Faith is Fundamental
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Introduction

I remember, at about the age of 10 or so, thinking about the bigness of the universe. These thoughts were tangled up with vague notions of the linked concepts of infinity and of God. I remember having a strange sense of vertigo thinking about the edges of the universe, and realizing that however big that was, there was something beyond that was even bigger. Beyond that beyond, there was something bigger still. As I struggled to grasp the unending biggerness of the continuing beyonds, my vertigo became a pulsing uneasiness, like a fear of falling into an endless pit…. This was, I now realize, an initial and quite emotional confrontation with infinite regress. Perhaps the fear I experienced explains why, for the next two decades, I gravitated towards a positivist, reductionist view of the world. Believing that everything could be broken down and explained in more fundamental terms, and ultimately in logical propositions, was a powerful and comforting idea. It was, however, as I later learned, an entirely hollow dogma.

As I think about my own experience, it helps me understand how the Pythagoreans must have felt. Having discovered the beauty and apparent rightness of geometric form and numeric ratios, they began to worship this perfection as being more important than the irrational and irascible gods that ruled over the messiness of earthly existence. Such a faith surely eased the fear of the unknown and the unpredictable. The vestiges of that faith remain today in our use of the word “rational” and in the moral rightness the word conveys. Yet, the Pythagoreans encountered inconsistencies that conflicted with their faith commitment. Specifically, certain geometric features were incommensurable with the ratio of any two natural numbers. As we know today, the ratio of the circumference of a circle to its diameter is equal to the number pi, which cannot be expressed as the ratio of two natural numbers. What we now call the Pythagorean Theorem also proves that the hypotenuse of a right triangle, with sides of length equal to one unit, is equal to the square root of two, also not a ratio of natural numbers. I can imagine the fear and loathing that the proof of incommensurability might have created in the heart of a true believer. Legends say that Hippasus, the discoverer of such a proof, was thrown overboard by his fellow mathematicians.

Modern physics has been struggling with fundamental inconsistencies for more than a century. FQXi, in the current essay contest, has now posed the question - what is fundamental? Many essays will likely speak to physical objects, properties, relationships, mechanisms or processes in the effort to define a new and secure theoretical foundation for physics. But I strongly doubt that the reassurance and clarity we are seeking can be found in such concepts. I argue that the problem rests with something deeper, something more fundamental - our faith. We each carry with us a set of beliefs, as articles of faith, that guide our path in both life and in science. These articles often remain unexamined, yet they exert a profound influence on what we pursue, what we perceive and how we respond. I suggest that faith may be interfering with physics.
Support from Notable Physicists

The idea that faith, and sometimes fear, drives our thinking is not a novel idea, and it is not unusual even among physicists. Max Planck is the source for one of the more common tropes about the difficulty of paradigm change in science, usually cited as “science advances one funeral at a time”. The point is, we tend to hold on dearly to the ideas that we are familiar with, and tend to reject new or different ideas that conflict with our established notions.

A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it. Max Planck

Albert Einstein is also frequently cited for his “science without religion is lame” quote. There is considerable controversy about what Einstein actually meant, particularly in the science versus religion debate. In context, however, the quote clearly displays his belief that there is a sphere, “religion”, outside of science, from which aspirations and faith arise.

But science can only be created by those who are thoroughly imbued with the aspiration toward truth and understanding. This source of feeling, however, springs from the sphere of religion. To this there also belongs the faith in the possibility that the regulations valid for the world of existence are rational, that is, comprehensible to reason. I cannot conceive of a genuine scientist without that profound faith. The situation may be expressed by an image: science without religion is lame, religion without science is blind. Albert Einstein

More recently, a statement by renowned physicists Stephen Hawking and Leonard Mlodinow has been characterized as giving up on the idea of a “Theory of Everything.” Again, there are disagreements about what this actually means, but the statement clearly articulates the belief that reality is not independent of the models and theories we use in our interrogation of it.

