WHY PHYSICS KNOWS NO BOUNDS

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Abstract. Once physics is understood to be particular type of pattern-seeking activity, it becomes clear that its purview will necessarily expand with the exponentially increasing human capacity to recognize patterns. Its current restriction to the exploration of exceedingly simple physical systems will be progressively relaxed, until it ultimately encompasses the whole of extant knowledge. Although the scope of physics is in this way effectively unlimited, there are still certain systems forever beyond its grasp. The existence of such unfathomable yet entirely naturalistic systems is reminiscent of the ancient and medieval concept of the supernatural.

1 Introduction

Why do tensions in the Middle East persist? Why have the works of Shakespeare endured? What system of government maximizes the product of the contentedness of its citizenry? Why does Jane love Tom? Surely, you might think, I cannot possibly intend to argue that these are ultimately questions of physics. But I do. They are not questions for the physics of today, but they are surely questions for the physics of tomorrow. There are reasons to believe that this tomorrow will not be several billion years hence, but at most a few hundred. To see this, consider an explicit definition of physics that corresponds to our usual understanding the term.

Physics is that branch of knowledge devoted to finding patterns in simple systems.

By "simple system" I mean one whose shortest complete description in terms of distinguishable characteristics has a length that does not exceed the readily available information storage capacity of the average physicist. By this definition, a cube filled with a gas in equilibrium is a simple system. Its specification in term of macroscopic properties such as temperature, density, and pressure suffice as a complete description. The vastly longer specification of the state of each of its molecules is unnecessary. Differences in these states are indistinguishable to an observer using known instruments except in so far as they affect the aforementioned macroscopic variables. A cow, by contrast, is not a simple system. Its description in terms of distinguishable characteristics – for example, the positions and behaviors of its numerous parts including each of its hairs – exceeds an average physicist's capacity to memorize. Currently, the rough line of demarcation between simple and non-simple system is well below the complexity of the macromolecules of interest to biochemists.

However, even today scientists who study such molecules -- usually with the intention of finding the pattern that underlies their tendency to fold in various ways [1] -- augment their personal information storage capacities artificially. They use computers. The information storage capacity of computers has long been recognized to be undergoing exponential growth. This is a consequence of an observation in 1965 by Gordon Moore [2], one of the founders of Intel. He noticed that the density of transistors in integrated circuits has been increasing exponentially. The doubling rate of this density is no longer than 18 months. Moore Law, as this observation has come to be known, not only drives a corresponding exponential growth in computer memory, it also underlies the exponential growth the computational speed of these machines.

In time physicist will become more tightly integrated with their computers. The neural implants that will facilitate these unions will likely become as common as the contact lenses and hearing aids of today. A growing number of the physicists of future eras will themselves be computers – artificially intelligent beings. In either case, these physicists will reap the benefits of Moore's Law to an extent not realized today. The exponential growth in their mental capacities will progressively increase the complexity of the systems that they regard as simple. Eventually, perhaps after only a hundred years, they will come to regard as simple certain systems that we find utterly intractable – the unenhanced human brains of our era. Their physics will subsume our psychology. For them, explaining Jane's love of Tom will be a physics problem.

2 Limits to Exponential Growth?

Surely, Moore's law cannot apply indefinitely. The density of transistors cannot exceed the density of atoms. We might suppose with Ray Kurzweil [3] that Moore's law is merely the latest expression relevant to current technology of an historical exponential growth in computational capacity. Such a rule could be expected to hold indefinitely, if it is in general true for a technological society that the rate at which computations occur dy/dt -- the rate at which information grows -- is directly proportional the information y that exists,

$$\frac{dy}{dt} = ky \, .$$

The constant of proportionality k, the exponential growth factor, being a characteristic of the leading computational technology is unlikely to decline. The reason is simple. Inventive societies always replace their most recent computational technology with superior ones. The exponential growth rate will also be sustained by increasingly intelligent generations of computer designers, as intelligent machines begin to design their successors. Should the growth of computation capacity continue at or near its current rate, the consequences are shocking. We can estimate the time at which a future superbrain will be as challenged by finding the patterns underlying the human brain as a physicist today would be challenged by a system sufficiently simple to fall within the purview of current physics. To begin, we equate two ratios. The first is the size of a conventional physics problem (10^4 bytes) to that the memory capacity of a current physicist (10^{13} bytes). The second is the size of a full description of the human brain

(10^{16} bytes) to the memory capacity of a superbrain. Doing so allows us to solve for the memory capacity of a superbrain that would be as taxed in contemplating the complexities of the human mind, as we are in contemplating, say, the black hole information problem. Simple arithmetic informs us that the superbrain must have an information storage capacity of 10^{25} bytes. How long would it take for this superbrain to appear as a machine intelligence, assuming that current memory capacity of computers is 10^{12} bytes and the growth of this capacity is governed by Moore's law? Assuming a conservative growth factor of 2 years (Moore's original estimate), we find that

$$(\text{superbrain capacity}) = (\text{current computer capacity}) \times 2^{t/(2\ \text{years})}$$

or

$$t = 86 \text{ years.}$$

It is entirely possible that this superbrain would be stymied in its attempt to find deterministic patterns in the human brain by the organ's intrinsic chaos. The computational barrier posed by chaotic systems is not absolute, however. It merely demands improved efforts in error correction and initial value specifications. These are engineering problems whose severity would presumably decline as rapidly as the superbrain's mental capacities increase. Irrespective of whether the superbrain likely to appear within a century can immediately solve its physics problem – explaining from first principles Jane's love of Tom, my point is that it will regard this fantastically complex problem with the same optimism that we accord the physics problems of our day. It is, moreover, inconceivable that this superbrain would not make short work of current physics problems. Whatever currently undiscovered patterns that exist in nature and are relevant to our unsolved problems of physics, such a mind will have detected.

3 A Supernatural Sector of Reality?

What sort of systems are forever beyond the superbrain's capacity to fully understand? Other superbrain's evolving at the same or greater exponential rate. It will be unable to find deterministic patterns in such a hyper dynamic system. Any pattern it finds in a "snap shot" of another, more rapidly evolving superbrain will immediately have become obsolete. In short reality will contain an effectively supernatural sector, entities completely beyond comprehension irrespective to the time and effort devoted to the task. Elbert Hubbard, an American publisher of the 19th century, expressed conventional scientific optimism when he wrote that "the supernatural is the natural not yet understood." The poet William Butler Yeats expressed a similar sentiment in writing that "As life becomes more orderly, more deliberate, the supernatural world sinks farther away." Here in contradistinction to these thoughts it appears that a supernatural sector inevitably emerges from the natural world whenever physical law is exploited to ignite a sufficiently explosive growth of an erstwhile natural intelligence. This, perhaps, is how gods are born.

[1] O. Alvizo, B. D. Allen and S. L. Mayo, "Computational Protein Design Promises to Revolutionize Protein Engineering," *Biotechniques*, **42**, 31-39, 2007.

[2] Moore, Gordon E. "Cramming more components onto integrated circuits" Electronics, Volume 38, Number 8, April 19, 1965

[3] Ray Kurzweil, *The Singularity Is Near*, Penguin, New York, 2005