THE PROBLEM WITH A THEORY OF EVERYTHING.

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Theoretical physics has a gaping hole somewhere between the fundamentals and the beginning of it all. But, the search for a theory of everything may yet be entirely in vain as mathematical necessities and our hard-earned physical knowledge stands in the way of the true light.

THE PRIMARY CRITERIA OF A THEORY OF EVERYTHING.

In 1905, the young Swiss Patent Office assistant Albert Einstein first postulated the relationship between energy and matter, later adapted into the famous equation: $E = mc^2$, and whilst many of the apparencies raised by the relationship have since been most thoroughly investigated there still remains the question of how the energy is put into particles. That question may sound crude – the energy is an apparent property of particles – but physicists are now turning despairingly to mathematical theories to explain how – what were at first believed to be – fundamental particles hold all multitudes of properties; from charge to mass the question to ask is not now “What is everything made up of?” but rather the more subtle “How is everything made up?” and it is this simple change in query that holds so much hope with contemporary science.

The theories heralded as the great explainers of these problems are the future candidates for a ‘theory of everything’ (ToE) but what is rarely discussed are the criteria for such a theory and the problems that such requirements raise. It is commonly accepted that a ToE should be:

1. Able to accurately describe all physical phenomena,
2. Compact and neat,
3. Predict the past,
4. Predict the outcomes of future interactions,
5. Have a mathematical basis provable through practical observations.

Everything – as may already be obvious – is an extremely large field, and whilst it will be quite some time before we have all of the knowledge to construct a ToE, it is worth exploring the limits of observation and reasoning to create a secondary set of criteria that produce themselves from the inadequacies of our current theories. This is the nature of this study – what are the secondary criteria of a ToE?

THE CURRENT ‘BEST GUESS.’

Currently, the ‘best guess’ for a ToE is string theory and thus this is the first staging post upon our line of enquiry. String theory states that all fundamental point-like particles are actually one-dimensional entities called ‘strings’ and that the ‘vibration’ of a string determines the properties of the object and thus also the type of particle. It is important to remember as always in quantum physics that what we call objects and particles are of course scientific constructs arising from a necessary need to analogise physical phenomena for easier understanding; our strings are nothing more than a framework for understanding a single-dimensioned object and their vibration nothing more than a property rather than a physical action.

From this theory a number of questions arise, and the one which is most apparent is this: "How are strings created?" For this, an explanation is offered in the ways of the strong interaction, which is predicted to call these entities into existence although at present a mechanism has not yet been developed.

Another advantage of string theory is that it postulates quantum gravity better than any other current theoretical framework, with the graviton simply a massless state of a string. Here, another fundamental enquiry is launched: "Is there a need for a graviton?" Just because our understanding of fields and interactions has so far called upon the use of bosons does not mean that gravity will follow this rule through inevitability. If we strictly follow the classical definition of general relativity then gravity arises from the bending of space-time and gravity waves are thus simply the ripples caused by a high energy impact – of course, this does infer the question of what space-time itself is made of and due to the classical nature of the theory it is unlikely to work upon quantum entities.

A more subtle part of string theory's reasoning relies upon the use of zero-dimensional objects, identified as 'point particles,' for which measuring instruments may become exceedingly close to but never directly observe. This issue is rather reminiscent of the 'renormalising infinities' problem which plagued quantum theory throughout the 1960s and perhaps another Feynman, Tomonaga, and Schwinger scenario will once again eclipse the problem entirely – but until that event the issue will continue to disease the theory.

When we return again to a slightly larger scale, yet another problem presents itself. Hadrons gain their properties from constituent quarks whilst it is apparent that quarks gain their properties from the vibration of a string. How then does the vibrative property issue the breadth of properties observed upon the particles of the standard model? Again, an entirely new mechanism may be required in order to satisfy the demand for a full explanation. This is the nature of the universe; everything happens for a reason and things do not simply leap into existence including the very properties of the most fundamental of things.

The mathematics of string theory – the very foundations – relies upon not just the four dimensions we are already familiar with, but a host of anywhere from 10 to 26 unique dimensions including our familiar height, width, length, and time. Using additional dimensions within the mathematics of string theory allows for easier calculations and faster insights, however, the question is nevertheless raised of how these extra dimensions have so far escaped detection. It is believed that compactification is the primary solution to this issue, whereby the additional number of dimensions are 'curled up' in such a way that they are infinitely small – rendering direct observation impossible and reintroducing infinities into the mathematics of quantum physics. In such a universe it would seem outrageous to even consider that a ToE is possible if our best current theory is provably unprovable.

