A Brief History of Everything.

"Knowledge is hot water on wool. It shrinks time and space."
Mark Z. Danielewski

What are the fundamental building blocks of all matter? How do objects behave at the microscopic level? How can something resemble both a particle *and* a wave? How can something be both dead *and* alive? What can we say to deliver at least a little bit of peace to those facing death? How do we capture moments of beauty, and how do we accept that they are fleeting- *mono no aware,* the awareness of impermanence? What makes the flowers beautiful? What is it about purple and gold, asters and goldenrods?

Is there a single answer, a single phrase, a single formula that could not only unify all these questions, but answer them? As far as we know, no, but how do we know? If such a thing does not currently exist, could it?

Yes, and no.

A theory of everything, or a unified field theory, is a singular, comprehensive, theoretical framework that explains all aspects of the universe. If such a theory exists, it remains undiscovered. That said, the quest for a theory of everything is not new. Ancient cultures sought unified explanations, entire schools of thought and philosophies were devoted to the question; humans have always wanted to *know*. When you strip away scientific language associated with a theory of everything, like "unified field theory" or "theoretical framework," the search for a theory of everything reveals both our innate curiosity about the world, and our belief, or perhaps our hope, that a single principle can encompass and explain everything.

In the modern, scientific world, a potential theory of everything entails concrete terms. While the science itself may be beyond our scope of understanding, the comfort afforded by numbers and mathematical operations may provide a clearer idea of what a theory of everything could be. In physics, a theory of everything must unify the four universal forces: electromagnetism, the strong nuclear force, the weak nuclear force, and gravity. The search for a theory of everything drove much of Albert Einstein's work in the 1930s and 40s, and while this isolated him from mainstream physics at the time, it is currently a central question of physics- arguably *the* central question. And as we'll soon explore, the relatively recent development of string theory has exciting implications for the future of physics and the search for a unified theory.

But returning to our broader discussion of a theory of everything, it is still unclear what a single theory would accomplish, or what we want it to accomplish. The latter transforms what should be the most objective idea into one that is subjective. Different people want to know different things. Everyone has a different threshold for satisfaction, the point in which they stop asking, "why?", though many of us would continue to ask why for the rest of our lives if we could. All this is to say, a theory of everything, at least in the general sense, says as much about us as it does about the subjects it intends to explain- as if we could even separate the two in the first place.

The questions of science, art, religion, philosophy, mathematics, literature, politics, economics, medicine, epistemology, psychology, anatomy, astronomy, astrology, cosmology, cosmetology, physiology, paleontology, anthropology, chronology, and so on, etc., etc., etc., are interlinked. Academia enforces structures and categories for obvious, organizational reasons, but so much can be gained by looking at what resides in the spaces in-between.

To seek, to wonder, to question is our nature; metacognition defines our species. Sometimes, we seek to know, but from the day we are born, we know to seek. Sometimes, all it takes is a single question: where do I start?

Above is a dot. If you were to enlarge it and hollow out its insides, you would have an outline of a circle, something that resembles an 'O.' Pinch the sides ever so slightly, and you'd have a 0. Whatever you want to call it, however you want to see it, above is a Start.

Rotate the line 90°. What now?

1.

What is the smallest particle you can think of?

Maybe it's been five, ten, twenty plus years since you last sat in a chemistry classroom, and your knee-jerk response was "an atom," which you may have followed with, "no, wait, an atom's made up of smaller things, protons, electrons, neutrons…electrons are the smallest, right? Then sure, an electron is the smallest particle I can think of." Or maybe you took it a step further, and recalled that subatomic particles are composed of even smaller particles called quarks, leptons, and bosons.

Whatever it was you named or imagined, its visual representation, the image that flashed in your mind, may have resembled a microscopic rendering of the dot that appears at the top of the page. Or, conversely, if you were to enlarge the image in your mind's eye, it may resemble the dot that appears at the top of the page. Perhaps your image resembles something *more* detailed than the dot, like a sphere, a tiny sphere, stationary? Rotating?

Now, before you grow too attached to this sphere of yours and claim it as the tried and true smallest particle in the universe, blink. Wipe your mind's eye clean. Then, reimagine a potential smallest particle, but this time, one that resembles not the dot above but the line that appears slightly farther down the page. Got it? Great. Get acquainted.

Pick it up. What does it feel like? How heavy is it? For the time being, forget that we're dealing with the smallest particle in the universe. Better yet, imagine that the object in your hand is a highly enlarged version of that particle, large enough that our senses can interact with it. *Now* what does it feel like? How heavy is it? What material is it made of? What color is it?

Could it be an ant's jump rope? A piece of hair? Bread bag twist tie?

As you glance down at it, something peculiar happens: it grows taught, as if being pulled on either side by millions of invisible, tiny hands, and it starts to buzz, like a guitar string directly after being plucked. Believing you have in your possession something of great value, you clasp your hand around it and turn on your heel to find the nearest person and tell them, "you won't believe this," and you unfurl your fist only to reveal an empty palm. Sorry, it had to return to its true size, but wasn't that fun while it lasted?

This dreamlike sequence of events is a reenactment of the fundamental principles of string theory. A theatrical, silly reenactment, sure, but sometimes that's the best way to make sense of a phrase such as this: a theoretical framework in which the point-like particles of particle physics are replaced by 1-dimensional objects called strings. Brian Greene, a leading string theorist, offers a slightly more whimsical take on this, describing elementary particles according to string theory as "tiny, 1-dimensional filaments somewhat like infinitely thin rubber bands, vibrating to and fro."

If vibrating, microscopic strings aren't odd enough, consider the following: according to string theory, there are 10 dimensions: 9 spatial, 1 temporal. 10 may seem so arbitrary a number- why not 11? 12? 100?

