

Theories of everything?

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

Exam Wednesday, May 8, 1:30-4:30, here

Open book, open note, open internet

Electronic submission encouraged,. You need to bring your own laptop. But blue books available if you do not want to use a laptop.

4 essay questions.

419 Term papers due on Thursday, May 3.

Late papers not accepted.

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%)

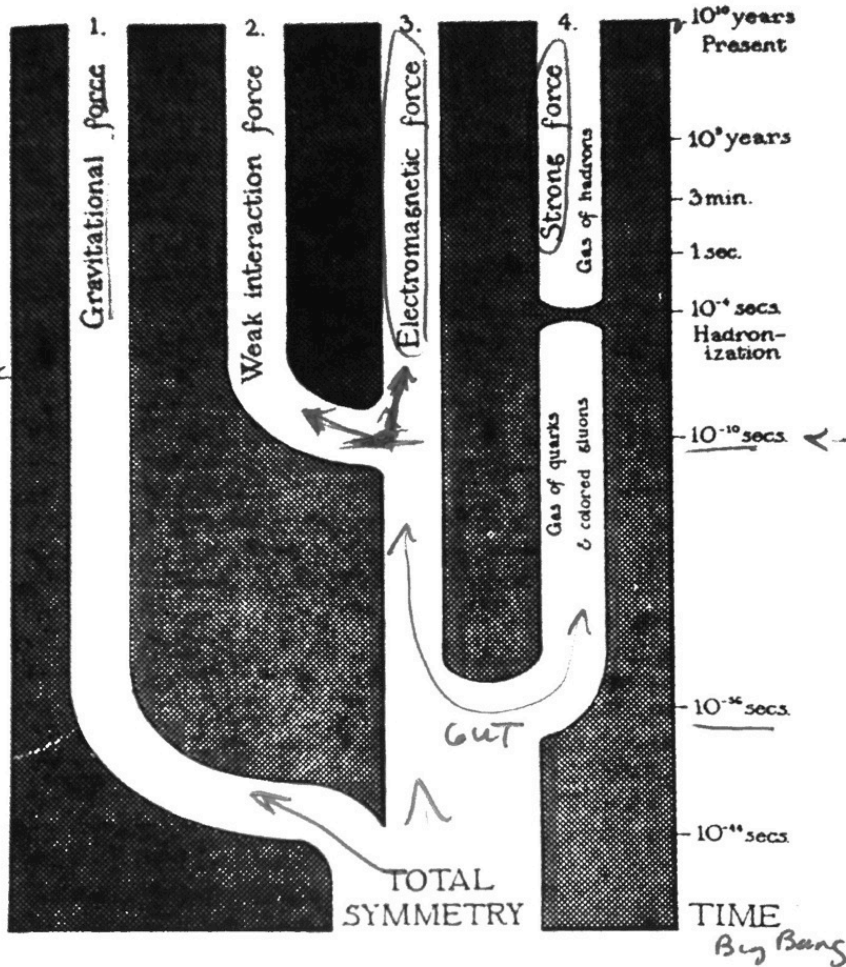
BUT

- 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.

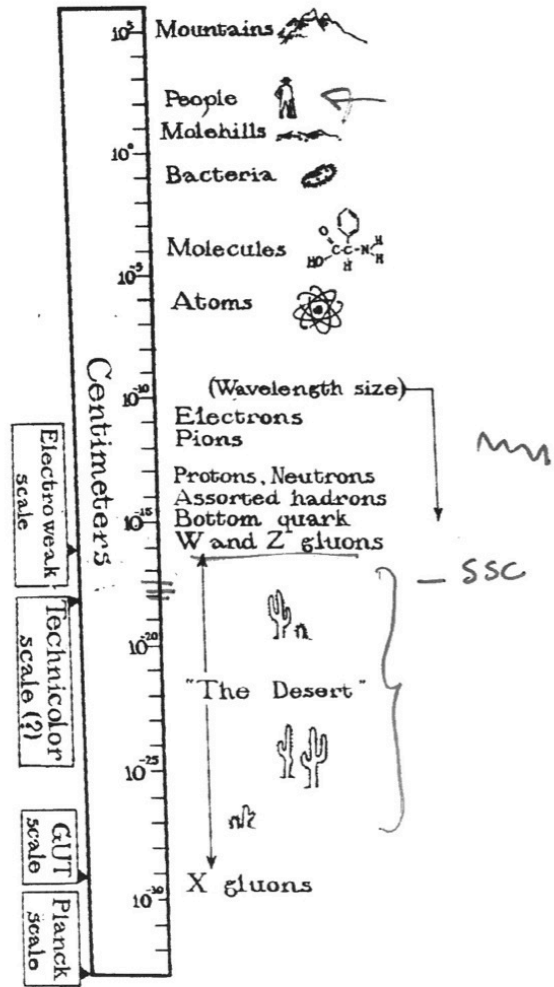
	Fermions			Bosons	
Quarks	u up	c charm	t top	γ photon	Force carriers
	d down	s strange	b bottom	Z Z boson	
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
	e electron	μ muon	τ tau	g gluon	
				Higgs boson	