Moreover, strings are predicted to measure a mere Planck length (10^{-35} m), such that they are consistent with current beliefs about the scale at which quantum gravity acts. This scale, withal, is unobservable by all current scientific instruments and will remain that way for many years as engineers and scientists carefully hone their equipment to have resolutions orders of magnitude smaller than our current fermion and boson measurements. Furthermore, at such small scales, it is probable that other phenomena will become a major hindrance to any such project and thus it may be entirely impossible to observe strings.

THE SECONDARY CRITERIA OF A THEORY OF EVERYTHING.

With all of this considered, the possibility of a ToE is now tainted with an additional set of criteria imposed entirely by the current limits of our best theories and arbitrary primary criteria. A secondary set of criteria could be considered as follows, a ToE should be:

1. Able to explain how fundamental particles come into existence,
2. Provide an explanation for quantum gravity,
3. Avoid or use a mathematical framework with infinities,
4. Able to explain how particles get their properties,
5. Have a deeper view of additional dimensions (if they exist).

If the former and the latter set of criteria are ever fully satisfied by a singular theory then I believe that humanity may finally have unlocked the final secrets of the universe. Where do we go from there?

WORKING BACKWARDS – WHAT DOES THE PAST HOLD?

As a race of intelligent beings, humans have thus far prospered incredibly well on the journey to uncover the hot boiler room of the universe – the 'big bang.' But with a ToE, we will finally be able to fully explore what happened an arbitrarily infinite time after the 'creation event' that brought our universe to bear.

A more detailed understanding of the very fundamentals of the universe would thus allow us to more accurately describe the initial creation of matter and how interactions developed from their initial combined state. Furthermore, we would be able to describe the conservation laws in effect at the primordial point, such as the conservation of energy, and thus understand the matter-antimatter ratio difference and if energy is a fixed quantity or held in balance by 'antienergy' as it the case in other conservation scenarios.

The possibilities are boundless in much the same way as our universe itself.

WILL WE EVER FIND A THEORY OF EVERYTHING?

The scientific community is divided into two groups: those who believe in a ToE, and those who do not. Both sides of the argument are certainly greatly persuasive and the officious zeal of contemporary efforts also present modern science's expectation that a ToE should be possible.

But, here I reference Gödel's incompleteness theorem by stating that any formal definition of a ToE must contain statements that can be neither tested nor proven by the ToE itself and thus also the consistency of the theory cannot be proved within the ToE itself.[1] This may all sound proverbial and in cases entirely inapplicable but recall point five of the

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[1] Paraphrased from Raatikainen, 2020 (see Bibliography)

primary criteria: a ToE must "have a mathematical basis provable through practical observations," any arithmetic logic that seeks to express fundamental reason must be subject to Gödel's incompleteness theorem as a theorem based formally within the realms of mathematics.

If you need a less mathematically-rooted argument, consider this: all of physics is composed of approximations, who is to say that a thrown ball does not teleport to the other side of the world by way of a wormhole in an infinitely short amount of time before returning to its apparent position and continuing its Newtonian journey to rest? It may sound preposterous, but we have no way of observing and rigorously testing that this is not the case. If somewhere our mathematics and theories slipped even slightly into incorrectness the effects may be enormous and cause our entire chain of logic within the quantum universe to be skewed away from that which is true.

As humans, we can try and be as accurate and precise as possible, but it is unlikely that rode the wave of subsequent theories into the present without some mistakes and inaccuracies. Our understanding of the basic components of nature is founded upon continued approximations that cannot be proven in every possible situation – there is no $\lim_{n \to \infty}$ **for real life enabling us to rigorously prove every theory and law to an infinite degree.**

There is also the looming possibility of the anthropic principle: whereby an infinite number of universes exist but ours exists such that intelligence is able to develop, or that we are part of some 'grand design,' or even that we are a successful universe in a chain of black and white holes. All of these predictions are equally as probable as any others – we simply do not yet *know*.

All of this imposes a certain impossibility upon a theory of everything, and maybe that is the way it will stay.

> *"Isn't it enough to see that a garden is beautiful without having to believe that there are fairies at the bottom of it too?"*[2]

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