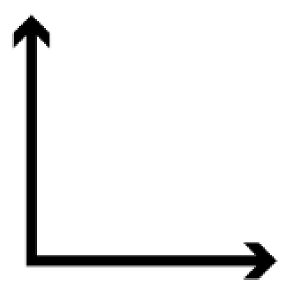
The reason that string theory requires 10 dimensions exactly is not arbitrary, is a matter of pure mathematics, but for our purposes, it's enough to simply accept that a universe governed by string theory not only has 10 dimensions but *requires* the existence of 10 dimensions. Learning about string theory means repeatedly asking the question *why?* Learning about string theory and maintaining your sanity means knowing when it's time to stop asking *why*.

Still, the existence of 10 dimensions sparks some exciting, relevant questions. In this context, 'dimension' refers to a measurable extent of some kind (length, height, width, etc.). We're familiar with dimensions when it comes to buying and assembling furniture, and the dimensions we're talking about when we talk about string theory aren't all that much more complicated.

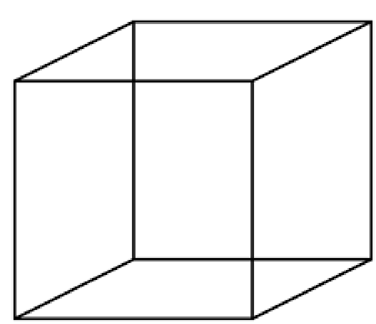
So far, we've already familiarized ourselves with two of these 10 dimensions:

- The 0th dimension: a dot- no length, no width, no height. Nothing.
- The 1st dimension: a line (or a string)- only width. Or, only length. Or, if you turn your head to the side, only height. Whatever direction of motion you like, there can be only one.

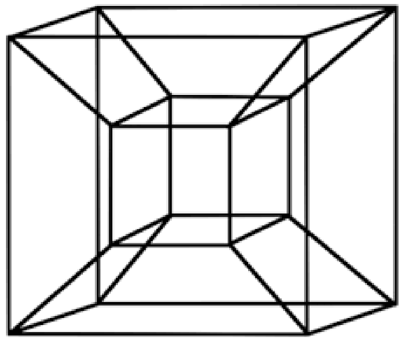
You can imagine a line as a large collection of dots, in effect multiplying the 0th dimension by itself to produce the 1st dimension. By extension, you can multiply the first dimension by itself- a straight line by a straight line- and the result is two straight lines, perpendicular to one another, length and height, or length and width, or even height and width, if that's how you'd like to see it; an x and y graph.



Enter the third dimension, and you now have width, depth, and height. Or, to make it more clear, you now have a box, which may or may not have a dead cat inside. You're free to move around- *congrats!*



The fourth dimension is where things get weird. The fourth dimension is the time dimension, which can be visually represented by the tesseract, a 4D cube:



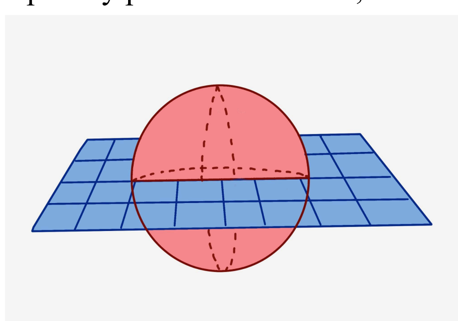
Visual representations, as you can tell by the complexity of the tesseract, become more and more difficult to decipher beyond the third dimension. Since we ourselves are 3D beings, our ability to comprehend shapes intuitively ends with the 3D cube.

A different way to think about higher dimensions is to imagine yourself not as a *3D being* but a *2D being*, consisting only of length and width. Because you are 2D, so is your world. WIn our 2D world, we live on a piece of paper (and, since we're already heavily relying on hypotheticals, let's ignore the height of this piece of paper so that it really is 2-dimensional).

But this world is only 2D to the extent that we *believe* it is. In our everyday lives- departing briefly from the thought experiment we understand- we understand our world as 3D because that is what we can observe. What we consider the *true* number of dimensions- 3- is the number of observable dimensions: length, width, height. Higher dimensions may exist all around us without our knowing, manifesting themselves in sneaky ways.

Returning to the 2D world of our thought experiment, imagine that all objects, regardless of how many dimensions they possess, are able to pass through one another seamlessly. Now, picture a ball, we'll say a red ball, as it passes through a sheet of paper, a heightless sheet of paper, that is- a 3D object passing through a 2D object.

As 3D beings, we can hopefully picture this. If not, here's an image:



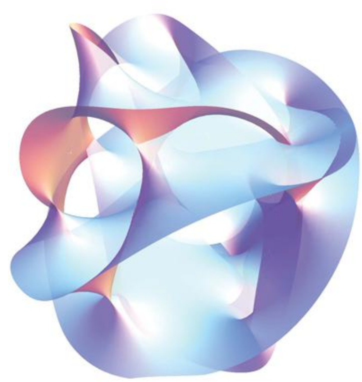
But as 2D beings, how would this look? You can imagine it unfolding as follows: a small red dot, a point, appears like a star in your sky, which of course looks nothing like the sky we're familiar with, as there is no up or down in a 2D world.

Alarming enough as is, this “star” starts to expand. To your horror, it transforms itself into a growing circle, and you rush along the two axes of motion you have access to to tell your family you love them, for you figure this is surely end times. But then, something strange happens. The circle starts to shrink. It exits the way it entered- seamlessly, quietly, no more than a red point in its final stages.

