DEFINITION OF PHYSICS[1]

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ABSTRACT

What is physics? What would a good definition for it be, if possible at all? This question takes the author on a search for the most important in the history of physics starting in antiquity. Following that, he discovers a certain synthesis of philosophical and religious ideas that gave physics a new wind in Modernity, which he calls Pythagorean Faith. Recognizing the very specific character of the known laws of nature, namely, a particular minimax of their complexity, leads to a new formulation of the physico-theological argument, the Pythagorean argument for the intelligent design of the universe. In conclusion, the author comes to a new definition of physics.

Keywords: book of nature, cognitive self-consistency, minimax of complexity, physico-theological argument, Pythagorean faith, Pythagorean universe.

Physics is a science that looks for fundamental laws of nature and applies them in explanations of natural phenomena and technological inventions.

You can find this or a similar definition in textbooks, encyclopedias, and AI's. Some add that physical laws are expressed mathematically, as equations. What are these fundamental physical laws, however, why and to what extent does this knowledge serve as an explanation of natural phenomena and for inventions? Why the laws are what they are, not something else? Why were we able to discover them to the current extent? What is the meaning of all that? The moment you begin asking such questions, all the standard definitions of physics fall apart into the original chaos of incomprehensibility.

Viewed from the historical perspective, physics is a project of rational cognition of nature that unfolded through centuries, and millennia, in dramatic reconstructions. Physics is not only knowledge of material reality but reality itself, of the cultural and civilizational order. Giving definitions to reality is difficult.

> "*All the world over and at all times there have been practical men, absorbed in 'irreducible and stubborn facts': all the world over and at all times there have been men of philosophic temperament who have been absorbed in the weaving of general principles. It is this union of passionate interest in the detailed facts with equal devotion to abstract generalization which forms the novelty in our present society*."[1]

wrote Alfred North Whitehead, and this perspective on physics seems particularly insightful and precise. In places with merely "practical men," knowledge about nature was formed just as a disconnected assortment of empirical observations and recipes. On the other hand, those "men of philosophic temperament" who weren't particularly interested in facts presented knowledge about nature in terms of general abstractions only. Physics was really born when the two cognitive aspects were united in one personality. Reflecting on this idea, Arthur Koestler highlighted that,

> "*This new departure determined the climate of European thought in the last three centuries, it set modern Europe apart from all other civilizations in the past and present and enabled it to transform its natural and social environment as completely as if a new species had arisen on this planet*."[2]

[1] Translated from Russian by Lev Burov

The aforementioned leads to the question: by what means could we manifest our attention to small factual details, what means are maximally appropriate for describing however small a detail, and also providing objectivity, separate from all that's merely human, while at the same time allowing to formulate general principles that the facts would strictly adhere to? We know only one such means, that in principle could have any claim to that role—the language of mathematics. A claim is not the same as fulfillment, however; between them could be an impasse. Furthermore, this impasse is suggested by common sense, by the impressive difference in scale between humans and the Universe.

As a language to describe quantitative relations between things, the language of counting, accounting, and blueprinting, mathematics has been known from prehistory. Apparently, the problems that were the most difficult and thus the most stimulating to its development were in temple building. The complexity and magnificence of temples of the archaic civilizations of Egypt, Crete, and the Middle East bear witness to a significant facility in mathematical arts, reached over more than three thousand years ago.

It was Pythagoras and his school who made the revolutionary step forward, which was in the discovery of the idea of mathematical proofs. In order to duly appreciate this step, one should keep in mind that there was no practical need for proof. The statements carefully proven by Pythagoreans were either already known and beyond doubt or offered no practical interest. Architects, astronomers, and land surveyors used recipes inherited from time immemorial to solve corresponding problems. They did not need proof of these traditional recipes, moreover, the question itself would have been cause for confusion and suspicion of ignorance, if not madness. The idea of proof was discovered by Pythagoras not for some need but as a contemplation of eternal perfect truths, as a form of communion with the divine, valuable in itself. Here's how Bertrand Russell writes about it:

> "*The changes in the meanings of words are often very instructive. I spoke above about the word 'orgy'; now I want to speak about the 'theory'. This was originally an Orphic, which Cornford interprets as 'passionate sympathetic contemplation'. In this state, he says, 'The spectator is identified with the suffering God, dies in his death and rises again in his new birth.' For Pythagoras, the 'passionate sympathetic contemplation' was intellectual, and issued in mathematical knowledge. In this way, through Pythagoreanism, 'theory' gradually acquired its modern meaning; but for all who were inspired by Pythagoras, it retained an element of ecstatic revelation. To those who have reluctantly learned a little mathematics in school, this may seem strange; but to those who have experienced the intoxicating delight of sudden understanding that mathematics gives, from time to time, to those who love it, the Pythagorean view will seem completely natural even if untrue… So much by way of explanation of the two aspects of Pythagoras: as a religious prophet and as a pure mathematician. In both respects, he was immeasurably influential, and the two were not so separate as they seem to a modern mind… The combination of mathematics and theology, which began with Pythagoras, characterized religious philosophy in Greece, in the Middle Ages, and in modern times down to Kant. Orphism before Pythagoras was analogous to Asiatic mystery religions. But in Plato, St Augustine, Thomas Aquinas, Descartes, Spinoza, and Leibniz there is an intimate blending of religion and reasoning, of moral aspiration with logical admiration of what is timeless, which comes from Pythagoras and distinguishes the intellectualized theology of Europe from the more straightforward mysticism of Asia. It is only in quite recent times that it has been possible to say clearly where Pythagoras was wrong. I do not know of any other man who has been as influential as he was in the sphere of thought. I say this because what appears as Platonism is when analyzed, found to be in essence Pythagoreanism.*"[3]

Another intuition of Pythagoras that also carries an enormous historical significance was that numbers lie at the foundation of nature's harmony, of the Pythagorean *cosmos*. Thus, cognition of the cosmos is to be sought on the path of mathematics. It is reasonable to suppose this intuition arose not only from Pythagoras' discovery of the numerical laws of musical harmony but also from the experience of the *theoretical* beauty of the mathematical proofs. The Pythagorean creed "all things are numbers", from which came all of mathematical physics, should seem mad to the laity. Even today it can seem that way, highlighting its exceptional boldness and depth. This intuition was taken up by Plato on the sign above the entrance to his Academy, "Let none but geometers enter here." One student of Plato was Eudoxus of Cnidus, and it was to him that Plato posed the problem of finding some universal mathematical principle of the motion of the planets [1]. Eudoxus' solution was to represent planetary motion as a superposition of circular ones; later the idea was perfected by Ptolemy. Plato generalized the Pythagorean vision of the fundamentality of numbers, expressing it in his theory of forms, structuring eternal matter. The latter obtained laws as if stretched like a canvas over forms - analogized as the Platonic solids - by the Creator-Demiurge, as a mysterious Pythagorean Timaeus tells [4]. Commenting that Werner Heisenberg wrote that here Plato foresaw the mathematical symmetries deep in the fabric of the universe. Consciously or not, the author of "Timaeus" also left here an underdetermination of nature by the laws, thus, the possibility of free will. Stretching matter over forms maybe not be very tight, leaving a little wiggle room for chance and free agents to finalize the state of matter without violating the laws.

The next important step in mathematics was made by Euclid, who ordered the amassed proofs using a small number of axioms, the self-evidence of which caused no doubt, as well as theorems deduced from them. In this way, mathematics obtained the characteristic noted by Whitehead, that of unity of general principles and facts implied by them to any level of detail. This unity was meditated upon and translated as a religiously charged experience of perfection and beauty. It seems that everything was ready then to fully engage in the pursuit of those physical forms spoken of by Timaeus, the mathematical principles of nature. This movement in thought, however, had to wait two thousand years more. Throughout the entire antiquity, there was just one single mathematical physicist - Archimedes - who was remembered but followed by nobody. Something blocked the expansion of the ancient mathematicians into physics and astronomy. Historians hypothesize the following factors which could have formed such a block.

First, the mathematicians of antiquity were for the most part if not all Platonists, and not every aspect of this teaching encouraged detailed investigations of the physical world. Plato analogized the material world to shadows on the walls of a cave thrown by the primary world of forms. In the system of Plotinus, nature took up the lowest echelon of emanations. Such a view implied the devaluation of material reality and the impossibility of an at least somewhat precise description of the latter. The other factor was the mentioned terrifying abyss between the scales of man and the Universe. You can find hints towards the possibility of traversing this abyss in Greek mythology (as marriages between gods and humans) and in Plato himself (as a certain divinity of man). Apparently, the hints were not sufficient. Historians also note a third factor impeding experimental science in antiquity, namely the Platonist and stoic vision of the universe as a deity; indeed, performing experiments on a deity could not look like the brightest of ideas. In light of the above, it no longer seems so surprising that the first real critique of Aristotle's physics was made only in the sixth century, by a Christian Platonist John Philopon of Alexandria. However, further progress of science was severed for a long time by the Barbarian Invasion to the west of the Mediterranean and the east, by the transition of the Empire into a rigid totalitarian phase.

