Theories of everything?

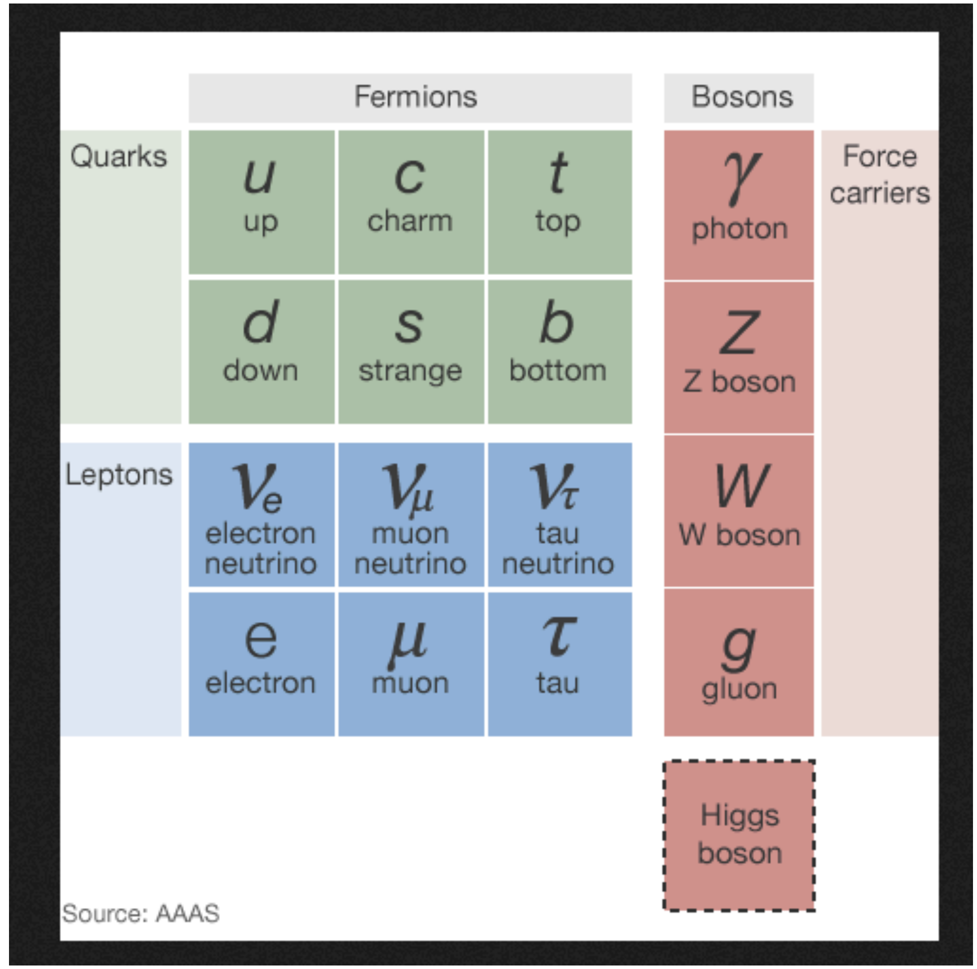
- What is the goal a unification?
- Are we close to the end of science?

The “Standard Model” (1970s)

