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ARTICLE

Is the "unreasonable effectiveness of mathematics" a miracle that points to God? Wigner and Craig on the applicability of mathematics

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Abstract

Eugene Wigner's 1960 article on the "unreasonable effectiveness of mathematics" used the word "miracle" of the fit between abstract mathematics and physical reality. William Lane Craig has developed a theistic argument from Wigner's hints, claiming that the best explanation of the "miraculous" fit is divine creation. It is argued that this argument does not succeed. An Aristotelian realist philosophy of mathematics renders the applicability of mathematics to physical reality unmysterious by showing that mathematics, like any other science, is a study of certain aspects of reality, hence there is no miracle of fit. However, that does not preclude other arguments for the existence of God involving mathematics, for example design arguments from the elegance of the universe's structure, fine-tuning arguments or ones from the nature of mathematical understanding.

Keywords: mathematicity, unreasonable effectiveness, philosophy of mathematics, Aristotelian realism, argument to God from mathematics, William Lane Craig, Eugene Wigner

Introduction

Eugene Wigner's 1960 article, *The unreasonable effectiveness of mathematics in the natural sciences*, now cited 4000 times, is probably the most celebrated philosophy of mathematics article of the last century. Its appeal rests on its case that the fit between mathematics and physical reality is somehow mysterious.

Its much-quoted conclusion is: "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" (Wigner 1960, p.14). The word "miracle" appears another eleven times in the article. Wigner does not intend that to be read literally, and simply leaves the mystery unsolved—no doubt contributing to the article's popularity.

But it is reasonable to ask whether "miracle" might be taken literally, and to ask whether a miracle needs a miracle-worker. Is there an argument for the existence of God from the otherwise inexplicable "mathematicity" of the physical world? The theist author William Lane Craig has developed carefully-argued philosophical versions of the argument.

We will examine the phenomena adduced by Wigner, then the argument of Craig. We will argue that this argument is not convincing. It depends on philosophies of mathematics such as formalism and Platonism which imply a gap between the world of mathematics and the world of physical reality, rendering their match a mystery. An Aristotelian realist philosophy of mathematics which sees mathematics as a science of certain aspects of physical (or any other) reality will dissolve the mystery of the "applicability" of mathematics. Mathematics is "applied" from the start, so there are not two realms which need a God to join them in marriage.

The Wigner-Craig argument is distinguished from several others that can be made which take some mathematical aspect of reality to point towards God. They include design arguments from the specially elegant or beautiful mathematical structure of the world, fine-tuning arguments, and arguments from the nature of mathematical understanding. Those arguments may have some credibility, but they are distinct from that of Wigner and Craig.

Finally, there is a reason why the theist should prefer a necessitarian account of the mathematicity of the universe—that is, one in which the mathematical necessities in physical reality are not put there by (and hence point to) God but instead constrain God. As is widely agreed, the most pressing philosophical problem for classical theism is the problem of evil. If, as Leibniz thought, God does not create a better world because (as a matter of mathematical necessity, due to the interconnectedness of the world) there is no better world, then the problem of evil becomes solvable.

Three questions on the relation of mathematics to reality

Before examining the arguments of Wigner and Craig, three questions on the "effectiveness" of mathematics as applied to physics or any other science should be distinguished. As we will see, different authors emphasise one or other of them, so it is helpful to have the distinctions clear before describing particular views.

First, there is the question of why mathematics, including elementary mathematics, is effective in or applicable to physical reality at all. That question has a low profile in Wigner's article but is the focus of, for example, Kant's theories that geometry and arithmetic arise from the mind's imposition of the forms of space and time on an unstructured and unknowable "noumenal" reality. One might attempt to argue to God from the "mathematicity" of the universe, its being describable by mathematics at all; that approach is taken by Heller (2019, p.241), explained further in (Trombik 2025), section 3.2) but it is rather different from that of Wigner and Craig and is not pursued here.

Secondly, there is the question of why many of the abstract and esoteric theories of modern higher pure mathematics, such as abstract groups, Riemannian geometry and Hilbert spaces, turn out long after their discovery to be relevant to high-level physics such as quantum mechanics. It appears surprising that tensor mechanics just happened to be studied by Einstein and proved to be the right mathematical language for general relativity, and that infinite-dimensional Hilbert spaces over the complex numbers were found to be perfect for quantum mechanics. That phenomenon is much more evident in contemporary fundamental physics than in other sciences, which require some forms of mathematics but do not generally benefit from the most abstract mathematical technology (with some possible exceptions such as stochastic differential equations in finance). Wigner and Craig's arguments mostly relate to this second question.

