The Micro Structure of the Universe Explains How it Works, How We Think, Our Physics, & the Tricky Effectiveness of Mathematics in That Physics.

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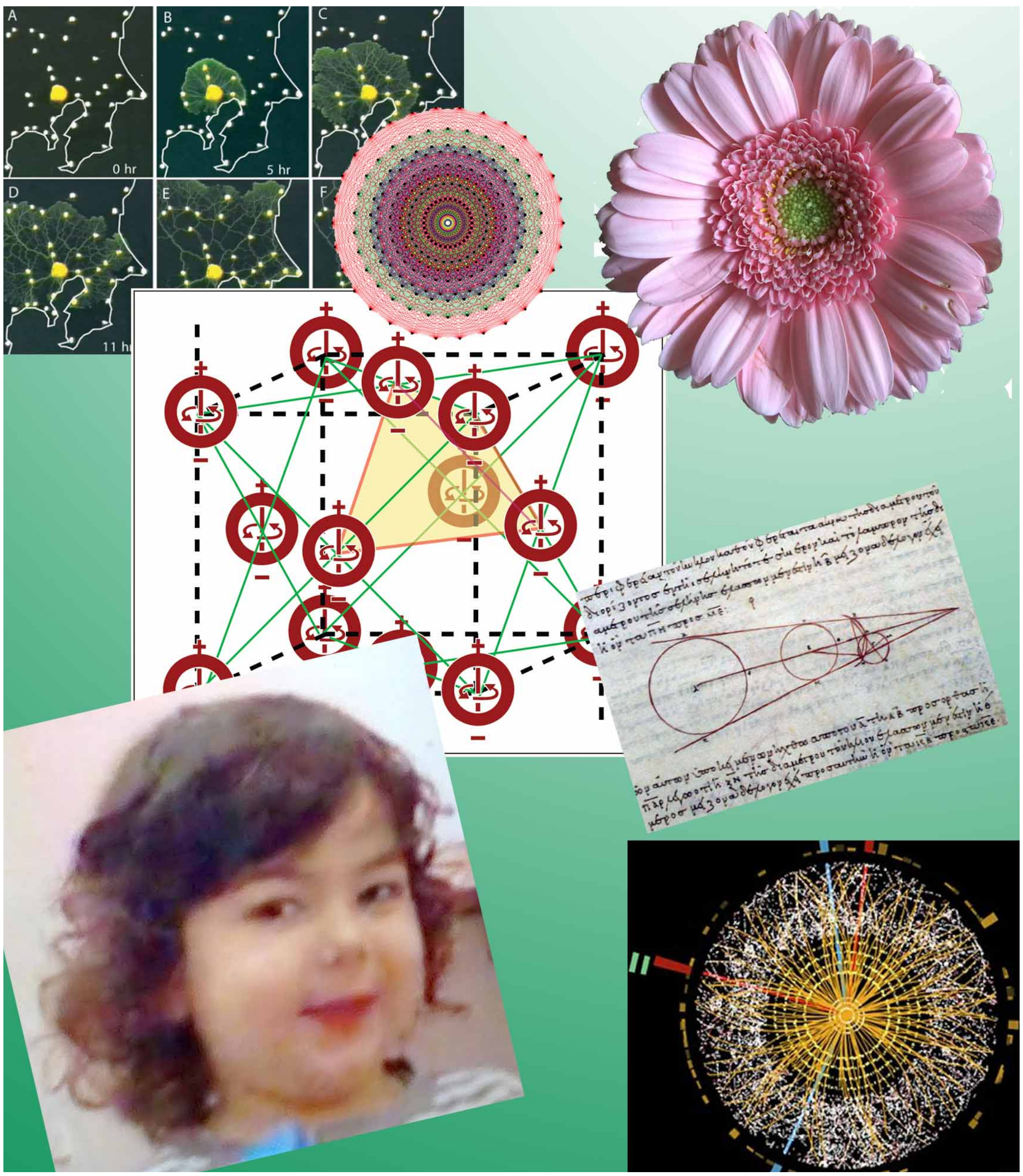

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I. Introduction.