Source: AAAS

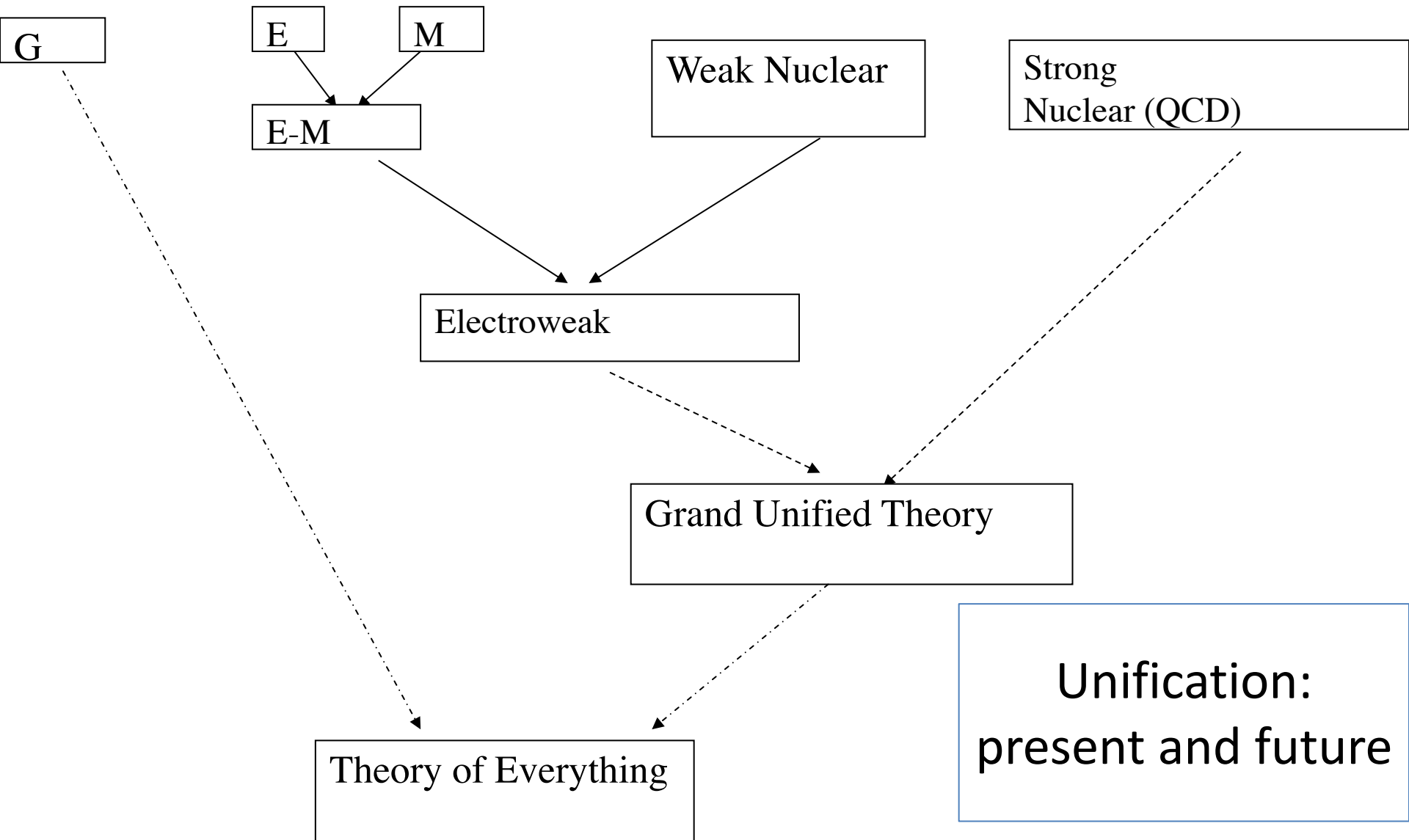
FOUR FUNDAMENTAL INTERACTIONS




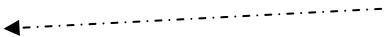
The evolution of the universe as a succession of broken symmetries. If the ideas of modern field theory are right and broken symmetries are restored at high temperature, then at the very earliest times the four known forces of nature, now seen as distinct, were unified.