Thirdly, there is the question of accuracy of mathematical predictions. Wigner calls attention to the fact that the predictions of fundamental physics made on the basis of mathematical laws often prove later to be experimentally verified to very many decimal places, sometimes to as many decimal places as powerful experimental measurements can reach. That is not true of mathematical predictions in economics (Velupillai 2005), or in weather prediction.

All of those "fits" of mathematics to physical reality might be regarded as surprising and thought to need explanation, but they are distinct phenomena and *prima facie* their explanations might be different. Indeed Wigner and Craig find elementary mathematics unsurprising but believe the other two questions are either unanswerable or need a divine intervention. Wigner emphasises the difference between the first and second questions: "whereas it is unquestionably true that the concepts of elementary mathematics and particularly elementary geometry were formulated to describe entities which are directly suggested by the actual world, the same does not seem to be true of the more advanced concepts, in particular the concepts which play such an important role in physics" (Wigner 1960, p.2).

It will be argued here however that an Aristotelian realist philosophy of mathematics gives essentially the same answer to all three questions, while undermining the appearance of surprise. Mathematics, whether elementary or advanced, and whether badged as pure or applied, describes absolute mathematical necessities which any physical reality must obey, and obey exactly (where precision is relevant). Since they are necessities, no God is needed to determine them, and hence there is no argument from them to God.

Distinction from design arguments

These questions and the arguments of Wigner and Craig need to be distinguished carefully from design arguments for the existence of God, even though design can have mathematical aspects. In Paley's classic version, the intricate internal arrangements of living organisms are compared to the design of clockwork and an inference is made to the existence of a divine designer. Even though clocks work with "mathematical precision" and their structure could be described mathematically, the argument does not arise from mathematics but from the contingent fact that organisms and clocks have a certain complex structure (which allows them to perform certain impressive tasks).

The same is true with arguments from fine-tuning, which again involve some mathematics but where the argument arises from a contingent property of the universe. It is said that the values of the fundamental constants of nature lie in certain narrow ranges which permit a physical universe with life to appear; it appears to be contingent that those values are as they are, so a divine explanation of their being there is reasonable (Lewis and Barnes 2016). That argument resembles a design argument in beginning with a contingent fact about the universe, but it is not an argument like that of Wigner and Craig from the mathematicity of the universe.

Similar arguments could arise from the beauty of the universe. If it is thought that the universe could be either beautiful or not, then its being beautiful (perhaps in a mathematically describable way) could give rise to an argument that God created it that way (e.g., Kessler

2022). That is again a possible argument from a contingent way the universe is to a divine act of creation choosing that option, but it is not an argument like that of Wigner and Craig.

A different argument begins with the "miracle" that the universe is "rational", "intelligible" or "comprehensible". This means that the observed mathematical structure of the physical universe must be adapted to the cognitive capacities of humans: neither so simple that the world is virtually structureless, nor so transcendent or complex that our minds could not grasp it (Heller 2019, p.242; more extensively in Coyne and Heller 2008). Or it can be argued that human mathematical understanding of necessities is itself miraculous and does not fit into a materialist view of the universe, and hence points to God. Perhaps what is needed to grasp mathematical necessities is something like Aristotle's *nous* (medieval Latin *intellectus agens*), a divinely-granted faculty of the soul capable of grasping the necessity of first principles (Bronstein 2016; Kuksewicz 1988). Those arguments are worth pursuing but like design arguments they proceed from contingent facts about the universe and are quite different from the argument of Wigner and Craig.

Two senses of "surprising"

As well as distinguishing questions on the applicability of mathematics, it is desirable to distinguish two senses of the notion of "surprising" (or "unreasonable") which plays such a prominent role in the arguments. The notion is used without much explanation, especially in Wigner, but his arguments cannot be evaluated without some querying of it.

Is that notion intended in a subjective or objective sense? In the subjective sense, a fact is surprising when we (due often to our cognitive limitations) are in fact surprised by it. That kind of surprise needs no explanation beyond our limitations, and any sense of surprise is dissipated when an explanation appears and we understand it. For example, an amazing observed mathematical regularity is that a number is divisible by 9 if and only if the sum of its digits is divisible by 9. But when one sees a proof of that regularity that explains why it must be so, one's amazement abates. The necessity of the regularity is absolute, and there is no role for a God to impose it. It could not have been otherwise. Hence, there is nothing inherently "unreasonable" in the apparent coincidence and no argument from that regularity to God.