The Foundational Questions Institute's essay contest subject *Trick or Truth: the Mysterious Connection Between Physics and Mathematics* [1] was treated in 1959 by the eminent physicist Eugene Wigner in his essay [2] *The unreasonable effectiveness of mathematics in the natural sciences* and specifically physics. He could not explain why that is so, concluding that "the miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve…". Given the lack of either a theory of everything in physics, or of a fundamental theory of mathematics, this lack of understanding is justified. I believe however that it may well be possible to explain the intimate connection between mathematics and physics, but only in the context of new unified theories of physics that may be closer to the inner workings of Nature.

In Section II the capacity of mathematics to reveal and predict concepts in physics but also to distract and mislead will be discussed. Section III shows that mathematical intelligence is not limited to the human mind and our computers but is also manifested within brainless creatures such as the slime mold amoeba, and in a broader sense in inanimate Nature itself. The reasons for this are examined in Section IV where it is suggested that the structure and action of the Universe at its tiniest scale is responsible for all of physics, and that basic concepts in mathematics must be sought there as well. Section V shows how some basic elements common to physics and mathematics may emerge naturally in my exploratory outline 'theory of everything' *Beautiful Universe* [3] (BU).

II. Mathematics Reveals & Predicts Concepts In Physics But It Can Also Obscure And Mislead.

Mathematics is used pragmatically without worrying about overall consistency.

Wigner's honest admission of failure to explain the correlation between physics and mathematics is due to the fact that in his day, as is the case now, physics was a hodgepodge of theories, working beautifully within their own domains, but failing to mesh together in a simple meaningful way at a fundamental level. There is still no simple unified, universally accepted theory explaining the basics of Nature's workings. This is reflected in the various mutually incompatible branches of our physics and the mathematics used in them. The most glaring case involves the two main pillars of physics. Despite some new notions linking the two for example in Black Hole physics [4], General Relativity (GR), the physics of the very fast, vast and heavy, does not share the same concepts, mathematical methods or areas of applicability with Quantum Mechanics (QM), the physics of the very small - electrons, sub-atomic particles and the smallest domains believed to be at Planck Scale. GR uses tensor algebra, while QM makes use of matrices, probability and differential equations.

The incredible effectiveness of mathematics in physics.

Mathematicians may protest that this is not their fault: they provide very useful tools and it is not their responsibility which ones are selected for a given problem in physics. The fundamental importance and usefulness of mathematics in physics is beyond question. It formulates, quantifies, summarizes and clarifies laws and relationships in virtually every branch of physics. Without it physicist will have to resort to hand-waving to explain things. Mathematics is capable of describing observed physical processes in nature qualitatively for example plane geometry can describe the reflection of light from a flat mirror (equal angles of incidence and reflection). Mathematics is also quantitative. A Euclid could also tell you, without actually measuring it, that a sphere fitting inside a cylinder has a volume equal to 2/3 that of the cylinder [5]. This may not be as abstract as it sounds and may apply to the physics of quantum potential wells.

Mathematics predicts the discovery of new phenomena in Nature.

Even in speculative theoretical physics where no law has yet been proven and in experimental physics the language of mathematics is of the essence. Mathematics allows the prediction of phenomena that have not yet been discovered in Nature. In astronomy the discovery of Pluto and Uranus came about purely through the solution of differential equations of planetary motion[6]. An even more amazing case concerns the discovery of the positron. This came about because Dirac's relativistic equation [7] contained a square term allowing for positive or negative roots. The negative solution was for the familiar electron, but what did the positive signify? Dirac interpreted it as a hitherto unknown anti-electron with positive charge. Two years later exactly such a particle, the positron, was discovered in the lab.