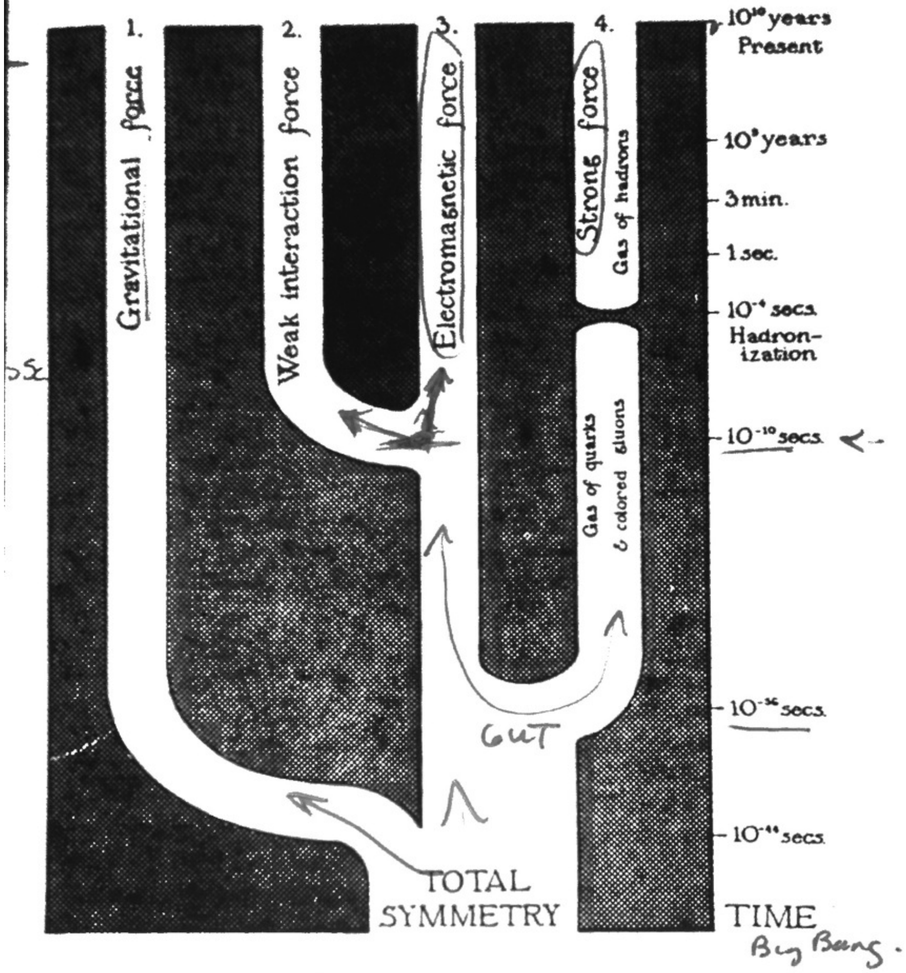
- Table shows the basic particles (61)
- 3 leptons and 3 quarks
- We never see free quarks
- All have now been seen
- The interactions between the particles is mathematically simple but very difficult to “solve” except on big computers
- Almost complete agreement with experiment. (0.02%)

BUT

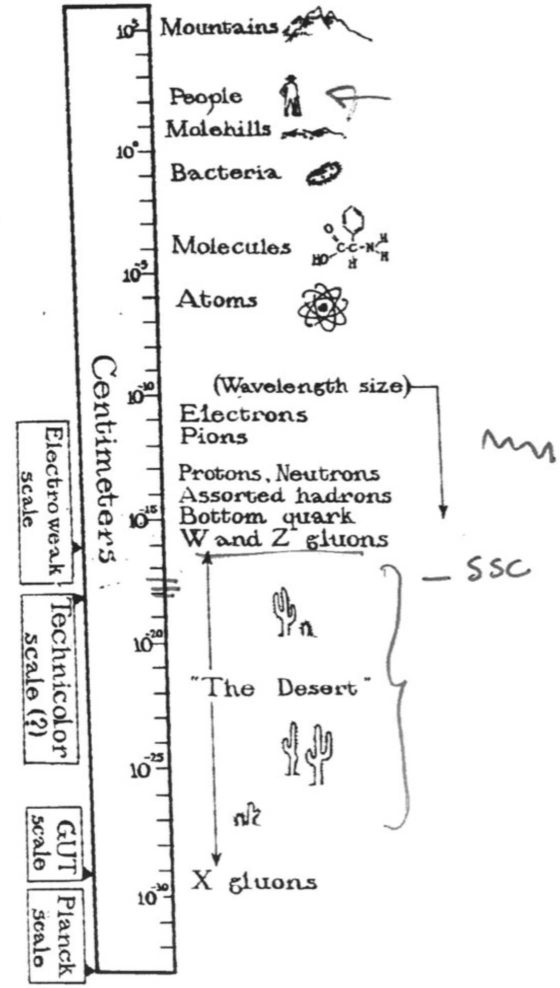
- Why so many parameters? (19)
- How to combine with gravity
- Are there more particles such as WIMPS for dark matter?
- Neutrino masses & oscillations
- Matter/antimatter imbalance.