On the other hand, something can be called objectively surprising when, even after the facts are known, something of objectively low probability has occurred—for example, a tossed fair coin comes up heads ten times in a row. What is expected, on the basis of how things actually work, is that a tossed fair coin comes up sometimes heads and sometimes tails, in an unpredictable pattern. If something other than that occurs, it is objectively surprising; the surprise is not merely relative to our stupidity.

In fact the opening paragraph of Wigner's article makes this distinction with a memorable example, though the point does not recur in the article. Wigner imagines a statistician explaining the normal distribution of a population to a mathematically naïve former classmate. The classmate says:

> "And what is this symbol here?" "Oh," said the statistician, "this is pi." "What is that?" "The ratio of the circumference of the circle to its diameter." "Well, now you are pushing your joke too far," said the classmate, "surely the population has nothing to do with the circumference of the circle" (Wigner 1960, p.1).

Wigner comments, "Naturally, we are inclined to smile about the simplicity of the classmate's approach" (Wigner 1960, p.1). That is because "we", the mathematically literate, can understand why the formula for the normal distribution must contain pi—even though the naïve classmate is right to be astonished initially at such an unlikely appearance of pi. Our surprise dissipates when we understand the necessity of the reasons.

We should bear this example in mind when examining applications of higher mathematical concepts of whose grasp we are less certain. Whenever an example of something surprising is given, we should ask if better understanding of mathematics on our part would dissipate that surprise. If there is talk of esoteric concepts like infinite-dimensional Hilbert spaces, we should guard against being in the position of the naïve classmate who understands insufficient mathematics. Any case where surprise could be relieved by more mathematical knowledge is not miraculous and there can be no argument to God from it.

The argument of Wigner's "unreasonable effectiveness"

Wigner advances several cases of the allegedly "unreasonable effectiveness" of mathematics in physics. The first one is Newton's inverse square law of gravitation: that the force of gravity exerted by two bodies is exactly inversely proportional to the square of the distance between them. Wigner writes:

> The law of gravity which Newton reluctantly established and which he could verify with an accuracy of about 4% has proved to be accurate to less than a ten thousandth of a per cent [...] [it is] a monumental example of a law, formulated in terms which appear simple to the mathematician, which has proved accurate beyond all reasonable expectations (Wigner 1960, p.8).

Wigner thus emphasises in this example the accuracy of predictions, rather than the application of mathematical concepts as such. Are the mathematical concepts used in this example in themselves surprising? Wigner says that the most sophisticated one, a second derivative, "is simple only to the mathematician, not to common sense or to non-mathematically-minded freshmen" (Wigner 1960, p.8), that is, it is objectively simple but subjectively not.

So in this first example, the only objectively surprising or miraculous aspect claimed by Wigner is the accuracy of predictions. His conclusion is somewhat different in his second example, the high-powered mathematical concepts used in "ordinary, elementary" quantum mechanics. As Wigner describes it, Heisenberg had devised some rules of computation to summarise experimental results in some simple cases such as the hydrogen atom. Born noticed formal similarities between those rules and the pure mathematics of computation with matrices, and it was then proposed to use the mathematics of matrices instead of the rules of computation. "There was, at that time", Wigner says, "no rational evidence that their matrix mechanics would prove correct under more realistic conditions" (Wigner 1960, p.9). However, it did prove correct, not only in realistic conditions but in much more general conditions. "The miracle occurred only when matrix mechanics, or a mathematically equivalent theory, was applied to problems for which Heisenberg's calculating rules were meaningless" (Wigner 1960, p.9), such as heavier atoms. A calculation with the next heaviest atom, helium, "agrees with the experimental data within the accuracy of the observations, which is one part in ten million. Surely in this case we «got something out» of the equations that we did not put in" (Wigner 1960, p.9).

Wigner thus emphasises again the accuracy of predictions. He does not offer an opinion at this point on whether matrix mechanics is really complex or objectively surprising, though he does note its disconnection from experience. That is an example of a phenomenon Wigner mentioned earlier in the paper, one which has been taken up by many commentators:

> Whereas it is unquestionably true that the concepts of elementary mathematics and particularly elementary geometry were formulated to describe entities which are directly suggested by the actual world, the same does not seem to be true of the more advanced concepts, in particular the concepts which play such an important role in physics [...]. The complex numbers provide a particularly striking example for the foregoing. Certainly, nothing in our experience suggests the introduction of these quantities (Wigner 1960, p.2).