In some cases 'old' ideas in mathematics fit new concepts in physics, for example when Einstein was reminded how tensors can describe General Relativity, a theory that successfully described the bending of starlight around the our Sun millions of miles away. What sort of trickery is that? There must be some inherent truth in mathematics that perfectly matches something in physics, hence in Nature itself.

Mathematics can seriously distract from the physical makeup of Nature.

Not all mathematics enlightens physics. Fertile human ingenuity and imagination has constructed an extravagant world of mathematical concepts and ideas that seem to profligate, combining and multiplying to beget new theorems. Some may eventually find surprising practical applications in physics or elsewhere, but most of mathematics is done just for the love of it and remains 'useless'.

Worse still, in some cases physical truth is obfuscated by our ability to spout very different sorts of maths that can be used to describe the same phenomena. Ptolemy's epicycles explained some aspects of planetary motion in an Earth-centered system, but Kepler's ellipses offered a physically realistic explanation within Copernicus' solar-centered model. Knowledge of these ellipses paved the way for Newton's discovery of the inverse-square law of gravity, and for his development of the calculus to describe his laws of motion. In the modern era matrices,those orderly arrays of numbers, were shown to describe quantum behavior just as well as Schrödinger differential wave equation involving imaginary numbers.

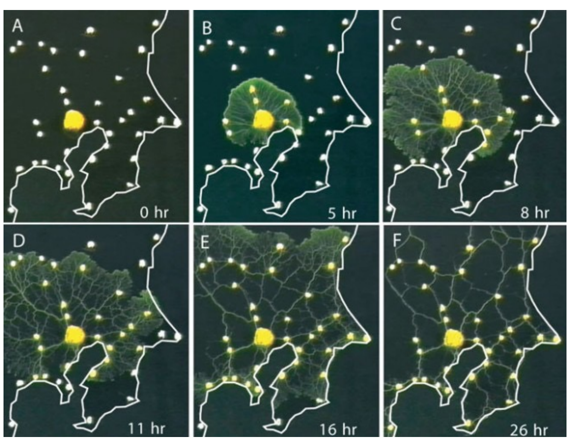
The resulting concepts of quantum probability are successfully used to interpret quantum behavior, but there is no physical proof that this is more than just a computational convenience without any basis in how particles and fields actually behave. The very success of this approach distracts from the search for a simpler causal physical reality in Nature that explains such phenomena. In Section V below I explain how quantum probability has a physical explanation within the conceptual and mathematical simplicities of my *Beautiful Universe* model. String Theory's reductionism however requires whole branches of new mathematics to create a 'landscape' of solutions that is virtually impossible to apply or prove experimentally. The siren call of mathematical beauty may be partially blamed for such excesses.

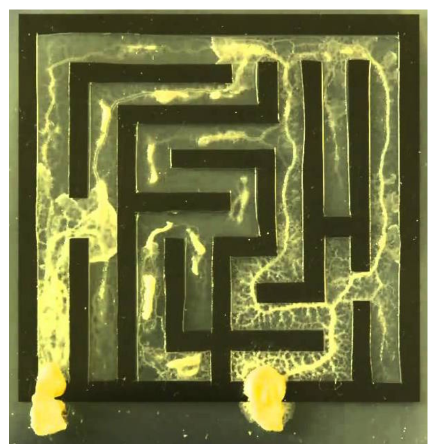
While the upper stories of the houses of physics and mathematics are transparent, ethereal and abstract, its foundations may well be firmly rooted in the physical stuff of the universe - space,matter, energy, light, sticks and stones. In the next section we look down from our exalted state of knowledge of physics and mathematics, and are surprised how Nature itself manifests such knowledge without human intervention on the humblest levels.

III. Nature's Own Mathematics: Intelligence With Or Without A Brain.

The slime mold's uncanny ability to solve problems in a maze or network.