When Galileo claimed that the Book of Nature was written in the language of mathematics, his thought did not at all consist in the notion that natural processes allow for quantitative analysis, and that there exist interrelations and correlations between measured values. Then, as now, the notion was a banality, while Galileo's thought was revolutionary. In reality, Galileo heralded specifically the program of searching out the "postulates" of nature that intellectually was provoked by the mathematics of antiquity. Galileo was much closer to the Pythagoreans than to empiricists a la Francis Bacon [5]. For many today, especially for scientists, it could prove difficult to evaluate how revolutionary was the idea of mathematizable nature, since these days it permeates everywhere; one way or another people hear the idea from childhood. Still, to an unadulterated mind, nature does not at all resemble Euclid's construction. If we can pull ourselves away from the presumptions of our post-Galilean time, we can realize that the idea of the fundamentally mathematizable matter was so far from banal that its more adequate evaluation would be "crazy enough to have a chance of being correct," as Niels Bohr once said about something else.

The natural world should be based on those perfect forms of reason that are in principle accessible to human cognition and more than deserving efforts for their discovery - this strange conviction was natural for Christian Platonists, founders of the physics of modernity, Galileo, Kepler, Descartes, Leibniz, Newton. Those people were winged by the synthesis of Pythagoreanism-Platonism and the Bible, and by the power of this faith they moved the mountains of knowledge. Reflecting on that, Einstein wrote:

> "*The interpretation of religion, as here advanced, implies a dependence of science on the religious attitude, a relation which, in our predominantly materialistic age, is only too easily overlooked. While it is true that scientific results are entirely independent of religious or moral considerations, those individuals to whom we owe the great creative achievements of science were all of them imbued with the truly religious conviction that this universe of ours is something perfect and susceptible to the rational striving for knowledge. If this conviction had not been a strongly emotional one and if those searching for knowledge had not been inspired by Spinoza's Amor Dei intellectualis, they would hardly have been capable of that untiring devotion that alone enables man to attain his greatest achievements... This firm belief, a belief bound up with deep feeling, in a superior mind that reveals itself in the world of experience, represents my conception of God*."[6]

This "Pythagorean faith," which was never established or discussed by any council, played one of the greatest roles in the history of humanity. It's core tenets can be outlined like so [7]:

1. *Theism:* the world was created by an all-good, all-wise God. This principle implies the wholeness of the world and its ultimate beauty. It also imparts reason and value to its cognition as a special communion with the Creator. This conviction is common to both Platonism and the Bible. Christianity strengthened it with the unity of the eternal Logos, through which all came into existence. Alternatives to theism include teachings about a coming to be of the world through meaningless chance, chaos (chaosogenesis), creation of the world by conflicting deities (polytheism), as well as assurances in the meaninglessness of the very question of origin, cause, reason of the world (skepsis). Among many of these alternatives, there is no meaning in pursuing knowledge about the universe.
2. *Transcendentality: the universe is neither a god nor a living being.* This Biblical principle stands to contradict various Pantheist and Platonist teachings about the universal Soul. Its importance is in the liberation of the physical experiment from associated religious anxieties.
3. *Divine sonhood: Man is made in the image and likeness of the Creator, his Heavenly Father.* From here comes faith in the ability of the genuine rather than illusory cognition of the Cosmos and the meaning of this cognition. This principle is common to the Bible and Platonism. The Biblical vision of love as God's essence gives this principle additional power.
4. *The divinity of mathematics: the perfect world of mathematical ideas belongs to the mind of God and is available to man.* From this follows the unique significance of mathematics as communion with the Highest through the vision of eternal universal truths. This Pythagorean principle was adopted by the Christian Platonists. Generated by this intuition, mathematics is subject to a particular aesthetic of elegant forms of reason. It discovers the beauty of eternal patterns of ideas.
5. *Mathematical matter: the material world is structured by a harness of mathematical ideas.* This Pythagorean insight is central to mathematical physics. It is the thread of Ariadne for the search for the laws of nature. Mathematics, from this perspective, is not just a collection of whatever formulas and proofs but only the elegant (non-banal but simple, symmetric, rich with solutions and unexpected connections).

This implied that the strategy of looking for the logical harness of the matter was implicitly based on faith in the perfection of axioms of matter, its Platonic forms or laws, combining in themselves sufficient simplicity to be discoverable with sufficient constructive complexity for the diversity of nature. The consequent development of physics demonstrated the adequacy of this strategy. Let's try to mark out the main qualities of the physical laws, discovered in the centuries since then. Fundamental physical laws, or mathematical principles of the structure of matter, have a very specific character. They are [8]:

- expressed by simple formulas, which reflects the mathematical simplicity of the underlying ideas;
- aesthetically attractive, and elegant: they follow symmetries, invariants, correspondences, and equivalencies;
- extremely precise: today, up to 12 decimals;
- universal: capture about 45 orders of magnitude from the size of the visible universe to the Higgs boson and the top quark;
- ordered by the difficulty of discovery: classical physics is simpler than the quantum and relativity theories, not vice versa;
- asymptotically precise: classical conclusions regarding observations are the same as those of relativity and quantum theories in the corresponding mathematical limits: infinite speed of light and Planck constant at zero;
- syntactically correlated: some deeper laws can be obtained from less so by syntactic transformations (correspondence principle, which played an important role in discovering Quantum Mechanics);
- anthropic (sapientic), that is compatible with a highly diverse life that includes sapiens, reasoning living beings;
- even with all these parallels and correspondences, barely discoverable, that is discoverable at the limit of genius pioneers' abilities.