FOUR FUNDAMENTAL INTERACTIONS

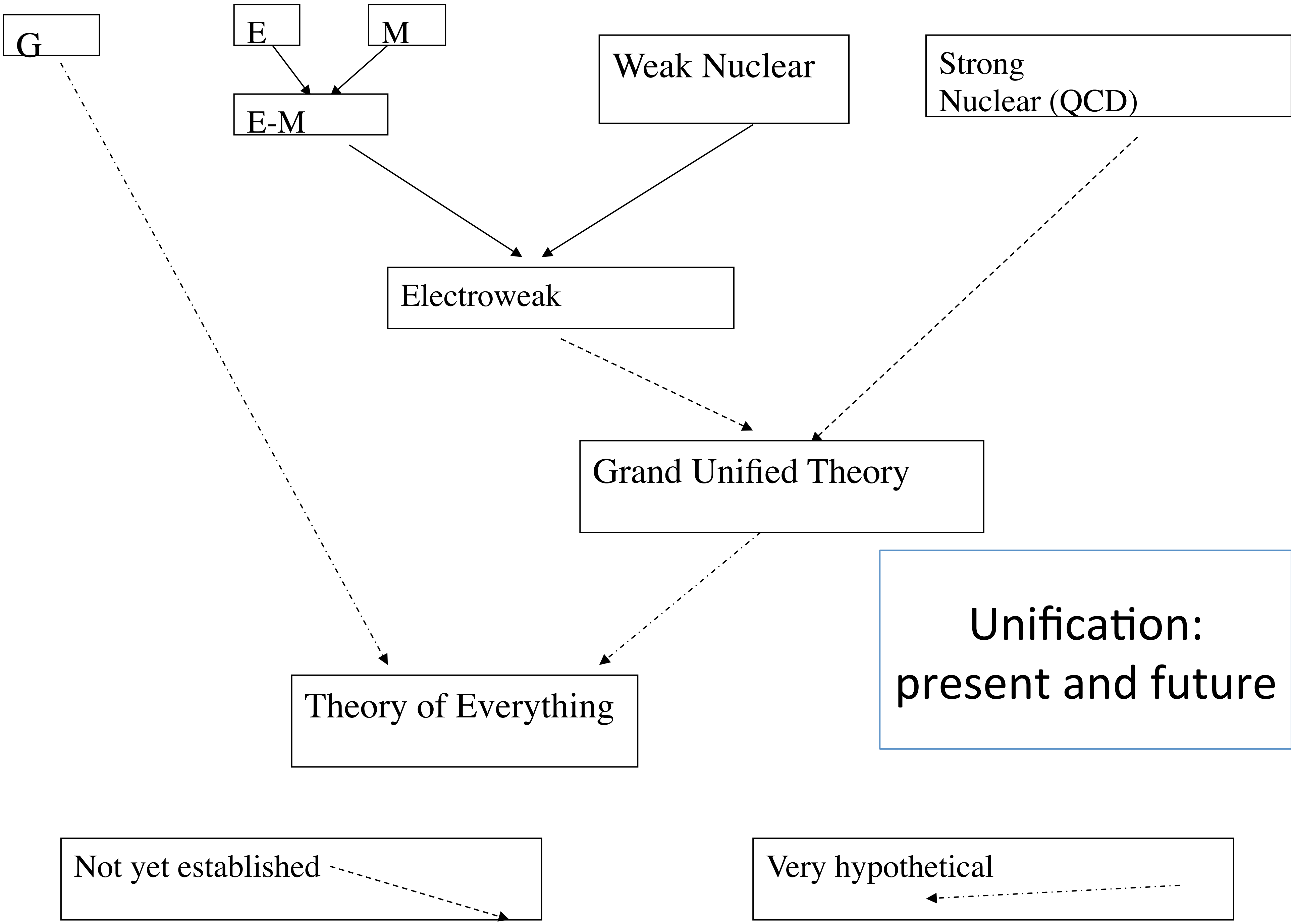


The evolution of the universe as a succession of broken symmetries. If the ideas of modern field theory are right and broken symmetries are restored at high temperature, then at the very earliest times the four known forces of nature, now seen as distinct, were unified.