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.

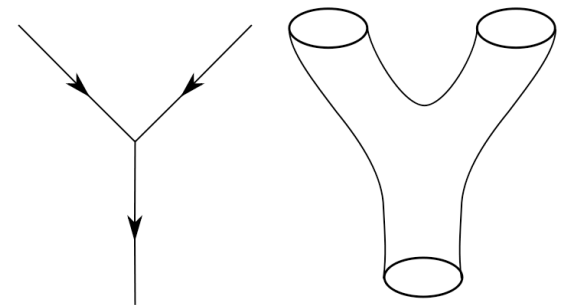
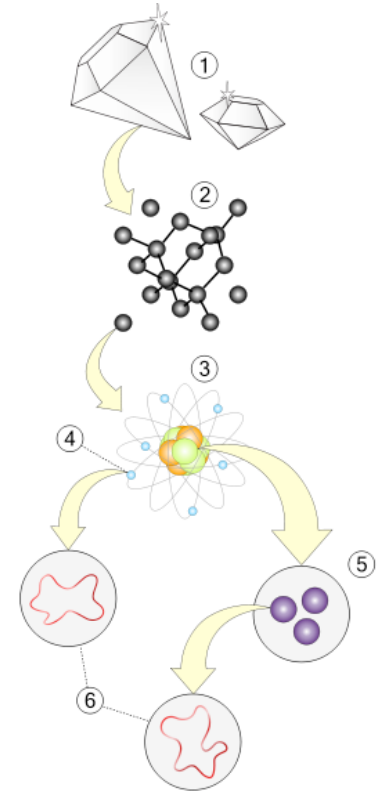


Not yet established 

Very hypothetical 

String Theory

- Generalization of quantum field theory. Hot topic of last 20 years
- Objects are not “points” but “Loops”
- Particles are “vibrations” of the loops like tones on a guitar string.
- One of the modes is a graviton that causes gravity
- Open strings are photons.
- Space time is in 10 dimensions. What happened to the other 4? Compactified so we cannot see them now.
- Latest version is M-theory in 11 dimensions. Can contain “branes”: (membranes): generalizations of strings to higher dimensions.
- **More complicated, so fewer results**



- **Successes (all disputed)**
 - Combines quantum mechanics and gravity
 - Can predict black hole properties
 - Why the universe is matter and not antimatter
 - What the dark matter is
 - Why quarks and leptons come in three similar families
 - Cosmological history of inflation, flat space-time
- **Problems**
 - Too many possible theories (10^{500} theories) One can get many physical laws. Each describes a different universe
 - Little or no experimental confirmation, energies too high (10^{14} times LHC@CERN), lengths too small.
 - Have not yet explained “standard model” details, too complicated, too many theories

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 an electron (0.511 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." Leibnitz, "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

Feynman's viewpoint

The Character of Physical Law

“Some people have used the inconsistency of all the principles to say that there is only one possible consistent world, that if we put all the principles together, and calculate very exactly we shall not only be able to deduce the principles, but we shall also discover that these are the only principles that could possibly exist if the thing is still to remain consistent. That seems to me a big order. I believe that sounds like wagging the dog by the tail. I believe that it has to be given that certain things exist—not all the 50-odd particles, but a few little things like electrons, etc.—and then with all the principles the great complexities that come out are probably a definite consequence. I do not think that you can get the whole thing from arguments about consistencies.”

Reductionism vs Emergence

- Reductionism: the universe is just the sum of its parts
- Emergence: complex systems can have simple behaviors that are almost independent of the underlying laws.
 - Hydrodynamic behavior of liquids & thermodynamics just rely on conservation laws.
 - Theory of critical phenomena shows universal properties of systems at phase transitions.
 - Why are planetary orbits nearly circles? Feynman
- 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 there is a lattice? Problem is that there is no successful theory.

Why is the universe comprehensible? Is it?

What breathes fire into the equations? Why is there something rather than nothing?