Mathematics is a human invention. Or is it? Consider the amazing ability of a humble amoeba, the slime mold, a brainless single-celled organism, to solve a maze or





recreate the transportation network of Tokyo on a map (Figure from AAAS). When this sticky single-celled brainless yellow fungus was allowed to spread all over a plastic maze and nourishment in the form of oat flakes was placed at two opening, it eventually 'solved' the maze by spreading along the shortest route between the openings. In other experiments the mold traced out Tokyo's railway lines on a map where food was placed at the locations of main stations [8] [9] [10]. Does mold think? Arguably yes, but not the way we do - no deductive reasoning is involved, just a sort of trial and error: the mold tendrils retract where the path does not lead to food. This simple behavior has evolved to follow the path along the most efficient available route between two points. Such random 'testing' however is akin to a well-known mathematical procedure, Monte Carlo Integration[11].

My own1980's efforts to solve the related Traveling Salesman Problem [12] using a BASIC nearest neighbor algorithm - start at the perimeter and go to the nearest point, and from there to the nearest point, and so on was not as successful: The little printer attached to my Sharp pocket pocket computer churned out a path between a dozen points, but it is known that a nearest path algorithm does not yield the shortest overall path. The slime mold's path through the maze, however, was the optimal solution! The problem was "understood" by an organism at its own level. Another example among many of using a natural substance to demonstrate mathematical prowess is DNA when used in jars as a computational tool capable of solving difficult problems including a Hamiltonian Path problem[13].

Logical thinking is due to the biological evolution of the brain responding to Nature at the molecular level.

On the face of it our Mathematics is invented, not discovered. This seems to me to be axiomatic and will be assumed to be true for the purposes of this paper. Of course this pre-empts the counter-argument that mathematics is something that exists "out there" in an ideal Platonic world of its own, waiting to be discovered by some intelligence, human or otherwise. Even if this was the case, such an act of discovery of a pre-existing mathematics, would require a creative act of reasoning only possible for an intelligence capable of putting two and two together, so to speak. Whether mathematics pre-exists intelligence or not, intelligence is required to discover or invent it as the case may be.

Mathematics as an invention or discovery of the human mind resides in the brain, a complex organism that has evolved and grown in complexity over millions of years in myriad organisms that have engaged in intimate physical ways with their surroundings and always at a molecular level.[14] Mind is one of the four entities (Mind, Physical Nature, Physics and Mathematics) and the relations between them necessary to explain the intimate relation between physics and mathematics that so amazed Wigner and generations of thinkers before and after.

IV. The Discovery Of The Laws Of Mathematical Physics.

Nature's own physics: it just does it.

Molecules of metal illuminated with light release electrons. Photosynthesis does something else, converting light into a chemical reaction. A sunflower turns to face the light to benefit from its energy more efficiently. This in-built reaction becomes "part of its nature". As organisms evolved into ever more complex living organisms one can speak of this response to light as instinctive behavior such as that of a bird navigating by the sun during its migration.

A spider thread is suspended between two twigs. Following the effects of gravity and the tension of its molecular forces, the thread will always trace a particular curve. A physicist who knows nothing of spiders analyzes similar forces mathematically and plots the resulting catenary curve, identical to that of the spider's thread. The shores of a lake trace a gravitational equipotential contour line The water 'solves' the equations defining the curvature of the surface of the surrounding hills. Another example of a 'natural solution' is when a string stretched between opposite corners of a unit square will be exactly √2 units long. These are examples of how Nature itself behaves in a exact and repeatable way following 'laws' that are both physical and mathematical, manifested in the patterns, shapes and attributes that occur, well, naturally.

Humans discover mathematics.

From single-cell organism to our sophisticated modern minds we interact with physical phenomena directly. With memory and increasing intelligence we begin to anticipate patterns and make abstract mental maps and models. A chimpanzee, or a human toddler 'counts' beans one by one, an example of base-one arithmetic. Counting leads to arithmetic and as arithmetic becomes ever more sophisticated we eventually struggle, as I and many others did, to solve Fermat's Last Theorem [15]. From other lines of thought such as the observation of shapes and imagining others that may not be found in Nature, such as the straight line or the circle, geometry is born. The use of symbols for quantities lead to the creation of algebra. These mathematical fields have been proliferating for centuries without limits.