The distance scales of the universe in powers of 10, from the Planck scale to the size of the universe. There may be a "desert" in the microworld. One of the main insights of modern physics is how the microworld influences the macroworld.

Unification: present and future



A new paradigm

Assuming that the effort to unify QM and GR is successful, all forces (fields) and particles will be seen as the same kind of entity. This includes the geometry of the universe, which GR has made into a dynamical entity. The structure of the universe, and of spacetime itself, is determined by the interactions between the various particles.

Examples of parameters in current theories

- Mass of proton and electron (.511 Mev/c)
- Fine structure constant, dimensionless parameter describing interaction between charges and the electron-magnetic field. Why should it have exactly the value: 137.035989?
- Number of families of particles = 3
- Number of dimensions of space-time = 4
- Weight of empty space: 0.

"There is an infinite number of possible universes and as only one can be actual there must be sufficient reason for the choice of God which leads him to decide upon one rather than another. And this reason can only be found in the fitness or the degree of perfection which these worlds possess." Liebnitz, "The Monadology" 1714.

"Concerning such [dimensionless constants] I would like to state a theorem which at present cannot be based upon anything more than upon a faith in the simplicity, i.e., intelligibility of nature: there are no arbitrary constants of this kind; that is to say, nature is so constituted that it is possible logically to lay down such strongly determined laws that within these laws only rationally completely determined constants occur (not constants, therefore, whose numerical value could be changed without destroying the theory)." Einstein

Why is the universe comprehensible? (after Hawking)

1. There is a complete unified theory which we will discover if we are smart enough.
   – But we will never be sure if we are right.
2. There is not an ultimate theory, just an infinite sequence of theories that are more and more accurate.
3. There is no theory; events cannot be predicted beyond a certain extent but occur in a random or arbitrary manner such as in QM.

Reductionism vs Emergence

- Reductionism: the universe is just the sum of its parts
- Emergence: complex systems can have behaviors that are almost independent of the underlying laws.
  - Hydrodynamic behavior of liquids & thermodynamics just relies on conservation laws.
  - Theory of critical phenomena shows universal properties of systems at phase transitions.
  - Will we ever be able to understand French grammar based on the standard model of physics?
- Perhaps the "real universe" and physical laws are very different. We just see the "low energy behavior".
  - Planck Length 10^{-35}m, Planck mass 10^{-5}g. Space-time continuum at these scales is questionable. Perhaps a lattice?

John Lukacs, NYT 6/17/199[illegible]

PHOENIXVILLE, P[illegible]

"Boondoggle" is a rela tively new Amer can word. Originall a braided leathe lanyard worn b Boy Scouts, in th 1930's it was applied by critics of th New Deal to "useless tasks pe formed by recipients of its doles."

The proposed supercollider in Texas, at $8.4 billion, may be one of the greatest boondoggles of all time. But the main problem concerns something more fundamental than cost.

The supercollider is a 53-mile circular tunnel that would accelerate atomic particles at supersonic speeds, smashing atoms into smaller and smaller bits. Many of its proponents tend to argue, among other things, that science may discover the smallest building block of the universe and that the universe can be explained by a Grand Unified Theory. Both assumptions are outdated.

The reduction of the universe to an essential basic particle was first attempted in the 5th century — theoretically, since he had no microscopes or atom-smashers at his disposal — by Democritus, who gave us the name and theory of the atom, establishing it as the basic unit of matter, a notion that has not changed for more than 2,000 years. Democritus was a materialist: He believed that the human soul itself consists of nothing but atoms. Plato did not believe a word of that.

We shouldn't, either. Consider only that Democritus thought the atom was absolutely indivisible. We know that this is not so: during this century (mostly because of equipment capable of "smashing" atoms) physicists have found that atoms include other, smaller particles.

But what is the essence of some of these particles? Are they — more exactly their tracks and patterns — not produced by the scientists themselves? This suggests a truth that we often ignore: that, just as nature came before man, man came before the science of nature. Thus the history of science — indeed, science itself — cannot be anything but the history of scientists. Especially when it comes to subatomic particles, we cannot speak of "nature" or of "matter" but only of situations that occur during and because of our observations of matter. It is impossible, as Werner Heisenberg proved with his Uncertainty Principle almost 70 years ago, to exclude the observer from what he observes.