Wigner here calls attention to higher rather than elementary mathematics, the second of the concepts of "mathematicity" noted above. Mentioning also the Hilbert spaces over the complex numbers that appear in quantum mechanics, he claims a "miracle", which is a different kind of miracle from the high accuracy that was the basis of the earlier examples. It is the "miracle" that highly abstract concepts invented by pure mathematicians for largely aesthetic and formal reasons later prove to be the right ones for physics. He writes "It is difficult to avoid the impression that a miracle confronts us here [...] [this] has no reference to the intrinsic accuracy of the theory" (Wigner 1960, p.7).

Wigner thus advances two different kinds of mathematical "miracle" for which we have no explanation. One is the recurrent discovery that concepts of advanced mathematics are the right language for physics; the other is the extraordinary accuracy of mathematically-described physical laws, well beyond the experimental data that first suggested them.

Wigner's formulation of the "gap" between pure mathematical concepts and the physics that they later apply to is driven by his formalist philosophy of mathematics (Ferreirós 2017), which he explains—rather lightly and imprecisely—early in the paper in a section *What is mathematics?*. "Mathematics", he says, "is the science of skillful operations with concepts and rules invented just for this purpose [...] Most more advanced mathematical concepts, such as complex numbers [...] were so devised that they are apt subjects on which the mathematician can demonstrate his ingenuity and sense of formal beauty" (Wigner 1960, p.2). That is not the only possible philosophy of mathematics, and it is one that tends to place a large gap between mathematics and any science of reality such as physics.

Craig's argument from mathematics to God

William Lane Craig argues that Wigner's talk of "miracle" should be taken literally. There is something genuinely miraculous or objectively surprising in the applicability of mathematics to physics, and the best explanation of that is the existence of a miracle-worker, God. His argument relies mainly on the second of the questions above, on the relevance of advanced rather than elementary mathematics, and thus on Wigner's argument that what is miraculous is the applicability of higher mathematical concepts invented for other purposes.

Craig summarises his extension of Wigner's argument as follows:

(1*) Mathematical concepts arise from the aesthetic impulse in humans and have no causal connection to the physical world.

(2**) It would be surprising to find that what arises from the aesthetic impulse in humans and has no causal connection to the physical world should be significantly effective in physics. Therefore, it would be surprising to find that mathematical concepts should be significantly effective in physics.

(3*) The laws of nature can be formulated as mathematical descriptions (concepts) which are often significantly effective in physics.

(4**) Therefore, it is surprising that the laws of nature can be formulated as mathematical descriptions that are often significantly effective in physics.

(5) The fact that the laws of nature can be formulated as mathematical descriptions that are often significantly effective in physics merits explanation.

(6) Theism provides a better explanation of the fact that the laws of nature can be formulated as mathematical descriptions that are often significantly effective in physics than does atheism (Craig 2021, p.209).

Craig plainly intends here an objective concept of "surprising". Like Wigner, he says little about his notion of the aesthetic, but both authors intend it to cover the development of interesting pure mathematical concepts unrelated to experience.

Craig's philosophy of mathematics is not formalist like Wigner's, but (almost) Platonist. Like formalism, however, Platonism sees a large gap between the objects of mathematics, "abstract" Platonic entities like numbers and sets that exist in a non-physical, non-causal realm, and physical reality. As Craig says, Platonism in itself tends to make any applicability of mathematics seem surprising, as there is no way that Platonic objects can constrain what happens in the physical world:

> For the *non-theistic* [Platonist] realist, the fact that physical reality behaves in accord with the dictates of acausal mathematical entities existing beyond space and time is, in the words of philosopher of mathematics Mary Leng, "a happy coincidence". For consider: If, *per impossibile*, all the abstract objects in the mathematical realm were to disappear overnight, there would be no effect on the physical world. This is simply to underscore the fact that abstract objects are causally inert. The idea that realism somehow accounts for the applicability of mathematics "is actually very counterintuitive," muses Mark Balaguer. "The idea here is that in order to believe that the physical world has the nature that empirical science assigns to it, I have to believe that there are causally inert mathematical objects, existing outside of spacetime," an idea which is inherently implausible (Craig 2021, p.204).