Humans discover physics.

Such insights were useful in describing Nature: An apple falls down, and instead of merely stating a qualitative law that "Things fall down" - a quantitative law of physics could be codified using abstract symbols. A Newton states that gravity obeys an inverse square law, describing this physical phenomena succinctly and quantitatively using a precise mathematical language.

Now, granted that human beings could understand Nature so well, how come there is the *possibility* to make such efficient mathematical models of Nature's workings? The inverse square law describes natural phenomena that pre-existed humanity and all biology, and is presumed to have been at work soon after the Big Bang. Exactly how are the concepts of force, weight, distance and the Gravitational Constant G that make up this inverse square law are embedded in Nature to allow them to be so usefully and perfectly formulated? We do not know, but we could speculate.

V. Physics & Mathematics Become One In a Beautiful Universe.

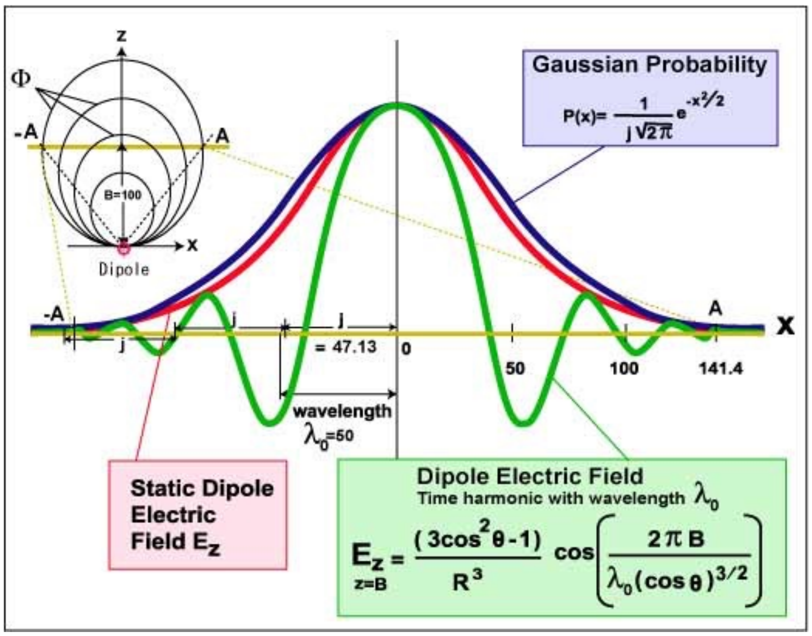
We have no unified theories of mathematics nor of physics yet.

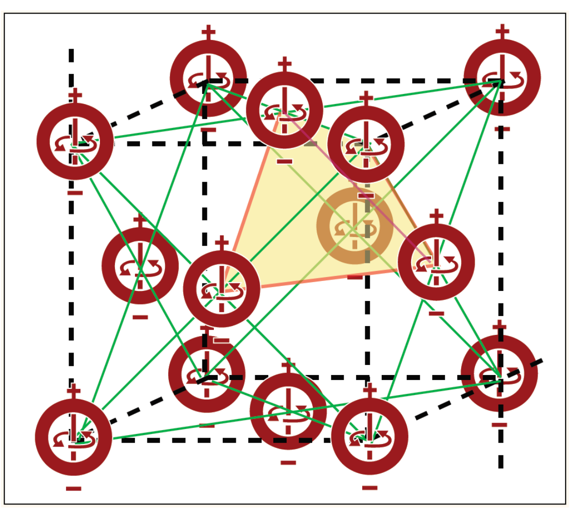
A century ago, Whitehead and Russell bravely sought to discover the roots of mathematics [16]: to find if possible a small set of axioms from which the whole of mathematics can be shown to have grown.The effort failed and I do not know if other such attempts have been made on that level of seriousness. Had any succeeded we would have heard about them and their axioms would surely be taught in our schools today.