“There is no picture- or theory-independent concept of reality. Instead we adopt a view that we call model-dependent realism: the idea that a physical theory or world picture is a model (generally of a mathematical nature) and a set of rules that connect the elements of the model to observations. This provides a framework with which to interpret modern science. Though realism may be a tempting viewpoint, what we know about modern physics makes it a difficult one to defend.” Stephen Hawking and Leonard Mlodinow

Many arguments can be made about what these great scientists meant and the context in which their statements were made. I have no doubt some will suggest that they do not support my thesis. Nevertheless, I believe they should open the door for a discussion of the ways in which our faith, what we believe, influences our views and practices of science. To put it another way - when we do science, or talk about science, we cannot park our faith at the door; it comes inside with us and directly influences what we study, what we see and what we conclude.
The claim that we cannot do science without some kind of faith may not be very controversial. However, I also claim that findings in mathematics and physics over the last century provide consistent and emphatic evidence that some of the articles of faith we tend to hold dear are not supported or reasonable.

**A Series of Problematic Findings**

**Space and Time**

Albert Einstein’s Theory of Special Relativity, published in 1905, overturned the prevailing Newtonian concept that space was a fixed frame of reference for objects moving in time. The Newtonian concept was, more or less, consistent with our normal experience – objects appear to move within a fixed background reference frame. But the Michelson-Morley experiments (1887) inconveniently showed the speed of life to be equal in all directions of motion. Einstein’s theory solved the problem by redefining the relationship of space and time – there is no fixed frame of reference. Time and space can be re-visualized as a four dimensional topological manifold, a “loaf” of space-time. Any given slice of the loaf (or conic section to be precise) represents one observer’s frame of reference as a function of their location and motion. Considering the entire universe as a whole, there is an observer somewhere in the universe for whom our past is their present and, correspondingly, an observer for whom our future is their present. Past - present - and future are all there, which yields a peculiar form of observational determinism – our future has, in some reference frames, already happened. Numerous physicists and writers have claimed that our sense of time is an illusion. That our everyday experience of the flow of time is a fraud? That our choices and our future have somehow already happened?

The flow of time plays an important role in thermodynamics. The Second Law posits that closed systems inevitably progress toward states of increasing homogeneity, the technical measure for which is entropy. Entropy always increases. A block of ice melts and becomes a puddle of water; an egg falls and breaks and cannot be reassembled. This indeed, is consistent with our perceptions of the effects of time. We remember the past, we experience the present, we anticipate the future, and we cannot go backwards. Yet all of the interesting structures in the universe, including planetoids, stars and galaxies, crystals and fluid flow, life forms, human technology and creativity, all exhibit increases in order, structure and variety quite at odds with the Second Law’s imperative for homogeneity from increasing entropy. Why? Local structure and order emerges by exporting entropy to the larger environment. The entire universe as a whole continues to run down, but as it does, local pockets of increasing organization and structure emerge. This counter-entropic process is explained in the theory of non-linear dynamic systems pioneered by Ilya Prigione and others. In open dynamic systems where energy is in flux, stable structures tend to emerge in the otherwise chaotic flow by dissipating energy and maximizing efficiency, thereby minimizing entropy. The result is a stable, persistent structure - one that effectively gathers information and responds with intelligence.

This raises uncomfortable questions about causality and teleology. What is the cause of the emergent order? How does intelligence emerge from unintelligent components such as molecules, cells, plants, ants or humans?
Quantum Physics

One of the very first things I learned in physics was Heisenberg’s Uncertainty Principle. In its simplest form, this principle recognizes that one can determine precisely the position of a particle, or its momentum, but not both, since making the measurement of momentum changes the position, and vice versa. This seems like a simple matter, until it is extended to the probabilistic world of quantum physics. We are unable to peer into time or space at the smallest scale, below Planck space and Planck time. Even if we could, these tiny bits of reality contain no useful information – their interiors are subject to infinite probabilistic variations, a state some refer to as “quantum foam.”

The complementarity principle of Neils Bohr affirms the reality, and the apparent paradoxes, of quantum physics: wave-particle duality, quantum superposition, and the entanglement of paired particles. Two entangled particles are created and move in different directions. They share specific characteristics, such as spin, but until measured, the spin is indeterminate. When one of the particles is measured and the spin is determined, the other particle, no matter how far away, will prove to have the same spin. It is as if the first particle to be measured “chooses” and the other particle obeys instantaneously, in what Einstein labeled “spooky action at a distance”. Several explanations have been offered to explain this phenomenon, none of which has been confirmed. One is that somehow the two particles communicate with each other, through unseen, potentially massless messenger particles traveling faster than the speed of light. Or perhaps there is a form of “non-local” coordination that extends outside of space and time. Alternatively, perhaps, when the particle measurement is taken, the outcome applies backwards in time to when the two particles were created, as if the particles had always been that way. This theory, called retro-causality, suggests the end-state of a quantum choice can determine past states as well as the intervening space-time trajectory.