All but one items in this list relate to the "unreasonable effectiveness of mathematics" in physics, as Wigner called it [9], see also [10]. The anthropic point h) is discussed in many articles and books as the fine tuning argument, see e.g. [11-14]. There are just a few authors who realized that the unreasonable effectiveness and the anthropness of the laws should be considered together, since their requirements on complexity are opposite. Even a small increase in Kolmogorov's complexity of laws would lead to a gigantic leap in difficulty of their discovery, just like when guessing passwords. At the same time, existing estimates of the fine tuning of fundamental constants indicate that were the laws even a little simpler, the resulting universe would not muster the structural diversity for the simplest life, not to mention for a brain appropriate for cosmic cognition. In this way, the Pythagorean creed expressed the latent certainty in that this minimax of complexity of laws is not empty and that the actual laws of our universe belong to it. Who knows, maybe, no other laws are there? As physicist Squires speculated, the laws of our universe could be simplest among those allowing life [15]. Philosopher Robin Collins calls this minimax "balance of complexity and simplicity" [16]. The same idea was paradoxically expressed by physicist Alexei Tsvelik as "life in the impossible world" [17,18].

The Universe in which we find ourselves is more than just anthropic, more than just allowing the appearance of thinking living beings, sapiens. It is much more than that, it is Pythagorean, as I call it, or cognitively self-consistent: its fundamental laws not only are sapientic but with staggering precision are cognized by its sapiens. The popular multiverse explanation of the anthropness of our laws, of its fine-tuning, fails to explain its Pythagorean character [19]. To the best of our knowledge, there is only one coherent explanation of this fascinating characteristic of the Universe—it is a product of an intelligent design. If so, the rational strategy of cognition demands reliance on this explanation as the main, accepting it as a *working hypothesis*. That's how the physico-theological argument of God's existence can be formulated today [16,19]; thanks to the "big bang" that occurred in physics since Kant's time, a significant part of his critique of the argument [20] became irrelevant.

Even though the Pythagorean creed was and remains openly acknowledged only by a handful of scientists and physicists, all physics came just out of that, see e. g. [21-24]. As described, physics reduces phenomena to "axioms," fundamental laws, being reductionist in their very essence. From here follows that it grows not only in-depth, in search for new and deeper laws, but also in breadth, applying the known laws to more and more complex systems. Physics studies the material world *inasmuch as it reduces to the laws*. There are serious reasons to believe that life and thought are not reducible to laws [8], but that topic lies outside the scope of this paper.

The notion that natural science in general and physics in particular are based on experience has long since joined the ranks of platitudes. The latter, however, have a tendency to lose an important part of the truth, becoming half-truths. What's lost here is the other source of physical knowledge: intuition of mathematical beauty. With all the indefiniteness of this entity, it played an irreplaceable role in the magical thread of Ariadne, again and again leading the founders from different epochs to great physical discoveries. As Max Planck wrote

"*My original decision to devote myself to science was a direct result of the discovery which has never ceased to fill me with enthusiasm since my early youth—the comprehension of the far from the obvious fact that the laws of human reasoning coincide with the laws governing the sequences of the impressions we receive from the world about us; that, therefore, pure reasoning can enable man to gain an insight into the mechanism of the latter*." [25]

Recently voices have come onto the scene asking whether physics has entered a dead end with this thread. What gives, they ask, that the Universe follows notions supposedly generated by biological evolution of what is beautiful and what isn't? [26]. We can answer that refusal to search for truth as beauty not only contradicts all of the experience of physics but it would have left us with no hint inside an infinite labyrinth of possible hypotheses. Moreover, beauty has never been just instrumental–it always sets the value, being "Moira and Eileithyia for every genesis", as wise Diotima taught Socrates [27, 28]. How many people would be willing to spend lives and taxes for the sake of a "theory of everything" if it's far from practical uses and foreign to all aesthetics?

This essay started with a definition of physics, so we can end with one.

Physics can be considered as an attempt to describe the fabric of the Universe on the path of mathematical beauty, with all uncertainty and mysteriousness of the latter. How far will humanity move along this path in the future we cannot know, but nobody has suggested an alternative road to that reality [29].

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