Something similar happened to Physics. Unification of its various branches has been its Holy Grail for over a century. It is well known that no simple, universally accepted Theory of Everything (TOE) in physics exists today and the field is just a collection of mutually incongruent theories[17]. Without such unified theories of mathematics and physics reduced to their most basic elements, it is safe to say no explanation can be had for exactly why mathematics can describe physics so precisely. The following selected examples from my sketch for a TOE, *Beautiful Universe* (BU) show how some well-known mathematical laws, concepts and procedures emerge simply, naturally and directly from such a theory based on nodes in an ether (figure at left). In fact I believe that physics and nature's mathematics become one and the same at the end of the great reductionist zoom-in to the smallest scales.

Some examples of how mathematics emerges in Beautiful Universe *theory:*

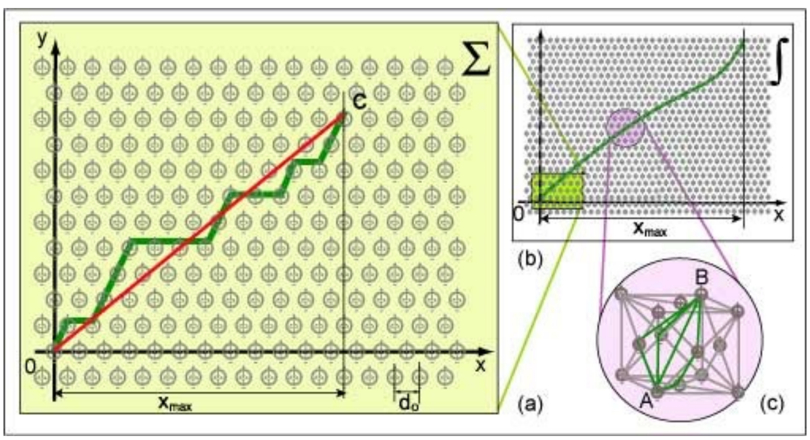
Probability. In BU the universe and everything in it is entirely made up of identical ether nodes rotating in units of Planck's constant (h). The rotation creates polarity and mutual repulsion and attraction as the case may be. In a vacuum the nodes self-assemble in a face-centered-cubic pattern (FCC). Energy propagates from node to node, transferring angular momentum through this lattice in the form of a dipole wave. This wave's intensity cross-section is almost identical to that of a probability distribution almost identical to that of the Gaussian probabilistic normal distribution curve [18]. The physics and the mathematics of Quantum Mechanics are united on that scale.





3D Geometry and symmetry . The BU lattice allows the definition of directions and spatial dimensions. Three suffice. The figure shows the vacuum state where the spin axes of the dielectric nodes are all parallel. In other cases the axes of some nodes rotate and the nodes click together (+ : - attract while -:- and -:+ repulse as with magnets) to form tetrahedral electrons. More nodes click in polyhedral knots to form the more complicated particles known in the Standard Model. Symmetry emerges naturallywithin the crystal-like lattice.

Chirality (handedness) occurs in (BU) because of initial cosmic conditions where all or most of the nodes spin in one sense (clockwise or anti-clockwise). It is theorized that the nodes spin follows the right-hand rule of the electro-magnetic field. This dictates how nodes assemble through the tension-compression similar to Snelson's tensegrity [19] sculptures (source of the rod and wire figures here where rods show compression and wires tension). In my BU spinning nodes would be located in place of the rods to form polyhedral particles with the strings indicating the direction of dielectric attraction or repulsion. Snelson has shown how such patterns define handedness woven into the very structure of a 3D lattice.



Calculus. Because the (BU) model does not have singularities (the nodes create a minimal space d_o between them) a discrete ∑calculus operates on that scale (a) in the figure). As the dimensions become macroscopic the operations become continuous and integrals ∫are used instead (b) as in our familiar Newtonian calculus. The concept of distance has to be modified as multiple paths could be taken in the lattice (c) .Can all of physics and its mathematical twin emerge from such an elementary model or one like it…?

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