One of the central features of quantum physics is the role of a conscious observer in establishing the conditions for quantum phenomena, e.g. collapse of the waveform superposition. In essence, there would be no physics if there were no observer. Some have speculated that, in some sense, the purpose of this universe has been to create the conscious observer that measures it. Others think that since consciousness is integral to quantum physics, consciousness in some universal form has to exist prior to quantum physics.

Considerable experimental and intense theoretical efforts have been devoted to the resolution of these issues. These efforts have been unsuccessful.

Mathematics and Logic

To many, the seemingly intractable problems highlighted above are merely bumps in the road. We are making inevitable, if invisible, progress towards a grand unified theory. When the next Einstein comes along, the current quandaries will be resolved. Truthfully, science has made great advances, and some of the puzzles of today will be reconciled in the future. There are some conundrums in mathematics, however, that will never be solved.
Among the most significant difficulties explored in the last century in mathematics are issues entangled with the concept of infinity. Alan Turing is sometimes described as the father of computer science, having proved the feasibility of a Universal Computing Machine. Such algorithmic creations are now ubiquitous. Turing also proved in 1936 that a certain computing problem, known as the halting problem, was undecidable. In the movie The Imitation Game, the Turing character watched helplessly at his computing machine as it first tried to solve the German Enigma code. The wheels kept spinning - a metaphor for Turing’s Halting problem. The team cracked the Enigma code, but the formal problem of determining if an algorithm will ever halt cannot be solved. In fact, it is claimed to be one of an infinite number of very difficult problems – called NP-hard, or non-polynomial. In 2000, the Clay Foundation offered $1M to anyone who can find a short cut to any NP-complete problem (a subclass of NP-hard). That would change the future of the world - because it has been proved that if you find a shortcut for one NP-complete problem, you can find shortcuts for all of them. The betting is there are no shortcuts, and that our universe is full of non-computable, undecidable problems. Of course, these problems can all be solved --- in an infinite amount of time.

A more profound difficulty was highlighted by the work of mathematician and logician Kurt Gödel. Later in life, Gödel was a friend of Einstein at Princeton, but his big contribution was proving in 1931 the two incompleteness theorems, at the age of 25. One theorem proved that in any self-consistent recursive logical system, there are true propositions that cannot be proved. The second theorem proved that such a system cannot demonstrate its own consistency. How bad is this? Well, the incompleteness findings apply to every branch of mathematics, including set theory and arithmetic. So, if you had planned on starting your quest for truth with logic and math, as I had, and as the positivists in the Vienna Circle had, you will be disappointed.

How did Gödel construct his proof? He relied on a particular category of logical statements that refer to themselves. “This statement contains five words” is self-referential. It is perfectly sensible, and it is true. But consider the sentence “This statement is false.” If true, the statement contradicts itself. If false, it curls back and bites its own tail. Quite simply, all systems of thought – logic, math, language, or your favorite theory of the universe – are subject to this constraint. If they are self-referential and self-consistent, then they are going to be incomplete. By analogy, we exist as conscious observers inside a box. Some of what we are trying to learn could only be observed from outside the box.

Many thinkers, over the millennia, have vested mathematics with an absolute and inviolable perfection. They had faith that mathematics was the fundamental truth, the foundation for all of knowledge. For some, this faith rose to the level of mysticism or religion. Gödel’s theorems, by proving that mathematics is not perfect, because it is incomplete even when consistent, makes such beliefs seem foolish. Yet, the profound but peculiar feature of self-reference that underlies those theorems introduces a different kind of mysticism to the question of knowledge and understanding. Critically, self-reference is not only fundamental to math and logic: It is also fundamental to quantum physics, to language and to the hard problem of consciousness. Self-reference invokes Godellian incompleteness.
Articles of Faith

There are certain fundamental articles of faith at the foundations of science that, presumably, we can all agree on. One of these is the belief that the regularities we observe and experience in the physical world are reliable, consistent and enduring. We reject the idea that nature is malleable and inconsistent. However, this presumption cannot be proved, and it can, potentially, be challenged by a single contrary experience. Indeed, there are many examples of anomalous or unexplained phenomena. Some people continue to believe that there can be exceptions to a given law of nature, for example by supernatural intervention, while others, presumably including most scientists, would argue that anomalies are all explainable within the laws of nature, although occasionally a given law may be inaccurate and needs to be updated. Nevertheless, the basic consistency of regularities in nature is a common belief that generally binds us together, and serves as a key foundation for the practice of science.