Consider the names physicists have given to many of these particles — names that are often nothing but tortuous linguistic inventions. In his book "The End of Physics — the Myth of a Unified Theory," the physicist David Lindley (senior editor of the journal Science) writes that "the quality of nomenclature in particle physics [has sunk] to new lows." Well after physicists discovered the "neutrino" (to be distinguished from the "neutron") we now have "selectrons" and "sneutrinos" and, "worst of all, the whole set of quarks turns into a corresponding set of 'squarks.' Where the addition of an initial S doesn't work, diminutive endings have been resorted to, producing a 'photino' to go with the photon, 'gluinos' for gluons."

It does not take much philosophical knowledge to recognize that we are, after more than 500 years, back in the presence of the medieval superstition of nominalism: the tendency to think that once we give a name to a phenomenon we've "got it." That is the very opposite of realism, which in philosophy, art and, indeed, in all intellectual endeavors began to replace nominalism around the time of the Renaissance.

But the assumption that the universe can be reduced to an original particle has already changed — or, rather, degenerated — into a second assumption, the myth of the Unified Theory. Many physicists are now inclined to believe that even if we cannot find the smallest building block of the universe, we can find a mathematical formula that will explain the entire universe: a Theory of Everything. . . .

Given sufficient money (and, I assume, voltage) the supercollider may or may not "produce" the basic unit of the universe, while it will create more subatomic situations that may be formulated mathematically. But more and more mathematical formulas about subatomic matters consist only of untested and untestable assumptions, all of them theoretical and abstract. The belief that the universe is "written in the language of mathematics" is not only wrong, it is entirely outdated. "What is there exact in mathematics except its own exactitude?" Goethe wrote. He was right, as mathematicians in the 20th century have confirmed.

Near the end of the Middle Ages, a few theologians (the "scientists" of that time) persuaded a king of France to give them permission for an experiment that had been forbidden by the Roman Catholic Church. They were allowed to weigh the soul of a criminal by measuring him both before and after his hanging. As usually happens with academics, they came up with a definite result: the soul weighed about an ounce and a half.

We laugh at such things, of course. But remember how much suffering such coarse and foolish ideas about the soul produced in the wars of religion during the transition from the Middle Ages to the Modern Age — not to speak of the fact that the soul-weighing experiment was somewhat less costly than the supercollider.

We ought at least to consider the possibility that 100 or 200 years hence people may laugh at the pretensions of some of our scientists, as well as at our gullibility at the end of the 20th century.

We live at the end of a century, and probably at the end of an age, when the time has come to rethink not only some of the technical applications but the very meaning of "progress." To oppose the supercollider is by no means a reactionary position. To believe that the U.S. must not commit itself to such a financial and scientific boondoggle is a step forward, not backward.

My argument is not simply that it is not given to humans to explain everything, including the universe. When human beings recognize that they cannot create everything and cannot see everything and cannot define everything, such limitations do not impoverish but enrich the human mind. They mark the evolution of our consciousness.

Nearly 50 years ago, the French Catholic writer Georges Bernanos said that the atom bomb was "a triumph of technique over reason." Fifty years after us, rats may scurry through the 50 miles of tunnels under Texas hardpan and a few tourists may gape at the remnants of the supercollider, at the ruins of a monument to unreason. □

A Brief History of the Multiverse - by Paul Davies (New York Times 04/12/2003)

Imagine you can play God and fiddle with the settings of the great cosmic machine. Turn this knob and make electrons a bit heavier; twiddle that one and make gravitation a trifle weaker. What would be the effect? The universe would look very different --so different, in fact, that there wouldn't be anyone around to see the result, because the existence of life depends rather critically on the actual settings that Mother Nature selected.

Scientists have long puzzled over this rather contrived state of affairs. Why is nature so ingeniously, one might even say suspiciously, friendly to life? What do the laws of physics care about life and consciousness that they should conspire to make a hospitable universe? It's almost as if a Grand Designer had it all figured out.