Craig's alternative is to place the abstract objects in the mind of God, who is of course not causally inert: "the *theistic* realist can argue that God has fashioned the world on the structure of the mathematical objects He has chosen" (Craig 2021). Craig thus takes the Platonist mathematics-reality gap as an opportunity for God to bridge the gap.

It is true that Craig adds some remarks that point to a different, design-type, argument. He writes:

> What remains wanting on naturalistic anti-realism is an explanation *why* the physical world should exhibit so elegant and stunning a mathematical structure

> in the first place. After all, there is no necessity that a physical world exist at all, in which case mathematical truths would not have been descriptive of the physical world. Perhaps the universe, in order to exist, had to have *some* mathematical structure—though couldn't the world have been a structureless chaos?—but that structure might have been describable by elementary arithmetic (Craig 2021, p.206), elaborated in (Craig 2023).

It is indeed contingent whether the universe should have an "elegant and stunning" mathematical structure rather than a simple one, and a design argument could arise from that. But that is a different argument from the one of Wigner as reconstructed by Craig.

Aristotelian realist philosophy of mathematics

Aristotelian realism is an alternative philosophy of mathematics to nominalism (including formalism) and Platonism. It sees mathematics as directly about the world, a science of certain aspects of physical (or any other) reality, such as quantitative and structural aspects. It thus sees the Wigner "unreasonable effectiveness" problem as largely an artefact of those philosophies of mathematics which place a wide gap between mathematics and physical reality. On an Aristotelian view, mathematics (whether elementary or advanced) describes truly the structure of the world, so of course it is effective. It is no different from the effectiveness of crop science in growing crops, because crop science states the facts about crops.

Islami (Islami 2016) well describes how "gap" philosophies of mathematics see the problem:

> What seems to be puzzling is the underlying difference between the *relata* of this relationship: physics is the study of inanimate nature, concerned with the discovery of laws of nature, while mathematics is the study of concepts (structures) and operations, which seems to be far removed from the empirical study of the natural world (Islami 2016, p.4839).

The most popular philosophies of mathematics do see it as "far removed" from the natural world in that way. Platonism (one version of which is favoured by Craig) regards mathematics as a study of another world, that of acausal "abstract objects". Nominalist views see mathematics as divorced from the natural world because it is not about anything at all, but either just a manipulation of formal symbols (as in the formalism favoured by Wigner), or pure logic or merely the "language of science", not itself contentful.

However, those perspectives do not exhaust the field of philosophy of mathematics, and, as is widely recognised, they all face serious difficulties explaining the applicability of mathematics, the very problem raised by Wigner (Körner 1960, ch.8). The main alternative, which places applied mathematics first, is Aristotelian realism (Franklin 2014a, 2022a) (It is inspired more by Aristotle's general realism about universals than by his specific remarks about mathematics). According to it, mathematics studies certain aspects of the natural (non-abstract) world, quantitative ones (such as ratio) and structural ones (such as symmetry). The ratio of one animal's height to another is a relation that is as real as the heights themselves, but ratio is studied by the pure mathematics of continuous quantity. Symmetry (whether exact or approximate) is a real and easily perceivable feature of physical objects such as faces and crystals, but is studied by a branch of abstract mathematics, group theory. Surprisingly, Wigner himself won his Nobel Prize in physics for his work on the role of symmetry in quantum mechanics, and expressed his understanding of it in realist terms (before taking up formalist philosophy of mathematics). He wrote, in terms very acceptable to Aristotelians:

> Against the group-theoretic treatment of the Schrödinger equation, one has often raised the objection that it is "not physical." But it seems to me that a conscious exploitation of elementary symmetry properties ought to correspond better to physical sense than a treatment by calculation (Ferreirós 2017, pp.66–67).

The case of group theory and symmetry is one example of a wider phenomenon that some historically-informed commentators on Wigner have noticed—that he exaggerated the lack of physical motivation for the concepts of modern higher mathematics. Many of them developed organically from real-world motivations, though of course gradually going beyond them. The ultimate point of them was to deepen our understanding of the mathematical structures that are perceivable in the physical world (Grattan-Guinness 2008; Lützen 2011).

