The Ubiquitousness of Mathematics

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We say mathematics is a ubiquitous activity performed by nature at best and by we humans. The mathematics of humans as an endeavor of human intellect is a systematic study of space, quantity, numbers, change and patterns or structures that either exist naturally or constructed abstractly using the principles of logic and deductions largely aided by imagination. We humans create models to study, navigate and discover the intricacies of the mathematics of nature - the most common phenomena in which the universe is ruled under. Nature is the greatest mathematician of all which does mathematics the best – as mathematics is the working language of nature and of the greater universe that is observable or otherwise. In this part of my exposition, I will write the abundance of mathematics that is ubiquitous in nature.

I present few of the mathematics nature perfectly does and speaks to us:

(1) The display of sophisticated and intricate wonders, beauty and symmetries that are abundant in nature, such as fractals and chaos. There is a branch of philosophy called aesthetics that studies beauty and nature.

(2) Particular suited elliptic paths planets and other galactic objects follow to rotate around a central object such as the sun.

(3) The formation and ultimate death of stars from a purely mathematical and physical perspective.

(4) The fascinating natural process how a conception develops and the timing it requires to come out of a mother's womb.

(5) Shading of their leaves trees do in cold tropics, to hibernate and protect themselves from severe cold weather and the time they start to blossom when spring comes. The hibernation mechanism is done partly by reducing the

size of their parts exposed to the outside environment in order to reduce the diffusion of cold in to them – fascinating mathematics.

(6) The periodicity of natural phenomena we see every year or season, that exist indefinitely but in a bounded domain of either temporal or spatial. Periodicity in general is one of nature's way of displaying it's work of mathematics.

(7) The sizing of petals or leave surfaces by plants based on where they grow (arid or wet and rainy zone) to control evapo – transpiration. Here, we observe a sophisticated and extraordinary mathematics performance of a resource management type in which a tree in a very arid zone minimizes the size of its petals in an optimal way to:

* control evaporation, as the rate at which water evaporates out is directly proportional to the surface area of the petal, and at the same time

* enable the tree to track enough amount of sun light in order to process its food.

These are few examples from the many perfect mathematical performances of nature.

We humans try to understand how nature does mathematics, by creating abstract models that imitate nature and prove and justify the truth of things in nature. Things naturally work and function in an optimal way with minimal errors and a small change in parameters that govern a phenomena will create a huge change on the result - which shows how nature is *stable* in a larger or what we call global perspective but at the same time *chaotic* locally. We see the chaotic part of nature by looking at the effects of a very minute change in the DNA results in a huge difference in creatures -- for instance we humans and chimpanzees have almost similar DNA sequencing with a very minute differences, but that very small difference creates that huge species difference.

Therefore as our mathematical activities, we represent quantities, axiomatize, hypothesize/make conjectures and theorize through mathematical expressions of symbols, variables and assumed to be properties, to prove and validate what we assumed is naturally true and valid. For instance we hypothesize and validate empirically that when a ball is rolling over a frictionless inclined surface, the distance the ball covers is directly proportional to the square on the time it takes to move from one point to the next lower point.

Next, I will discuss about a particular path of moving from one point to the next lower point which expedites time. For curiosity, which path do you think provides the shortest time in moving from one point to the next on a vertical plane which lies below but not on a vertical line? You may think the one which is the shortest segment or straight line segment that connects the two points has the shortest time, but that is not true. There is a longer path from the shortest path that will provide the shortest time – it defies common sense but true.

Such paths are needed to be followed to win in sports such as board skating and skiing. Every four years at Summer Olympics, athletes of skiing compete in a mountain side that is full of ice – called skiing. The game is to reach to the destination point down the hill with the shortest time. Assume all the participants of the game have same velocity, then one can ask, will there be a possibility of the existence of one person with the shortest time? The answer is yes. Here is how.

Before I provide the answer, let me say something about the history behind this path or curve of shortest time called *brachistochrone*. In 1696, a mathematician named Johann Bernoulli challenged mathematicians of Europe by posing a problem called the *brachistochrone* problem. The problem was, given two points P and Q in a vertical plane in which both are not in a vertical line but Q is below P. If a body is moving frictionless by only its own gravity along a path that connects both P and Q, which path will be the one with the least time ? As I said, the shortest segment will not provide the shortest time, but it is a curve called the *brachistochrone* – Greek word, which is a concatenation of: *brachistos* – shortest and *chronos* – time. The answer was given by several mathematicians of the time, such as Isaac Newton, Jacob Bernoulli (brother of Johann Bernoulli), Gottfried Leibniz, etc. Literally, the curve is a segment of a *cycloid* - a suspended cable on two poles. Therefore the body should follow a *brachistochrone*, the path with shortest time from P to Q.

Therefore, athletes who compete for Summer Olympic of skiing, the one to be a winner, has to go from point to the next lower point making zigzag like movements but following a path of a *brachistochrone* between consecutive points, until he/she riches the destination point. The one who almost makes such paths on the way down, although difficult to get those paths perfectly and continuously, will be the winner. But because they also have different speeds, the combination of their varying speeds and the paths they follow enable one to be a winner.

Natural examples who use such paths - paths of shortest time to pick their prey from below are seagulls or birds.

Seagulls or birds in general are one of the most fascinating creatures of nature - the flights, swifts, turns, dives and rises they make. Their flight mechanisms inspire humans the ambition to fly and hence a source of research for applied mathematicians and engineers alike for designing planes and their wings in regard to air dynamics and gravity to create levitation. Besides their fascinating acrobatic flights and perfect flawless moves they make, seagulls or birds also do amazing mathematics of differential geometry and physics. When they move from above to pick a prey they see on the ground or inside a sea or sea shore, the path they chose is not the straight segment from their position to the prey, but the path with the shortest time to reach to the prey – the *brachistochrone.* By choosing such a perfect mathematically proven path, a path of shortest time, birds and seagulls pick their prey swiftly and quickly – a fascinating natural act of doing mathematics.

Therefore,

(8) Brachistochrone – the optimal nature's curve/path of smallest time.

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