The fashionable scientific response to this cosmic conundrum is to invoke the so-called multiverse theory. The idea here is that what we have hitherto been calling ''the universe'' is nothing of the sort. It is but a small component within a vast assemblage of other universes that together make up a ''multiverse.''

It is but a small extra step to conjecture that each universe comes with its own knob settings. They could be random, as if the endless succession of universes is the product of the proverbial monkey at a typewriter. Almost all universes are incompatible with life, and so go unseen and unlamented. Only in that handful where, by chance, the settings are just right will life emerge; then beings such as ourselves will marvel at how propitiously fine-tuned their universe is.
But we would be wrong to attribute this suitability to design. It is entirely the result of self-selection: we simply could not exist in biologically hostile universes, no matter how many there were.

This idea of multiple universes, or multiple realities, has been around in philosophical circles for centuries. The scientific justification for it, however, is new. One argument stems from the ''big bang'' theory: according to the standard model, shortly after the universe exploded into existence about 14 billion years ago, it suddenly jumped in size by an enormous factor. This ''inflation'' can best be understood by imagining that the observable universe is, relatively speaking, a tiny blob of space buried deep within a vast labyrinth of interconnected cosmic regions. Under this theory, if you took a God's-eye view of the multiverse, you would see big bangs aplenty generating a tangled melee of universes enveloped in a superstructure of frenetically inflating space. Though individual universes may live and die, the multiverse is forever.

Some scientists now suspect that many traditional laws of physics might in fact be merely local bylaws, restricted to limited regions of space. Many physicists now think that there are more than three spatial dimensions, for example, since certain theories of subatomic matter are neater in 9 or 10 dimensions. So maybe three is a lucky number that just happened by accident in our cosmic neighborhood -- other universes may have five or seven dimensions. Life would probably be impossible with more (or less) than three dimensions to work with, so our seeing three is then no surprise. Similar arguments apply to other supposedly fixed properties of the cosmos, such as the strengths of the fundamental forces or the masses of the various subatomic particles. Perhaps these parameters were all fluke products of cosmic luck, and our exquisitely friendly ''universe'' is but a minute oasis of fecundity amid a sterile space-time desert.

How seriously can we take this explanation for the friendliness of nature? Not very, I think. For a start, how is the existence of the other universes to be tested? To be sure, all cosmologists accept that there are some regions of the universe that lie beyond the reach of our telescopes, but somewhere on the slippery slope between that and the idea that there are an infinite number of universes, credibility reaches a limit. As one slips down that slope, more and more must be accepted on faith, and less and less is open to scientific verification.

Extreme multiverse explanations are therefore reminiscent of theological discussions. Indeed, invoking an infinity of unseen universes to explain the unusual features of the one we do see is just as ad hoc as invoking an unseen Creator. The multiverse theory may be dressed up in scientific language, but in essence it requires the same leap of faith.

At the same time, the multiverse theory also explains too much. Appealing to everything in general to explain something in particular is really no explanation at all. To a scientist, it is just as unsatisfying as simply declaring, ''God made it that way!''

Problems also crop up in the small print. Among the myriad universes similar to ours will be some in which technological civilizations advance to the point of being able to simulate consciousness. Eventually, entire virtual worlds will be created inside computers, their conscious inhabitants unaware that they are the simulated products of somebody else's technology. For every original world, there will be a stupendous number of available virtual worlds -- some of which would even include machines simulating virtual worlds of their own, and so on ad infinitum.

Taking the multiverse theory at face value, therefore, means accepting that virtual worlds are more numerous than ''real'' ones. There is no reason to expect our world -- the one in which you are reading this right now -- to be real as opposed to a simulation. And the simulated inhabitants of a virtual world stand in the same relationship to the simulating system as human beings stand in relation to the traditional Creator.

Far from doing away with a transcendent Creator, the multiverse theory actually injects that very concept at almost every level of its logical structure. Gods and worlds, creators and creatures, lie embedded in each other, forming an infinite regress in unbounded space.
This reductio ad absurdum of the multiverse theory reveals what a very slippery slope it is indeed. Since Copernicus, our view of the universe has enlarged by a factor of a billion billion.
The cosmic vista stretches one hundred billion trillion miles in all directions -- that's a 1 with 23 zeros. Now we are being urged to accept that even this vast region is just a minuscule fragment of the whole.

