Qualities of Number in Relation to Nature

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This is an excerpt from the beginning of an in-depth article by Gopi titled "Avogadro's Number: Is the World Granular?" *You can find the whole article at* https://www.natureinstitute.org/s/gopi-vijaya-avogadros-number.pdf

Consider the experience of taking a walk in the woods. As the gravel crunches beneath your feet, the wind blows through your hair, and the sunlight plays hide-and-seek from between the leaves overhead, you focus on the path in front of you and pick out the details that draw your interest. What looked like a patch of shimmering yellow from a distance, for example, now resolves itself into a more differentiated experience: an aspen tree, with its leaves dancing in the wind. You focus your attention on specific details, and the details of the aspen leaves enrich the overall impression of the tree.

In relating to such details, you may, if you choose, pay attention to numerical patterns. Is there a pattern to how many leaves unfold and fan out from a twig? Do the veins on the leaves divide out in a particular way? As you observe, you can hold the original totality of the tree in your mind and look for specific patterns. You can start counting the number of leaves that appear on the twigs that developed during one growing season. There are rarely only one or two leaves on such a twig and usually not more than ten, but everything in between. You do not find a pattern. But when you look at the veins in many leaves you will notice a pattern: five veins usually branch out from the base of the leaf blade. This is not always the case, sometimes there are only three veins. The numerical pattern belongs to the aspen tree and there are variations; it is not fixed or rigid. What we think of as number in this context does not lead an abstract existence. It is intertwined with all the other features of the tree and can show itself when we study the tree from the perspective of numerical pattern.

Consider a different experience. You take a walk in a desert full of sand dunes. Richness of life is here replaced by the dryness and heat of the air and sand that surrounds us. What could appear at a distance as a smooth mound resolves itself into myriad tiny grains of sand that you can scoop up with your hands. You wouldn't think of trying to count them and no numerical patterns show themselves. The ever-changing shapes of the dune seem completely indifferent to the number of grains that are added to it or lost from it. It appears as if the numbers do not matter to the sand at all. One grain sits next to another.

When you pick up a cluster of quartz crystals and observe them in the sunlight, you can experience solidity in multiple ways — in the fixed shape, in its hardness, in the rigid features, and most importantly, in the inherent six-sidedness of the planar sides that make up the columnar sections. Here you have a specific relation to number, one that incorporates the geometric relationships of planes, lines, and points in the sides, edges, and tips of the crystal structure.

We can literally grasp and hold steady in our minds the fixed numerical relationships in a specific quartz cluster, just as we can hold the crystal in our hands. This is quite different from the form of a sand dune that changes as soon as we touch it. Numbers that we can attribute to this crystalline experience are neither mostly indifferent, as they are in sand, nor are they burgeoning with life and variety, as they are on a tree. Here we mostly experience numerical relationships that, in a way, appear to have come to rest.

These experiences highlight different ways of engaging with the world numerically. In each case, we focus on certain details — the veins in a leaf, the grains of sand, or the facets of a crystal — and different kinds of number relationships appear. In the case of plants, they retain an organic quality; they are usually not fixed in any rigid sense. Any statement we can make about the appearance of numerical relationships in the plant world always has the intrinsic "wiggle room" that is related to natural variation. A species of plants that normally has five petals in its flowers may surprise us with a four- or six-petal flower. These surprises are part and parcel of the way numbers exist in the living world. This does not mean these relationships are arbitrary. But they are imbued with the dynamic quality of the living world. They come into being and pass away in growth and decay.

PHOTOS: Craig Holdrege

When we see the five-pointed star at the center of an apple we have sliced in half, or the six petals and six stamens of a lily flower, we sense the connection of number to the whole. The number of grains in a handful of sand or a sand dune does not have this quality of inherent connection to the whole. There is a disconnect between number and the whole in this kind of granular phenomenon. This disconnect also extends to our own participation, since we are not drawn into any numerical relations; they are not essential when observing different piles of sand. Surely we can find, for example, an average number of grains in a small volume and extrapolate to a large volume. This method of relating to numbers is used in statistical analysis.

In the case of the crystals, where numerical and geometrical relationships are stable, our capacity to work with these relationships takes on a mathematical quality. Calculations derived from the study of crystals have historically led to the development of many fields in mathematics, as crystal observation and mathematics work hand-in-hand. For example, this interrelatedness led the famed 17th century astronomer, Johannes Kepler, to declare that: *Where there is matter, there is geometry.*[1]

Confidence in the stability of crystal structures was so deep-rooted that it led Kepler to create a picture of the entire solar system that contained crystal-like structures (the Platonic solids) embedded one inside the other, whose relative sizes gave the size of the orbits of the planets.

Kepler was also deeply interested in the musical quality of number, which is distinct from the spatially-oriented relationship to number that I discussed above. He saw the solar system as a harmonious arrangement in addition to being a spatial geometric arrangement. He went so far as to name his fundamental work in astronomy, which gave birth to all of modern astronomy, *Harmonices Mundi* (The Harmony of the World).

The experience of music can be something deeply inward. It moves our feelings and stems from a reality beyond what we can see with the eyes or touch with our hands. The experience of music seems to go beyond just the ears and penetrates the entire human organism, as any lover of music will attest. It is intimately woven with our living in time. We perceive rhythms and can find numerical patterns in music. As Kepler's contemporary, the philosopher-scientist Gottfried Leibniz, stated: *Music is a hidden arithmetic exercise of the soul, which does not know that it is counting.*[2]

We are largely unaware of numerical relations in our experience in music, while in crystals geometrical patterns are perceived clearly and consciously. In the living world numerical relationships show a flexible character. In a handful of sand, in a sand dune, number is arbitrary.

The landscape of numerical relations, as it is drawn out of our deeper feelings into the clear light of day, shows its own distinctive features. These features are essential in determining the way we approach measurements of physical properties in the world. It is important to keep the distinct quality of number in each given instance clearly in mind. We need to distinguish whether we are speaking of eight beats in music, or spatially, of five petals, seven grains of sand, or of a six-sided crystal.

The same numbers are embedded in contexts that reveal additional qualities such as inwardness, fixedness, flexibility or disconnectedness. We can train ourselves to see these different qualities. Before we engage in the task of measurement, we should take care to notice what quality of number relationships we are dealing with.

References

1. Kepler, J. (1601). *Concerning the More Certain Fundamentals of Astrology* (E. Meywald, Translation). New York, NY: Clancy Publications.

2. Gottfried, L., letter to Christian Goldbach, April 17, 1712. (*Quote after: Schäfke, R. Geschichte der Musikästhetik in Umrissen. Mit einem Vorwort von Werner Korte. 2 Aufl. Tutzing, Schneider, 1964, S. 289.)*