As 2D beings, we cannot see the sphere, only a 2-dimensional “slice” of it- a circle. As it moves through our world, the only indication of its movement is the expansion and contraction of a circle. The circle is largest in the instant that the widest band of the sphere, its ‘equator,’ intersects our 2D plane. The circle is smallest when the spheres ‘poles’ intersect with our 2D plane.

What we can picture so intuitively- a sphere passing through a piece of paper, or, in even more practical terms, a thumb-tack puncturing a flier to hang it on a cork board- looks radically different in fewer dimensions. We take for granted what we can see, touch, taste, smell, hear, and don’t often consider what we cannot. We let light and shadow inform our knowledge of the shape of an object. We let volume and clarity inform our knowledge of how far a sound has traveled.

All this is to say that you don’t always understand it when you’re in it. A beetle crawling on a forest floor can’t see the whole forest; she can’t even see the tops of the trees.



(Calabi-Yau Manifold, or, a 2D rendering of an 10D shape)

String theory is developing and gaining legitimacy in the physics world as a potential bridge between quantum mechanics and general relativity. The notion that the elementary constituents of the universe are not point-like particles as previously accepted, but rather strings, emerged in the late 1960s. In 1968, young theoretical physicist Gabriele Veneziano found himself unable to make sense of the strong nuclear force. Veneziano, then a research fellow at CERN who had been working on this problem for several years, one day came upon a stunning discovery: the Euler beta-function, a formula derived for mathematical pursuits 200 years prior, seemed to describe the properties of the particles he was working with.

This led to his realization that if elementary particles are modeled as tiny, 1-dimensional, vibrating strings, the Euler beta-function could describe exactly the very nuclear interactions that had troubled Veneziano for years. Although his observations on Euler's function were incomplete- as Greene puts it, "it was a formula in search of an explanation"- they created the blueprint for string theory as it exists today. And although string theory is a relatively new theory that must grapple with the unique challenge of requiring 10 dimensions, it has exciting, potentially revolutionary implications: it is a potential theory of everything.

Early in his career, Einstein set out to discover what he called a "unified field theory," or, a theory of everything. In Einstein's time, this meant showing how two of the universal forces he discovered- gravity and electromagnetism- were manifestations of the same, unifying principle. While he did not realize this dream in his lifetime, more than half a century later, physicists are bent on this search. Ideally, this unified theory would explain how not only gravity and electromagnetism are connected, but how all four fundamental forces of the universe- now including the strong nuclear and the weak nuclear force- are connected under a single principle. And as increasing research is conducted on string theory, physicists are growing more optimistic about its implications.

"For the first time in the history of physics we therefore have a framework with the capacity to explain every fundamental feature upon which the universe is constructed," Greene tells us.

To understand why string theory possesses such a capacity, we have to look at two other branches of physics: quantum mechanics, and Einstein's theory of general relativity. The quantum world deals with the very, very small, while general relativity deals with the very, very large. The microscopic and macroscopic. But how small is small? And how large is large? And in what ways do the fields "deal" with what falls into those categories? We'll start with the former, and try to detangle the entangled mess that is quantum mechanics.

And an entangled mess it is. In 1965, Richard Feynman, renowned pioneer of quantum mechanics, wrote:

> "There was a time when the newspapers said that only twelve men understood the theory of relativity. I do not believe there ever was such a time. There might have been a time when only one man did because he was the only guy who caught on, before he wrote his paper. But after people read the paper a lot of people understood the theory of relativity in one way or another, certainly more than twelve. On the other hand I think I can safely say that nobody understands quantum mechanics."

Granted, this was written about sixty years ago, and considerable strides have been made since due to extensive research and advanced technology. However, a fundamental principle of the idea Feynman raises remains, and that is the fact that quantum mechanics, in its microscopic glory, is nearly impossible to conceptualize in full by the human brain. Just as we conducted the thought experiment of a 3D sphere passing through a 2D plane, scientists must create models and representations to translate the absurdity of quantum mechanics into something they can experiment with. As Brian Greene puts it, "the only thing we know with certainty is that quantum mechanics absolutely and unequivocally shows us that a number of basic concepts essential to our understanding of the familiar everyday world *fail to have any meaning* when our focus narrows to the microscopic realm. As a result, we must significantly modify both our language and our reasoning when attempting to understand and explain the universe on atomic and subatomic levels."

So, modify we do. The particles Greene mentions- atomic and subatomic- are the "very, very small" constituents of quantum mechanics. *Atomic particles* are, well, atoms of a given element (hydrogen, oxygen, nitrogen). *Subatomic particles,* then, are what make up an atom. Protons (positively charged particles) and neutrons (neutrally charged particles) make up the center- *nucleus*- of the atom, while electrons (negatively charged particles) orbit the nucleus.

These subatomic particles can be broken down even further. Protons and neutrons are made of even smaller particles called "quarks" and "leptons." Electrons, on the other hand, are as elementary as you can get, as electrons are themselves a type of lepton. The subatomic particles that fall into the categories of quarks and leptons are called "elementary particles," meaning they cannot be broken down further. Each elementary particle has unique properties including mass, charge, and spin, but these properties are, at least for the time being, beyond the scope of our concern. Instead, we'll turn our attention to one particular elementary particle, our old friend the photon- *light.*

Photons are a major player of quantum mechanics, and we will soon find that their behavior is quite tricky. You may be familiar with the phase "wave-particle duality," or the expanded declaration that light behaves *sometimes like a wave, and sometimes like a particle.* To understand why this is true, or what it even means in practical, concrete terms (as practical and concrete as you can get in the quantum world), we can look at Thomas Young's 1802 double-slit experiment.