But caution is strongly advised. The history of science rarely repeats itself. Maybe there is some restricted form of multiverse, but if the concept is pushed too far, then the rationally ordered (and apparently real) world we perceive gets gobbled up in an infinitely complex charade, with the truth lying forever beyond our ken.

Is the Universe a Simulation?

NYT Edward Frenkel Feb 14, 2014

…..It seems spooky to suggest that mathematical entities actually exist in and of themselves. But if math is only a product of the human imagination, how do we all end up agreeing on exactly the same math? Some might argue that mathematical entities are like chess pieces, elaborate fictions in a game invented by humans. But unlike chess, mathematics is indispensable to scientific theories describing our universe. And yet there are many mathematical concepts — from esoteric numerical systems to infinite-dimensional spaces — that we don't currently find in the world around us. In what sense do they exist?

Many mathematicians, when pressed, admit to being Platonists. The great logician Kurt Gödel argued that mathematical concepts and ideas "form an objective reality of their own, which we cannot create or change, but only perceive and describe." But if this is true, how do humans manage to access this hidden reality?

We don't know. But one fanciful possibility is that we live in a computer simulation based on the laws of mathematics — not in what we commonly take to be the real world. According to this theory, some highly advanced computer programmer of the future has devised this simulation, and we are unknowingly part of it. Thus when we discover a mathematical truth, we are simply discovering aspects of the code that the programmer used.

This may strike you as very unlikely. But the Oxford philosopher Nick Bostrom has argued that we are more likely to be in such a simulation than not. If such simulations are possible in theory, he reasons, then eventually humans will create them — presumably many of them. If this is so, in time there will be many more simulated worlds than nonsimulated ones. Statistically speaking, therefore, we are more likely to be living in a simulated world than the real one.

Very clever. But is there any way to empirically test this hypothesis?

Indeed, there may be. In a recent paper, " Constraints on the Universe as a Numerical Simulation," the physicists Beane,Davoudi and Savage outline a possible method for detecting that our world is actually a computer simulation. Physicists have been creating their own computer simulations of the forces of nature for years — on a tiny scale, the size of an atomic nucleus. They use a three-dimensional grid to model a little chunk of the universe; then they run the program to see what happens. This way, they have been able to simulate the motion and collisions of elementary particles.

But these computer simulations, Professor Beane and his colleagues observe, generate slight but distinctive anomalies — certain kinds of asymmetries. Might we be able to detect these same distinctive anomalies in the actual universe, they wondered? In their paper, they suggest that a closer look at cosmic rays, those high-energy particles coming to Earth's atmosphere from outside the solar system, may reveal similar asymmetries. If so, this would indicate that we might — just might — ourselves be in someone else's computer simulation.

Kuhn's Postscript

Compared with the notion of progress most prevalent among both philosophers of science and laymen, however, this position lacks an essential element. A scientific theory is usually felt to be better than its predecessors not only in the sense that it is a better instrument for discovering and solving puzzles but also because it is somehow a better representation of what nature is really like. One often hears that successive theories grow ever closer to, or approximate more and more closely to, the truth. Apparently generalizations like that refer not to the puzzle-solutions and the concrete predictions derived from a theory but rather to its ontology, to the match, that is, between the entities with which the theory populates nature and what is "really there."

Perhaps there is some other way of salvaging the notion of 'truth' for application to whole theories, but this one will not do. There is, I think, no theory-independent way to reconstruct phrases like 'really there'; the notion of a match between the ontology of a theory and its "real" counterpart in nature now seems to me illusive in principle. Besides, as a historian, I am impressed with the implausability of the view. I do not doubt, for example, that Newton's mechanics improves on Aristotle's and that Einstein's improves on Newton's as instruments for puzzle-solving. But I can see in their succession no coherent direction of ontological development. On the contrary, in some important respects, though by no means in all, Einstein's general theory of relativity is closer to Aristotle's than either of them is to Newton's.