equations ever to be used to describe the real world. He was even an inspiration to Albert Einstein who developed the *theory of relativity*. He was also a strong believer of experimentation. "I have *no* reason to believe that the human intellect is able to weave a system of physics out of its own resources without experimental labor." However, it wasn't until Dirac's lecture in 1939 in Edinburgh that the word beauty was specifically used in mathematics. He proposed a *new principle of mathematical beauty*, "…that researchers should always strive to maximize the ***beauty*** of the mathematical structures that underpin their theories of the natural world." Most in the audience would have believed the opposite since it would have been to them notoriously subjective. "Dirac tried to forestall this objection by declaring that ***mathematical beauty*** – in common with beauty in art – cannot be defined, asserting that people who study mathematics usually have no difficulty in appreciating it," (from Graham Farmelo's book *The Universe Speaks in Numbers*, 2019).

This idea was certainly not new – Plato developed ideas on these lines, including Dante, whose *Divine Comedy* included includes many signs of the medieval preoccupation with the mathematical principles believed to underlie the structures and functioning of the cosmos. Dirac's basis for his talk was that even "…the research worker, in trying to express the fundamental laws of Nature in mathematical form, should strive for ***mathematical beauty***."

In PART THREE we will look next to the philosophers on beauty.