So Aristotelian realism sees mathematics as being directly about the properties of the real world (or sometimes properties that could be realised in the real world but may not be in fact, such as infinities). But it is not an empiricism. As in other fields, Aristotelians emphasise necessities, and the knowability of necessities. For example, ratios are in the world and are easily measurable, but the alternation of ratios is necessary and knowable (that for any non-zero lengths, weights, time-intervals etc, A, B, C, D, if the ratio of A to B equals the ratio of C to D, then the ratio of A to C equals the ratio of B to D).

A classic example provides a template of how Aristotelian realists see mathematical necessities in physical reality. In the eighteenth century, the seven bridges of Königsberg, in East Prussia, connected two islands and two riverbanks as shown in the diagram (Fig. 1).

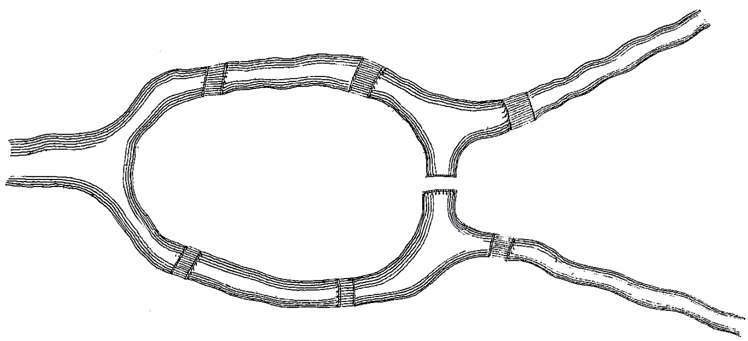

Figure 1. The bridges of Königsberg.

The citizens of Königsberg noticed that it seemed to be impossible to walk over all the bridges once, without walking over at least one of them twice. The mathematician Euler proved they were correct (Euler 1735; Räz 2018). Although new bridges could be built, nevertheless, with the existing bridges and land areas being as they are, it is absolutely impossible to walk over all the bridges once and once only. That is a necessity about the actual physical bridges and actual physical walking, not about some abstract model. The mathematical necessity is not in some Platonic world of abstract objects, or in some formalism, language or logical structure, but in the topological structure of the system of physical bridges. That necessity is inherent in the world and cannot be either imposed by or excepted from by God.

That kind of necessity is absolute and not the same as the "nomic necessity" of laws of nature. It is usually thought that God could have made the laws different so their necessity is less than absolute (and so, in principle there could be arguments to God from the choice of laws, but those arguments would be forms of design argument).

Nor does Aristotelian realism hold that the universe has its individual mathematical properties of necessity. The number of electrons in the universe is a contingent matter, although that number must satisfy all arithmetical properties.

On Aristotelian realism, there is in principle no problem with mathematics being "unreasonably" effective. Mathematics, whether elementary (mainly concerned with quantity) or advanced (mainly concerned with pure structure such as symmetry) describes possible structures that physical reality may have. It is for empirical science to measure whether reality has those structures (for example, whether space is Euclidean), and it is then for mathematics to draw the necessary consequences.

It is not surprising if initial observations only suggest a structure approximately, as in the case of Newton's measurements of gravity or Heisenberg's rules for calculating with hydrogen. If intelligent scientists guess from that the true structure, such as the inverse square law of gravity or the matrix mechanics (or mathematically equivalent) structure of quantum mechanics, that structure will give rise to indefinitely accurate predictions, just because it is the actual structure. Hence there is nothing surprising, in principle, either in the applicability of elementary mathematics, in the applicability of advanced mathematics (that is, mathematics that happens to be harder for humans), or in the high accuracy of predictions.

It is significant that the phenomenon of hyper-accurate prediction that gave rise to the third question above about the mathematics-reality fit occurs in elementary mathematics, and does so in a way that is provably comprehensible and so not a surprise to a mind with enough cognitive power. The digits of π, the ratio of circumference to diameter of any circle, have been calculated to over 100 trillion places. Each digit generates a prediction: that if a physical object is made more and more perfectly circular, the measured ratio of circumference to diameter will eventually be as that digit predicts. To a mind of limited cognitive power, that is amazing, but it is an absolute necessity that is fully comprehensible and does not require or admit of any outside power, divine or otherwise, to make it so.

That case is a model for understanding the necessity of application of the more esoteric concepts of higher pure mathematics, such as Hilbert spaces or Borel sets. A smaller proportion of humanity may understand them than understands the digits of π, but that does not make their necessity in applications any less comprehensible in itself, or any more in need of explanation from outside.

Mathematical necessity and theodicy

The essential motivation for Craig's argument is that theists should prefer a surprising, hence contingent, fit between mathematics and physical reality, in order to postulate God as a cause of the observed fit. There is however a reason why theists should prefer the fit between mathematics and physical reality to be absolutely necessary, namely, that it makes the problem of evil solvable along the lines of Leibniz's theodicy (Franklin 2022b).

Leibniz agrees that God ought to create the best possible world. He poses that as an upfront design problem: "God has ordered all things beforehand once for all, having foreseen prayers, good and bad actions, and all the rest" (Leibniz 1710, p.par.9, 128). As engineers are well aware, design is difficult, and purely logical and mathematical obstacles are among those that must be faced—perhaps, for an omnipotent God, the only ones that must be faced. The best-known of logical problems is the difficulty of reconciling free will for humans with an acceptably good outcome, as granting humans free will leaves God's world design hostage to humans' decisions to do evil.

The relevant mathematical constraints on God's action are those arising from the global-local distinction, one of the great themes of mathematics (Franklin 2014b). It is frequently found that what is possible locally—in some small region—is not possible globally, as the local solutions cannot be fitted together. The Königsberg bridges are an example. In any small part of the system, it is easy to find a path over all the bridges exactly once. But those paths cannot be fitted together to make a path over all seven bridges exactly once. What is possible locally is impossible globally, and the impossibility is mathematical and absolute, hence not subject to exception by God. Although God could make bridges or walking differently, he could not, while keeping the bridges and walking as they are, make it possible to walk over all the bridges exactly once.

Examples are found across many mathematical fields. They include the impossibility of building a circular staircase that goes up all the way round and ends at its starting point: any part can be made ascending, but the parts cannot be fitted together the solve the problem. Tuning and temperament in music involves mathematically unavoidable tradeoffs in dividing the octave into a small number of notes, tradeoffs which are resolved adequately but imperfectly in the standard system of equal temperament. The well-known Arrow impossibility theorems show that certain natural conditions on social choice cannot be satisfied simultaneously. The phenomenon is well-known to mathematical practitioners in many fields, though not to philosophers.

Such examples show what is wrong with the natural thought that it is easy to imagine God's improving the world by tinkering here and there, for example by removing a single toe-stubbing while leaving everything else as it is (Brown and Nagasawa 2005). There is no world in which a toe-stubbing is removed but everything else stays as it is. For a start, causes must act differently in that world, since the actual causes preceding the pain do not produce the same pain, so laws of nature are different. Changes in the world are not isolated but ramify globally.

If we consider from that perspective God's design of creation before starting, taking into account whatever knowledge of the future in different scenarios is possible for omniscience, it becomes clear that purely mathematical constraints make the design problem very difficult. According to the results of physics used in the "fine tuning" argument, God must choose the physical constants of the universe extremely close to their actual values to enable the conditions for life to arise. The tuning needed to do anything more detailed must be even more exact.

Leibniz's best-of-all-possible-worlds theodicy has not been considered credible in recent times. Modern developments in the mathematics of local-global interactions show that it deserves revival. In order to revive it, theists must come to appreciate how mathematical necessities constrain God. That is a way of thinking at odds with the Craig-Heller arguments, which look for contingencies requiring an explanation by divine creation.

Conclusion

Design arguments of all kinds arise from contingent aspects of the universe, which may require divine action to explain them. That is true of classical arguments from teleology or from the adapted complexity of living things, which are unexpected in a purely materialist universe and so may call for an external causal explanation. It is equally true of contemporary fine-tuning arguments, which begin with the apparent contingency of the settings of basic physical constants. As they apparently could easily have been different, their having just the unlikely combined settings that make our existence possible calls for an external causal explanation, such as by divine action. There could in principle be an argument from the universe having one or other mathematical structure which it need not have had, for example from its being finite or infinite, but that is not the kind of argument being considered here.

However, there is no such argument purely from the mathematicity of the universe or the effectiveness of mathematics in describing it. Mathematical truths are absolutely necessary, whether elementary or advanced, pure or applied. The digits of π are what they are necessarily, so they are not subject to God's will and there is no possibility of his writing a message in them. Similarly, the mathematical truths found to be instantiated in the physical universe cannot point to any contingent facts about creation, because they could not have been otherwise. Therefore, their being as they are cannot point to God.

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