- There is a complete unified theory which we will discover if we are smart enough. (but will we ever be sure if we are right? Experiment can never prove anything but only make a predictive theory plausible. It can disprove theories.)
- There is not an ultimate theory, just an indefinite sequence of more and more accurate theories.
- There is no theory; some events cannot be predicted beyond a certain extent.
- What about Descartes' great deceiver?
- Why is physics related to mathematics?

Feynman :The Character of Physical Law

What of the future of this adventure? What will happen ultimately? We are going along guessing the laws; how many laws are we going to have to guess? I do not know. Some of my colleagues say that this fundamental aspect of our science will go on; but I think there will certainly not be perpetual novelty, say for a thousand years. This thing cannot keep on going so that we are always going to discover more and more new laws. If we do, it will become boring that there are so many levels one underneath the other. It seems to me that what can happen in the future is either that all the laws become known – that is, if you had enough laws you could compute consequences and they would always agree with experiment, which would be the end of the line – or it may happen that the experiments get harder and harder to make, more and more expensive, so you get 99.9 per cent of the phenomena, but there is always some phenomenon which has just been discovered, which is very hard to measure, and which disagrees; and as soon as you have the explanation of that one there is always another one, and it gets slower and slower and more and more uninteresting. That is another way it may end. But I think it has to end in one way or another.

We are very lucky to live in an age in which we are still making discoveries. It is like the discovery of America – you only discover it once. The age in which we live is the age in which we are discovering the fundamental laws of nature, and that day will never come again. It is very exciting, it is marvellous, but this excitement will have to go. Of course in the future there will be other interests. There will be the interest of the connection of one level of phenomena to another – phenomena in biology and so on, or, if you are talking about explanations, and that is what I think there

John Lukacs, NYT 6/17/199:

PHOENIXVILLE, Pa. — "Boondoggle" is a relatively new American word. Originally a braided leather lanyard worn by Boy Scouts, in the 1930's it was applied by critics of the New Deal to "useless tasks performed 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.

Multiverse

If the universe we see around us is the only one there is, the vacuum energy is a unique constant of nature, and we are faced with the problem of explaining it. If, on the other hand, we live in a multiverse, the vacuum energy could be completely different in different regions, and an explanation suggests itself immediately: in regions where the vacuum energy is much larger, conditions are inhospitable to the existence of life. There is therefore a selection effect, and we should predict a small value of the vacuum energy. ...

We can't (as far as we know) observe other parts of the multiverse directly. But their existence has a dramatic effect on how we account for the data in the part of the multiverse we do observe. It's in that sense that the success or failure of the idea is ultimately empirical: its virtue is not that it's a neat idea or fulfills some nebulous principle of reasoning, it's that it helps us account for the data. Even if we will never visit those other universes.

Science is ... about explaining the world we see, developing models that fit the data. But fitting models to data is a complex and multifaceted process, involving a give-and-take between theory and experiment, as well as the gradual development of theoretical understanding... In complicated situations, ... mottos like "theories should be falsifiable" are no substitute for careful thinking about how science works. Fortunately, science marches on, largely heedless of amateur philosophizing. If string theory and multiverse theories help us understand the world, they will grow in acceptance. If they prove ultimately too nebulous, or better theories come along, they will be discarded. The process might be messy, but nature is the ultimate guide.

[Sean Carroll](http://SeanCarroll.com) edge.com

A pervasive idea in fundamental physics and cosmology that should be retired: the notion that we live in a multiverse in which the laws of physics and the properties of the cosmos vary randomly from one patch of space to another. According to this view, the laws and properties within our observable universe cannot be explained or predicted because they are set by chance. Different regions of space too distant to ever be observed have different laws and properties, according to this picture. Over the entire multiverse, there are infinitely many distinct patches. Among these patches, in the words of Alan Guth, "anything that can happen will happen—and it will happen infinitely many times".

“Theory of Anything” Any observation or combination of observations is consistent with a Theory of Anything. No observation or combination of observations can disprove it. Proponents seem to revel in the fact that the Theory cannot be falsified. The rest of the scientific community should be up in arms since an **unfalsifiable** idea lies beyond the bounds of normal science. Yet, except for a few voices, there has been surprising complacency and, in some cases, grudging acceptance of a Theory of Anything as a logical possibility. The scientific journals are full of papers treating the Theory of Anything seriously. What is going on?

Paul Steinhardt, *"Theories of Anything"* edge.com'

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.