The structure of the double-slit experiment is simple enough- a laser shoots a stream of photons through two vertical, parallel slits onto a wall opposite of it. The results, however, are where things get troublesome. To conceptualize the results, we can pretend that the particles are not subatomic, invisible light particles, but macroscopic raisin-sized paint pellets. *Red* paint pellets. And we are poised behind the slit, on one knee, paint-gun in hand, shooting these pellets through two slits onto a white wall, alternating between either slit upon each consecutive shot.

After a tedious hour-long session, your knees numb and wobbly, your forearm cramping, you are told that you can view the results. Shakily, you stand up, remove your goggles, and expect to see two bands of red paint on the white wall corresponding to where the slits are. What you find, instead, perplexes you- not two, but *five* bands of red paint, or varying intensity, staring back at you on the wall.

These results reveal the fundamentals of wave-particle duality. A particle, such as a photon or a paint-pellet, when passed through an opening in one wall, should land on the wall opposite at a single point, a splatter of paint. Thus, shooting paint pellets through two slits for an hour should, assuming your aim is on point and you alternate between either slit, produce two near-identical vertical bands of paint splatter. But the five red bands of varying intensity that you discover when you lift your goggles suggest that the paint pellets were not behaving as you'd expect them to. Rather, they were behaving as a wave.

A wave is a disturbance in a medium that transfers energy, sort of like wind. A wave has peaks and valleys (crests and troughs), and when two waves combine, the distribution of their crests and troughs creates what's known as an interference pattern. If the crest of one wave meets the crest of another, their amplitudes (heights) are combined- *constructive interference.* Likewise, if the crest of one wave meets the trough of another wave, their amplitudes cancel out (assuming, for simplicity, that the waves are of equal frequency and amplitude)- *destructive interference.* When a wave is passed through two slits, it splits into two waves of equal amplitude and frequency that intersect on the other side. This creates the interference pattern on the wall in which the brightest bands represent where the crests meet, and the blank spaces in between represent where the troughs meet.

If the results of the paint-pellet experiment reveal an interference-pattern that is only produced by waves, then it follows that the paint pellets were not behaving as particles, but as a wave. Perhaps it's easy to transfer pellets of paint into a wave of paint, but with light particles, it may not be as easy. It's also important to remember that a wave, unlike a particle, is *not* matter. Intuitively, and in our everyday lives, a wave is moving water. In physics, a wave is the movement *through* water.

It's puzzling, and a bit troubling to conceptualize photons within this duality. It's even more puzzling when we factor in the observer effect. The observer effect is the necessary disturbance of a system by observing it. In figurative terms, it's easy to imagine how, say, observing someone perform a task might change how they would go about it- when you make dinner alone, you steal a pinch of your roommate's cheese; when she's in the kitchen, you opt for no cheese that night. But when it comes to photons, which, as far as we know, don't possess human consciousness or follow social codes (but being as weird as they are, I wouldn't be surprised if they did), observing an experiment should not affect their behavior.

And yet, it does. And not in esoteric, wishy-washy, theoretical ways. When unobserved, photons passing through two slits create an interference pattern, meaning they act as waves. However, dare so much as glance at their movement through the two slits and you'll find that they form two, neat bands on the wall. When observed, photons, and other elementary particles like electrons, behave as particles.

The takeaway of all this is not to understand in any comprehensive way the nature of photons, but to know that their nature is beyond bizarre, and mirrors nothing that we interact with on a macroscopic level. This is why quantum physics is so mind-boggling, and so captivating.

Take our friend Schrödinger, for example. More specifically, take his cat, and put him in one of the two boxes placed before you. One of the two boxes is filled with a sleeping agent, the other is not (in the traditional thought experiment, the sleeping agent is actually cat poison, but I didn't want to place you in an uncomfortable situation). You have no idea which one. While the cat is in the box, is he sleeping, or awake? He must only be one, right?

Given every other thought experiment previously laid out and the promise that quantum physics will subvert expectations and thwart intuition, I'm sure you can guess where this is going: no, of course the cat is not asleep *or* awake, he's asleep *and* awake!

As a thought experiment, this dialectical framework in which two opposing realities exist simultaneously might be a fun exercise in philosophy, but in terms of physics, it's the reality of the quantum realm. If at any point you were interested in looking deeper into elementary particles, you may have discovered that one of their properties is "spin." We can imagine spin as exactly what it sounds like- a particle spinning, or rotating on an axis, like a globe. And for our purposes, spin has two possible values: up, or down. A particle can have up-spin, or down-spin.

Now that we have spin established, albeit rudimentarily, let's introduce entanglement. Entanglement, like spin, can mean exactly what you think it means. Two electrons meet, they perform some ritual unbeknownst to the macroscopic world, and they become entangled. Part of their entanglement contract is that one must only spin up, and one must only spin down. However, so long as we are not observing the electrons and their spin, *both* electrons have both up-spin and down-spin, simultaneously, all the time.

This is known as "superposition"- it really does help that a lot of these words mean what you think they'd mean- and it's what renders Shrödinger's cat asleep and awake simultaneously. It is only when the observer effect comes into play- i.e. when a human interferes with the electrons by observing them- does their spin take either the up or down position. Once one electron's spin is observed, the other entangled electron, no matter how far away it is in the universe, takes an opposite spin. But without any eyes on them, they are both spinning up and down.

Remember, Feynman didn't get it either. The principles of quantum mechanics oppose human intuition and reveal how little of the world we see in our everyday lives. All this stuff about entanglement and superposition and spinning electrons is happening right under our noses at this very moment, but to us, all we see is the quantum equivalent of a red circle in the sky, growing bigger, then growing smaller.

When we zoom out of the quantum realm, zoom out of the life-sized realm, keep zooming out past the planets, maximizing our scope to include entire galaxies, we enter the realm of general relativity. As Feynman says, general relativity is easier to wrap your head around than quantum mechanics. For one, you can directly observe the objects that general relativity deals with. While we cannot conceptualize how truly massive the Sun is or how great the distance is between us and it, we've at least all seen the sun with the naked eye.

General relativity describes gravity in Einsteinian terms, as opposed to Newtonian terms, the accepted framework of Einstein's time. The main concept necessary to understand general relativity is *spacetime,* a mathematical model that combines the first three spatial dimensions and the one time dimension into a single manifold. Space and time, thus, are not separate dimensions, forces, or entities- they are parts of a single object, or substance (I like to imagine spacetime as a jelly-like film).

It also helps to imagine spacetime as a blanket, or a trampoline. If you were to place a bowling ball on a trampoline, it would rest in the center and cause the fabric of the trampoline to droop around it. Now, if you were to drop a marble on the trampoline as well, what would happen? It would travel in a circle around the bowling ball, getting nearer and nearer, until eventually colliding with it. Since the bowling ball is more massive than the marble, it sits at rest in the center of the trampoline and attracts objects of smaller masses, like the marble, effectively pulling them into orbit.

This scenario translates quite smoothly to spacetime and gravity. Replace the trampoline with the elusive 'spacetime,' the bowling ball with the sun, and a marble with Earth. This explains why the sun is the fixed center of our solar system while planets with lower masses, like Earth, orbit around it. This is gravity. Objects of greater masses attract objects of lower masses towards their centers. Conversely, gravity is the warping of spacetime.

The warping of spacetime describes gravitational time dilation. Time dilation broadly refers to the difference in elapsed time as measured by two clocks. *Gravitational* time dilation occurs when the two clocks are situated at varying distances from a gravitating mass. The closer a clock is to the source of gravitation, the slower time moves, and vice versa.

This notion may be a bit difficult to digest. *How can time move slower or faster, and slower or faster than what?* The reason gravitational time dilation exists is precisely because of spacetime. Massive objects do not warp just space, as we'd intuit, but time as well. Gravity has both spatial and temporal elements. As objects near gravitational sources, time stretches out.

Like quantum superposition, time dilation seems more like a theoretical or somewhat figurative representation of phenomena, but really, it's the other way around. We *know* (to the extent that we can know anything) that time dilation is real. The 1959 Pound-Rebka experiment in which gamma rays were emitted from the top of a tower and measured by receivers at the bottom, revealed that the photons of the gamma rays gained energy when traveling towards a gravitational source. These results correspond with a slowing down of time as the photons were nearing Earth. While it is not necessary to understand why exactly this is the case, the Pound-Reka experiment and further experiments show demonstrably that gravitational time dilation is a measurable phenomenon.

The reason why gravitational time dilation seems so strange is because it simply doesn't affect us. Technically, yes, time dilation affects us and everything we are familiar with, but on so small a scale it is negligible. Only when the distance between the clock and the gravitational source is extremely large or the gravitation source is extremely massive is time dilation measurable.

Like quantum mechanics, to understand the concepts of general relativity in full entails a much deeper study and the application of mathematics. What matters is that until recently, the two fields were able to co-exist, as they were concerned with vastly different things. However, there are current problems in modern physics that require an application of both quantum mechanics and general relativity. The Big Bang, for example, entails an instantaneous transition from the most microscopic matter to the most macroscopic matter. Unfortunately, the math previously used to explain quantum mechanics does not neatly transfer to general relativity, and vice versa.

Which is where string theory comes in. By replacing point-like elementary particles with strings, string theory, if true, would unite gravity with the three fundamental forces that quantum mechanics explains- electromagnetism, strong nuclear force, and weak nuclear force. Certain strings possess qualities that match those required by the graviton, a hypothetical, elementary particle that carries the gravitational force.

But let's take a step back for a second. This is a pivotal revelation in physics, but why does this matter to *us?* Those of us who are not physicists, who don't particularly care for strings and point-like particles and cats in boxes, why should we care?

There's no single answer. One answer is that it doesn't matter, or that it doesn't *have to* matter. Another answer is that it's cool. Even if you have no interest in exploring the dense, complicated mathematics of it all, or the murky, minute details of the concepts, it's fun to picture everything around you as a collection of buzzing strings. Why not have a basic, elementary, barely scratching-the-surface understanding of things that interest you?

But beyond the scope of elementary particle physics, quantum mechanics, general relativity, and physics as a whole, there is a larger weight to it all: we attempt in part to understand the natural world- which is to say science- to understand our place in it.

For a brief moment, let us detach from the idea of science as a set of rigid laws enforced upon us by the universe, and try to push beyond. For the time being, let's detour from string theory entirely. Don't worry, it's not going anywhere.

Let's start over.

Where should we go? What might we find there? What makes a beginning a beginning, and what makes a beginning a *good* beginning? Perhaps a place and time in which nothing becomes everything.

The Big Bang describes the very beginning. What we're tempted to think of as the Big Bang if we were to try to visualize it- streaks of light racing one another against a dark, inky, vacuous nothingness; bits of flaming moon rock, the entirety of the universe, all matter, space, time, energy hurtling at near-light speed, trying to break out of a container trying to break out of itself- is really what came *after*. And, if we were to extend what came after as far as we could, past light, fire, the formation of Hydrogen, the formation of Carbon, past Early Hominids, the Indus Valley, irrigation, bartering, trade, the division of labor, the Gold Standard, the Industrial Revolution, the Macintosh prototype, we could have a straight line; a spool of yarn of which we hold the end and run forward, always forward, away from the beginning, hurtling blind and headfirst towards an end that is always one step ahead.

Rewind. Start anew, again. Watch, say, the redwoods of Yosemite shrink back into their youth, watch how they shed millennia of wisdom that have hardened and crystallized into their being, and receive in return their vigor, their curiosity, the beautiful oblivion of childhood, losing rather than gaining rings at every turn of the moon, reacquainting with their roots with the distant but familiar closeness of their infancy. Watch the earth cool down, the oceans fall, watch as massive, blue-white, sheets of ice, jagged and estranged against a dark sea, reunite like pieces of a puzzle, watch as their cracks seal, freeze over, become nonexistent once again.

Entropy, the second Law of Thermodynamics, which promises that everything- living, dead, otherwise, you, me- will move from an ordered state to a disordered state, forbids such a reversal. Entropy, like time, condemns everything to a single direction. Unless external energy is applied to its system, an ice cube, whose H_20 molecules are arranged in a lattice structure, must melt. The potential energy that maintains a solid will, in time, be released by entropy.

Just as an ice cube becomes a puddle, you too will move towards a state of disorder. You cannot revisit your life or your body as it was a year ago, a month ago, a day ago- you must age. Everyone and everything is a victim of entropy. Entropy, and time.

Not only is there a positive correlation between entropy and time, but a stunning entanglement of the two concepts. To understand this entanglement, we must reintroduce the concept of spacetime. Einstein proposed that not only does every object move *through* spacetime, but that it does so at the speed of light (Greene, 50).

Now, hold your horses- this is not to say that everything, including you, is zooming through its environment at light speed and that our tiny 3D pea-brains can't conceptualize this, so we slow it down. Maybe there's some convoluted truth or half-truth to that, but it's a bit too beyond our conceptual understanding, our *linguistic* understanding, to pursue. Rather, what Einstein was proposing was that a body's *total* speed through spacetime was that of light. So why is it that only light travels at the speed of light?

The better question is, why are we so damn slow? Travel back to the 2nd dimension. This time, there's no strange red circle entering our world. Instead, imagine a simple x-and-y axis graph. Label the x-axis "space" and the y-axis "time." Now, imagine an object with a finite amount of units to spend, perhaps a kid at an arcade with however many arcade tokens their parents allotted them that day. But this is the world's lamest arcade, and there are only two games: space, and time.

Now, if this kid, we'll call him Albert, an homage of sorts, were to *only* play the space game or *only* play the time, he'd likely earn a pretty high score, since he'd be devoting all his tokens to one game. However, before his parents dropped him off, they told him, "you have to split your tokens equally between Space and Time, or no arcade for a month." Al's a good kid, and he heeds his parents' warnings with diligence. With equal energy exerted on either game, how would his scores look now?

Apply this arcade scenario to the more abstract reality of spacetime, and you get the essence of Einstein's proposal. As an object moves through space, some of its energy through time must be diverted, and vice versa. The cost of moving through space is moving through time at a slower pace, or, aging.

The only exception to this phenomenon is, as we might expect, light. A photon moves only through space. All of a photon's energy is diverted to space, and none to time. Therefore, **light does not age.** Everyone and everything is a victim of entropy and time, except for light.

"God for all intents and purposes is an equal sign, and at least up until now, something humanity has always been able to believe in is that the universe adds up."

Mark Z. Danielewski

For the vast majority of human history, Earth was at the center of the universe. More specifically, humans were at the center of the universe. For God created us in His image, and His image required that all cosmological matters revolved around us. That way, we could always look up at the Heavens, and, as part of the tradeoff, would always be looked down upon by God.

Ptolemy (c. 100- c. 170 C.E.) was an Alexandrian astronomer and mathematician. He formulated the Ptolemaic system, also known as the geocentric model, which places Earth at the center of the universe (*geo* meaning "Earth," *centric* meaning "centric").

Now, the details of the Ptolemaic model are not hugely important, especially since they were proven wrong in the 16th and 17th centuries by Copernicus, who proposed the heliocentric (*sun-centered*) model of the universe that we're familiar with today. What is important, however, is how the Ptolemaic model marks a shift in the human tradition of science and religion. Although it was an existing fact of life that the universe revolved around Earth, Ptolemy showed through observations and mathematical formulae- albeit tampered with to support the heliocentric model- how he derived his conclusions.

Ptolemy was, unknowingly, sowing the seeds for a movement that would dominate the intellectual and theological spheres of Western culture in the following centuries. The Enlightenment, the Age of Reason, prompted a new way of thinking that infiltrated all areas of society, from political organization, to art, to the Church, to the natural sciences. As much as it was a movement, the Enlightenment was also a philosophy. To be an enlightened individual or an enlightened society was to live not according to blind faith, but to reason and rationality.

This philosophy manifested a number of ways. One such way was how it shaped religion and religious thought at the time. Religion- Western European Christianity, which is to say the Catholic Church- became an organized aspect of public and social life. While the celebration of reason that characterized the Enlightenment arguably gave rise to a more secular society by making science and the pursuit of knowledge out to be worthwhile and valuable, it also, in some ways, solidified and strengthened the presence of religion in public life, as Enlightenment thinkers sought an ontological explanation of religion and of God. At its core, the Enlightenment was based on the premise that as long as proper, extensive experimentation was conducted, all aspects of the universe could be explained through reason.

There's a certain comfort in absolutes, in facts; in the shunning of emotion and romance ('romance' referring to the Latin translation and post-Enlightenment understanding of romance as "subjectivity of approach, freedom of thought and expression, idealization of nature"). While the thought may be a bit cold, it would also be relieving to imagine the human body as a machine, such as a watch, made up of millions of moving parts working together, the brain biologically equivalent to the liver, human emotion a survival mechanism, love a chemical to deceive us into reproduction. This was a trade-off of enlightenment thought: the messier, more amorphous, less convenient aspects of life and love and thought and feeling are replaced with the cold, hard, unfeeling objectivity of empirical data and reason.

And so, with the Enlightenment comes curious, perhaps contradictory developments. What happens when reason only gets us so far, answers only so many questions? Must another path diverge?

"I circled right back to where I had begun, to the question of beauty. Back to the questions that science does not ask, not because they aren't important, but because science as a way of knowing is too narrow for the task," writes Robin Wall Kimmerer on Asters and Goldenrods.

Kimmerer, mother, scientist, professor, and member of Potawatomi Nation, asks questions about science, traditional knowledge, their relationship, and our relationships to them in her book *Braiding Sweetgrass.* She writes often of the Asters and Goldenrod flowers whose beauty have captivated her since birth. The effect of their colors in combination, the ways that the purple and gold flowers dance with each other, is a subject of great curiosity:

> "The human eye is superbly equipped to detect these colors and send a signal pulsing to the brain. This doesn't explain why I perceive them as beautiful…Why are they beautiful together? It is a phenomenon simultaneously material and spiritual, for which we need all wavelengths, for which we need depth perception. When I stare too long at the world with science eyes, I see an afterimage of traditional knowledge. Might science and traditional knowledge be purple and yellow to one another, might they be goldenrod and asters? We see the world more fully when we use both."

In her studies of ecology, Kimmerer forays into the world of higher education and scholarship, a world of facts and empirical evidence, a world upheld by the rigid structures of Western, Enlightenment thought, a world that holds "science as a way of knowing." In lab rooms and offices of university advisers, she experiences a disconnect from her traditional, Indigenous knowledge of ecology. Here, the beauty of the asters can be described only in terms of rods, cones, and color theory.

In the face of this dichotomy of science and traditional knowledge, the mutual exclusivity of science and spirituality, science and beauty, science and art, science and *anything not empirically verifiable* that dominates 21st century scientific scholarship, she asks, *what might we find when we go beyond this perceived division? How can we rethink the ways we try to understand the world?*

Central to her work and her life is the idea of mutual flourishing. She encourages us to not see ourselves not as atomized individuals, but rather as part of a collective whole, one with the plants, animals, and Earth. To take care of others and the Earth is to take care of oneself. Implicit in all of this is love and hope as means for change. To hope is to believe a better world is possible. To love is to believe that that world is worth building.

We look for meaning and hope in whatever ways make sense to us, and more often than not, we find it through and with others.

Rebecca Siddle, a healthcare chaplain ordained by the Presbyterian Church, describes her practice as "a ministry of presence."

Some find God in the Church. Some find God in the mountains. Rebecca finds God at Redstone Highlands, an assisted living facility in Westmoreland County, PA. Here, she works mainly with residents with dementia and Alzheimer's, many of whom nearing the end of their time on earth, and their families. Before working at Redstone, she was a chaplain at Shadyside Hospital, where she spent most of her time on the trauma floor.

"Why was I in this horrific accident? Where was God in all of this?" These were the type of questions she was faced with during her time there. How do you begin to answer something like that?

How do you look someone in their eyes in what may be their final moments? How do you hold the hand of a patient's loved one as their mother, father, sister, brother, child, friend, lover draws a final, shaky, courageous breath? How do you console the most inconsolable? Trapped in the sterile, white fluorescence of the ICU, perhaps the most Godless place on earth, how do you bear witness to the end of the world, and how do you do so with God on your side?

"It was really just about being present," Rebecca says. Her role as a chaplain is not about preaching or converting- it's about "meeting someone where they are. Not trying to get them to be something they're not." In their most dire moments, people do not want to be told who they are, who they should be, who to pray to. Many people don't want to be told anything at all. Much of Rebecca's work is about simply sharing a moment with someone, "being quietly with them."

Unlike patients at Shadyside, whose ages range across the human lifespan, residents at Redstone Highlands have something in common: they've been around for a while. They've passed milestones- college graduation, first job, first house, marriage, children; their children have passed those milestones, and maybe so have their children's children. But no matter how full a life, no matter how much time and experience and joy and pain one has amassed, there may be still more to say.

"What do they still need to say to their family members? Are they on good terms?" Rebecca asks. Helping patients and family members find their own courage, helping them find their own words, is central to her practice.

Rebecca tells the story of one man whose mother, a 90-year-old woman living at Redstone, was nearing the end of her life. This man was harboring what Rebecca describes as a "disproportionate grief"- not that anyone can grieve "too much" or expressed in incorrect ways, but rather the source of one's grief can sometimes be buried so deep it's hard to uncover. Within this particular man lived a grief born from decades of unspoken words. Rebecca tried to help him find these words. She tried to help him find his *own* words. Long afternoons filled with stretches of silence and moments of connection, this man sitting opposite his mother, both desperate to see each other clearly, and Rebecca seated to the side, moderator, bridge, overseer, or perhaps someone to sit quietly and listen.

When the man's mother passed away, did he feel a sense of closure? Did his mother? These are questions that can't be answered. Most of the questions Rebecca grapples with cannot be answered. But a noble thing it is to ask, anyway.

"People who are not comfortable with mystery are generally not comfortable with faith," Rebecca says.

There's something contradictory about that phrase; it's the pairing of "mystery" and "faith." Look up the word "faith" and Oxford Dictionary will tell you that faith is "complete trust or confidence in someone or something." Even outside of a religious context, we tend to think of faith in this way. Faith is trust, faith pushes beyond reason, faith is a shot in the dark. Of course, a dictionary definition is only as set-in-stone as we want it to be.

But still, there is something fundamentally conflicting in conflating "mystery" and "faith" in this way. It's human nature to doubt, It is also human nature to be uncomfortable with doubt. This seems to be a driving force of this tension: we doubt, we question, we wonder, because perhaps some vulnerable part of us, a part that longs to be protected, believes that if we doubt long enough, we will reach certainty.

At no point in one's life might the desire for certainty be stronger than at the end. How many times have you missed the final step or wiped out on a bike and thought, "this is it, I better be going somewhere beautiful!" What about lying on the cold, tile-floor in the bathroom, sick, hungover, what have you, and looking up and whispering, "God, if you get me through this time, I promise I'll devote my remaining years to you."

This last-ditch shout in the void is, if not familiar, understandable. The link between mortality and religion is so strong it almost doesn't feel like a link but rather an inherent component of both, or at least mortality as an inherent component of religion. The phrase 'childlike wonder,' perhaps, speaks to a curiosity that has not yet been extinguished by the constraints of a finite existence. Awareness of one's mortality itself may be enough to spur someone to put their faith into someone or something and cling onto it. If someone feels that they are approaching the end of their finite existence, the impetus to believe may increase:

> "All supernatural agents [God, ancestor spirits, Buddha, devils, angels], culturally familiar or not, may offer death-aware people a direct way out of the existential quandary, perhaps with the subjective possibility of literal immortality, or perhaps with a greater subjective sense of safety, power, or purpose springing from these transcendental agents" (Hansen and Norenzayan).

There is no value or moral judgment to be made here. As Rebecca says, to be with someone in their moment of need is to accept and see them through exactly as they are. But the comfort that religion and beliefs in certain deities provide touch circles back to ideas of mystery and faith, and how the two might co-exist. Could we find comfort in uncertainty? If not comfort, acceptance?

Death and the uncertainty surrounding it is, arguably, the biggest source of anxiety across the globe and throughout history. While the fear of death is innate, the treatment of the fear is not universal. According to Hansen and Norenzayan in their paper "Belief in Supernatural Agents in the Face of Death," it is common practice in many traditional cultures such as the Native American Cheyenne and the Ilahita Arapesh of Papua New Guinea to excite, rather than assuage, fears of mortality. Often, initiation rituals that include "rites of terror" are held to excite existential anxieties through simulations of uncontrollable situations- "risk of death from unidentifiable sources or sudden isolation and loss of hope"- then ultimately relieving the participant's anxieties by removing them from the simulation.

"By relieving the ensuing distress," Hansen and Norenzayan write, "successful completion of the ritual performance in turn authenticates the belief in culturally sanctioned supernatural agents." In the cultures discussed here, one strengthens their faith by embracing the fear of death, *embracing mystery.*

To live is to embrace the unknown, to do it everyday, consciously or not. The ways in which we construct the world around us, whether that be the development of a particular scientific theory or a tale of our creation, allow us to sink our teeth into mystery. Perhaps, we can detach from our desire to *know,* and lean into the opportunity to *learn.*

There is great value in experimentation and observation. Without it, we would not be aware of the behaviors of microscopic particles that inform the field of quantum mechanics. Without the technological advancements of the 20th and 21st centuries, we would not be able to detect photons and electrons, nor would we be able to observe the precession of Mercury to discover how it aligns with predictions made by general relativity. There's no doubt that science has improved the world in observable, material ways.

But in the face of present-day problems, the Climate Crisis, for example, so much could be gained through a more interdisciplinary framework. Biology is art; poetry is mathematics. Look at how Hilma af Klint drew the double-helix structure 40 years before Francis Crick discovered the DNA molecule, or how the study of human anatomy informed Leonardo da Vinci's *Vitruvian Man* and other works of Renaissance Art.

And so, as promised, we return to a question we proposed millennia ago: why does string theory matter to those of us not in the field, those of us who don't particularly care and need a reason to care?

String theory, as we know, exists as a potential unifying theory of everything. Exciting as that may be, a theory of everything, that which encompasses all elements of the universe, may be something eternally sought after. In the world of physics, string theory is an exciting contender for such a theory, but could a theory of everything truly encompass *everything?* Sure, it could unify the four fundamental forces of the universe, and that would be an awesome, groundbreaking achievement, but could a theory of everything, precise it may be, explain what Kimmerer feels when she looks upon the asters and goldenrods? Could it quantify how it feels for Rebecca to be present, to sit quietly with someone and simply share a moment with them, to share, perhaps, one of their *final* moments?

String theory matters to the degree that one is willing to make it matter. String theory may not save the world, but perhaps someone with no interest in or relation to physics, when introduced to a concept presented in simple, human terms, will ask a question, or another question, will delve deeper into the subject, find themselves reading up on entanglement or superposition or spin into the quiet hours of the night, begin to see new ways in which things are connected, will understand that there's no need to become an expert, that there are small ways in which everything they learn can be worked into all that they do, that knowledge for knowledge's sake can be a beautiful thing.

When you look up at the night sky and are overcome by an inexplicable sense of awe, the kind of awe that gnaws at your chest and sucker-punches you, leaving you breathless, the horror and pain and beauty and love that, no matter how many times I rewrite this sentence, transcends language, *the sublime-* which even in aesthetics and philosophy cannot even encapsulate itself, that which will always transcend itself- when you find yourself at the whim of the universe unraveling, observer and observed at once; when you find yourself swallowed by the dark, inky, vacuous nothingness peppered with brief moments of light from prehistoric explosions, maybe then, you'll find that everything matters.

In the midst of mystery, what a joy it is to wonder.

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