Most of us, and presumably all scientists, also share a belief that the regularities we experience are rational and comprehensible. We are driven to understand our experiences and to find explanations that are consistent and predictions that are accurate. This drive likely originates from evolutionary biology, since the most accurate and efficient responses to uncertain conditions would be rewarded under natural selection. At the same time, however, we do best when we recognize the value of a healthy skepticism. If we believe we understand something, we may tend to ignore the occasional anomalies, a tendency that can be dangerous in the Paleolithic jungle as well as in the laboratory. Believing that the world is comprehensible is not the same as believing that we have comprehended it.

As natural philosophy matured into modern science, another belief came to be generally accepted. That is that mathematics is the language by which we can best explore and describe the regularities of the physical world that we observe. This belief was the subject of the 2016 FQXi contest “Trick or Truth.” The nature of the relationship was elegantly articulated by Eugene Wigner in his famous essay on The Unreasonable Effectiveness of Mathematics in the Natural Sciences:

*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.* Eugene Wigner

As that FQXi contest demonstrated, there are wide ranging views on the relationship between math and empirical science and whether one is more fundamental. In this case it is helpful to distinguish between the practice of science and its reliance on mathematics as a valuable tool, and the metaphysical status of mathematics. It is also important to ask how one’s metaphysical belief influences one’s view of science. Clearly, the metaphysical commitments of the Pythagoreans and the positivists of the Vienna Circle proved to be problematic and ultimately had to be discarded before further progress could be achieved.

Beyond these three generally accepted, if qualified, articles of faith, there are others relating to the practice of science and its commitments to open and honest inquiry that are critically important but beyond the scale of this essay. However, I would like to address three specific
articles of faith that seem to be embraced by at least a few, or in some cases many, practicing scientists and writers of science. These have not been carefully catalogued and I do not attribute the items to any particular individual. Rather, the list is my paraphrasing of conceptual threads I have found in the science literature and seen attributed to science in our popular literature and culture.

1. The world is fundamentally random. There is no purposeful intentionality or agency involved in its functioning.

2. The world is causally determined, from small to large, from past to future. Reductionism is methodologically exclusive and determinism is inevitable.

3. The physical world is all there is. There are no non-physical causes. Emergent properties, including consciousness and our subjective internal states, are epiphenomenal.

The most significant feature of these beliefs is that they narrow the conceptual field of vision by rejecting broad classes of possible explanations for observed phenomena. In contrast, the principles referenced above dealing with the consistency and comprehensibility of the regularities of nature, using mathematical tools, are affirmative and not limiting.

Physicalism (#3) denies the possibility that non-physical causes, such as free will, top-down principles of emergent organization or divine influence, can have any efficacy in the physical world. This is an ideological contention, not a principle supporting curious inquiry. It also has a significant side effect: flattening the depth and richness of human experience into a single and extremely limited dimension. Belief in physicalism may be comfortable for those who are angry at harsh and judgmental religiosity or fearful of unknown influences, but it is not particularly useful to science or to human life.

Reductionism and causal determinism (#2) similarly exclude potentially useful avenues for understanding and integrating our experiences. We know intuitively that the whole can be greater than the sum of its parts, and the study of emergent phenomena bears this out. Entertaining alternative concepts such as top-down causation or the efficacy of free will should not be viewed as threats. Significantly, determinism has potentially negative consequences for human psychology, undermining the virtue of personal responsibility that is critical to civilization. I can attest that these conceptual approaches are appealing for their simplicity and clarity, and I believe they can be methodologically useful in the practice of science. But as ideological principles of faith they are inappropriate.

I’ve been particularly interested in the belief in randomness and the related distrust of the concept of agency (#1), which is most evident in the field of cosmology. This belief serves as the basis for the multiverse theory, which seems to be increasingly accepted as a consensus view. The theory achieved a milestone of public awareness in 2014 with the publication of Our Mathematical Universe, by Max Tegmark.
Under the multiverse theory, each of the quantum inflection points since the early history of the universe (there are an immensely large number of them) has resulted in alternate universes, and our particular universe is merely one among the exceedingly many. Tegmark goes beyond, theorizing that the entire multiverse contains infinite sets of universes in a hierarchy of four levels, the highest of which contains all mathematically possible universes. This construction preserves the notion that cosmological history is random and denies any role for a selection process operating to winnow down the possibilities.

