SOL LEWITT: *THE LOCATION OF GEOMETRIC FIGURES…* **(1976)**

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In observing *The Location of Geometric Figures (A Blue Square, Red Circle, Yellow Triangle, and Black Parallelogram)*, a drawing by Sol LeWitt from 1976, I first noticed how precisely the four geometric figures referenced in the title intersect one another. From my perspective as a physicist, and according to the principles of mathematics that inspired LeWitt, these geometric figures and their placement are primary examples of the concept of symmetry. All symmetries are central to quantum mechanics, the physics that governs the atomic realm.

The ensemble of figures in LeWitt's drawing suggests carefully chosen positions and angles. For some reason, the artist decided to draw these shapes with deliberate asymmetry: they are off-centered and tilted. Their arrangement invokes ideas of partial or broken symmetries, which are fundamental to our understanding of the phenomena and forces that govern our universe. The universe started in a symmetric state, yet as it evolved its symmetries were broken. If the symmetry between matter and anti-matter—known as the Charge conjugation Parity (CP-) symmetry—had not been broken in the early universe, we would not exist. The violation of CP-symmetry brought about the matter-dominated universe we inhabit. The study of particle physics is essentially a hunt for this initial symmetric state.

In the 19th century, James Clerk Maxwell showed that the forces of electricity and magnetism, known since antiquity and thought to be wildly different phenomena, were actually related by a symmetry. His studies led to the theory of light propagation and eventually to Einstein's theory of special relativity, which showed that space and time were also related by a symmetry. Later the unification of electromagnetic and weak nuclear forces was formulated as an angle, called the weak mixing angle or the Weinberg angle. This work was being done in the 1960s; when LeWitt made this drawing in 1976, it was the golden era of particle physics. Informed, intelligent people at this time—even those outside the world of theoretical physics, like the artist—would have understood the idea that symmetries and angles are keys to unlocking the mysteries of nature.

LeWitt's drawing visually prompts us to ponder these concepts. Perhaps at first LeWitt created an initial symmetric state—and then broke it. The angles at which the figures intersect each other are not haphazard; if we study the precise tilt of the triangle, or the overlap of the square and parallelogram, maybe we can discover something about the artist's intentions.

As we examine the drawing, we see some text embedded within the figures. The text instructs the reader how to draw and place each geometric figure on the sheet of paper. This raises a question that relates more to philosophy than physics: which is the real object, the figure depicted visually by the lines or conceptually by the text? We are tempted to say that the lines delineate the real figure. Lines are certainly more universal; Euclid of Alexandria, the father of geometry, would have recognized the drawn triangle as such. The text in LeWitt's drawing was obviously added after the lines were drawn, and we can see how well it fits within each set of linear confines. Yet some textual description of the figures must have existed before the lines in the drawing were made. For example, the mathematical definition of a circle as the

set of points equidistant from a central point must have been known and digested by LeWitt in order for him to create the circle we see in his drawing.

Some thinkers have posited that fundamental particles like electrons or quarks do not exist apart from their descriptions. That is, an electron is not a "thing" that possesses charge or mass, but is instead the manifestation of these quantities and symmetries. If we knew the ultimate theory of nature (the so-called Grand Unified Theory) we would understand that all particles and forces are part of this ultimate symmetry—just as the mathematical description of a circle would exist even if no one had ever picked up a pencil to draw one.

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