Consider the alternative theory, one that accepts our observational experience of a single universe at face value. Under this theory, one has to conclude that at each quantum inflection point, or at each of the infinite possible points of divergence theorized under the infinite multiverse, a selection occurred by which the universe was guided along its unique trajectory to the end-state which we are now observing.

As there is no confirmatory evidence for either alternative, the choice boils down to an ideological one - what are you comfortable in believing? The scientific establishment and much of our modern culture seems to have become very uncomfortable with the idea of a cosmic selection process guiding our universe to its current state. Yet a century ago, this was likely the predominant view. Perhaps the ideological supremacy of the multiverse is a symptom of an underlying cultural rejection of religious ideas, rather than a reasoned response to open questions in physics.

Indeed, “cosmic intentionality”, a phrase I coined in “The How and the Why of Emergence and Intention” in last year’s FQXi essay contest, in my view provides a far simpler and more comprehensible alternative to the multiverse theory, in terms of explaining the varied observed phenomena of cosmic fine tuning, quantum indeterminacy and the narrowness of the mathematical frame in which we reside. As explained in that essay, the emergent cascade across physics, chemistry and life appears to be guided by a selective directionality featuring intention, attraction, cooperation and reciprocity, yielding increasing levels of complexity, intelligence and consciousness.

Conclusion

When facing his accusers, Socrates is quoted as saying “the unexamined life is not worth living for a human being.” I would suggest in this context the following corollary: “the unexamined faith is not worth believing.”

The scientific enterprise is, perhaps, the most successful and important institution in the history of human civilization. In its emergence, it has been guided by key shared principles that have led to its success. Among these are foundational beliefs, articles of faith, that influence what scientists study, what they see and what we conclude. These beliefs are fundamental to science.

This essay is, obviously, not a dispositive treatise on the articles of faith that would be optimal in the pursuit of physics. Rather, it is intended to open a discussion about what articles of faith practitioners and observers of science are bringing with them to the inquiry and whether those
articles of faith are appropriate and relevant. I believe we have an obligation to be clear about our beliefs, and to participate in an open inquiry about their usefulness. From such an inquiry, the scientific enterprise can only benefit.

I have also offered several observations that are worth factoring into this conversation. The first is that our goal of securing a consistent and complete truth about the physical universe and how it works is illusory. In particular, that goal is subject to the constraints arising from the conundrum of self-reflection and the accompany issues of incompleteness and undecidability. While we may fully explore our universe as observers from the inside, complete knowledge of the universe is necessarily inaccessible - unless you had infinite time and information, or the capacity to transcend the universe entirely.

I have also questioned a number of apparent beliefs that are interfering with our full and open exploration of our world. Among these are the belief sets that I have referred to as physicalism, reductionism and determinism. I have also offered a specific critique of the commitment to randomness and its role in the justification of the multiverse theory. My understanding, limited as it may be, of the emergent cascade displayed in the evolution of the cosmos suggests that cosmic intentionality may be a preferred hypothesis, one that necessarily requires the abandonment of the belief in randomness.

One of the consequences of a more open and honest discussion of our belief framework would be, I believe, an increase in our shared humility. Facts we may know, and theories we may argue about, but beliefs have a more vulnerable quality. While we may be committed to our beliefs, we know they cannot be proven but only accepted on faith. Conversations at this level would enhance professional dialogue and encourage our own self-reflection, opening the door for us to modify our own belief sets based on what we learn from others.

Ultimately, we may find, in all of our hearts, a set of beliefs that would meet Einstein’s definition of religion as the source of “our aspiration toward truth and understanding” and “the faith in the possibility that… the world… is comprehensible”. I can only imagine that this would reignite our shared sense of wonder, and encourage us to embrace the human experiences of joy, love, beauty and meaningful participation, including the full and enthusiastic pursuit of science, in this most marvelous world we live in.
Endnotes:


7 Plato’s Apology, downloaded from http://classics.mit.edu/Plato/apology.html 1-17-18

Selected additional references:


