What makes up Nothing? What makes up the empty space that is outside of the universe, outside of on earth, and fills most of what we know, right? Everything lives under this construct called space, and what makes of it. For centuries, this problem has been confusing and confronting physicists to develop more and more satisfying theories of reality. After all, how can we define the intangible space that we live in after we take out all the air? The furniture, right? All the things we call mass. After we take them out, how can we define it? Is there simply nothing? Or is there something? And that relates to a concept called a vacuum? How can we define it? How can we define a vacuum on the surface? This type of question is extremely paradoxical and self contradicting. Isn't nothing just made of nothing? Or is it a straightforward answer to this question? Is, we don't know yet, at least not entirely. There have been many efforts made to describe reality in a satisfying way, like how black holes evolve, how they explode. And how lights, how light moves. And these are all theories to explain how these complicated matters evolve and how they work.

But when we turn back and ask ourselves very simple question, well, what is nothing? We simply cannot answer that. I am not a physicist, but today i'll be sharing with you, not the complexities I found from mathematical equations. But from what I had found by retracing the footsteps about understanding of the vacuum. And by looking at how people came up with new theories, new ideas, by looking at how they confronted themselves against nature's paradoxes. We can perhaps all gain some insight on how sometimes not knowing something itself contains great value. Let's begin. Our journey begins quite recently compared to the vast thousands of years of human development to the discovery of a strange wave phenomenon. Everything is made of waves or a lot of things, right? Sound waves, water waves, guitar string waves, a lot of things you name it, right? All of these waves, they must pass through a medium and water waves, through water, guitar string, waves, through the strings. And it's really just middle school knowledge. But by the turn of the 19th century, there came an astonishing discovery, light that's really surrounding us everywhere, right? This thing that we call light, something we once thought of was a particle was shown to behave like waves.

Now, at the time, it was the prevalent idea that everything wave like should travel in a medium, right? Just as i've said, and like how water waves must pass through a water, it's our intuitive understanding of the world that guides us into thinking.

There has to be a medium for light as well, but we also know that light can pass through the vacuum, and isn't the vacuum just pretty much made of nothing?

This question that started this talk was presented to physicists at the time. So people had to come up with an explanation of it. People had to solve this dilemma. And that was when physicists, james clerk maxwell began propagating this famous concept called the luminous ether. And imagine and the theory is quite simple. Actually, it's just following the medium idea that everything has to live inside of a medium. And what maxwell thought of was that there is this ether thing that everything lies into, right? There's the substance. And one of the things he predicted that this theory will have some experimental tests that can really see if this theory works or not. Is that something called the ether went? Imagine, right? This is the ether, and we all live in it, and we can't feel it. We can touch it. But it's not moving anywhere, it's not going anywhere. It's just there. And us, people living on the earth, right? Earth is rotating around. We're not around, but inside this fit, if this entire ether thing is still unmoving, then on earth, on a rotating object, we will see the ether actually moving, right?

So then maxwell predicted that there will be all sorts of effects, right? Such as drag of objects, so that they might move slower through space. But sadly, there was no experimental experimental evidence supporting this idea. What did maxwell and his companions do? Well, they said, if this entire steel theory of ether didn't work, let's just make the ether theory move. They changed the theory so that when our earth moves and rotates, the ether rotates along with it. And then that's brought even more experimental predictions. But experiments failed. And it didn't match up with their predictions once more.

And again, and again, maxwell was pretty stubborn on this, and a few companions decided to stick with this idea and change it for a lot of more rounds to extend where it was. It became really complicated that it started predicting all sorts of supernatural things, things, and it's really untestable anymore. That was when einstein's theory of special relativity jumped in, einstein basically said, let's screw the entire ether theory. Let's just assume there is no medium whatsoever. The light can pass through. Let's just say the light can just pass through nothing. That's a ridiculous idea. But let's just say that, in fact, he invented or he used this mathematical formulation, and this is called special relativity. And he explained everything that maxwell had a hard time with using, basically a transition where a correction in space and time itself to put it. In other words, space and time is changed in moving objects. And in this diagram, you can see on the far left is an unmoving sphere that is moving at the speed of 0 meters per second.

And on the far right, this out object is moving very close to the speed of light at 0 . 9 c which is 90 % of the speed of light.

And when this object moves faster and faster, when we're standing still and we're looking at it, it becomes shorter. The length gets contracted. That's an experimental fact. We know we knew when maxwell was proposing his ether theory and we couldn't explain it. But einstein's theory said that this is basically because in the moving frame, when you right, imagine I am the sphere. My concept, my perception of space and time will differ greatly than yours. And that means that the the length we see, the time we see will all be changed. And einstein's theory was an instant success. It fitted with all experimental predictions. It was perfect, but only to the extent that it seems a little bit too perfect. Because what about the light theory that you just excluded from? Right? What about the ridiculous idea that light can just travel through a sea of nothingness and magically pass energy? Isn't that weird? How there don't need to be a medium for this thing? This wave called light moves through. Right? This is ridiculous. And when when einstein first proposed this theory, his entire thing wasn't successful. And he wasn't popular, because all of the other physicists thought this was only a temporary theory before the actual thing before the actual medium theory gets worked out.

After all, our intuition permits nothing else, but a medial and i'll come back to this idea later. Eventually, we move forward to the 20th century where we discovered that things on the smallest scale, on the smaller scale, on a scale, smaller than all our senses can feel.

Here see, things don't behave like the way they do in large scales like we see the world every day, things don't behave normally. And that was the discovery of quantum mechanics. There are just two basic principles I want to share with you today. That gives you an idea of how this entire subject works or what this thing says. First is the energy is discrete. There is no continuous energies. Each thing there can only be made of 1 plus 1 plus 1 packs of energy. There is no continuous amounts of energy.

The second thing is that this is also called the uncertainty principle and that we cannot measure both the position and the momentum to 100 % accuracy. And that sounds a little bit confusing. But it really means I cannot stand still here. In principle, even though ii think i'm standing still, I am not, my position can vary greatly. And that is very counter intuitive. How can we understand this? The real fun starts when you apply quantum mechanics, all these principles to things like light. We once more discover something, even stranger that light again, behaved like particles. What the hell is that? This light thing, it was a particle, it became a wave, then it ended up as a particle again. That is very confusing. And we feel we face the same position as physicists, perhaps, in the 19th century phase again. Right? At the time it was, how can light pass through a sea of nothingness?

Now, it's how can light be both a particle and a wave? You see how progress is made? It's when there are paradoxes, things that we can't seemingly solve. It's self contradictory. But these are good because it's indicators of progress. And that is when a theory try to combine wave theories, which is really what we first thought light was, and quantum mechanics, which is right, discrete amounts of energy. So continuous waves and discrete energies that is called quantum field theory.

So behind me, here is a simulation of what we now think constitutes the vacuum. What you are seeing now is that in this tiny space is probably smaller than a few nano meters. It's really, really small. There's these quark and glue on waves. These are waves that fluctuate in and out of existence very rapidly. And this is just a very exaggerated time scaling. The actual thing probably moves in and out, fluctuate bubble around much faster than this.

And so this seems unrealistic, because we don't see vacuum as this, right? We see nothing in there. But there are some physical realities with this formulation. For example, when these waves, right? These red parts show where they actually accumulate up, where there's a ton of these waves. So when these waves accumulate, things emerge. And these are called quarks. That is really one of the most fundamental particles of our universe that makes up the protons, the neutrons. And then eventually, it makes up the atoms, the molecules. And then us, we are all made of quarks. And these things, right? These waves that bump into each other and fluctuate and accumulate. And to a certain extent that there will be something that appear. So that is very strange. And it says the vacuum is perhaps not as empty as we thought it wasn't. We thought it was empty. We thought there was nothing inside, but now we see there's something inside.

How can we deal with this situation? We are, again, at this very interesting position where there's something new. And that's what we discovered. If this entire theory sounds a little bit bizarre, right? This is crazy. How can we be made of waves? You and me we are flesh and bone. We are made of particles or whatnot, write atoms and all of those. This is actually the most accurate theory we have to represent reality, the most accurate. And just to show how accurate it is, let me show you an example. This is the g value. You don't need to understand what the g value actually means. It relates to something about the electrons, magnetic properties.

Up there is our theoretical prediction of g down here is the experimental value of it. You can see the two matches are perfectly to about 12 digits. And that is one in a billion of a deviation. That is a very small deviation. You will be happy in any other subjects such as economics if you even get the place before the decimals, right? Right? This is very accurate. But let's just give a quick recap of what we have said right now about quantum mechanics, about quantum field theory. Quantum field theory says everything is made of waves. You and me, we are all made of fluctuations in space and time.

For example, something we may call electrons. How does that emerge? It's just the electron wave, and it fluctuates in space time, and then boom, there is an electron. So things are just fluctuations and waves. And because of this uncertainty principle, we cannot measure both the position and momentum, 100 % accuracy. So I cannot stand still. These waves have to fluctuate. They have to move around. They have to be very crazy about it. There we have it. But do we actually have everything? Have we understood everything? Right? This is incredibly accurate. But do we have everything? That is the question. And the question we're seemingly solving here is how question, how particles move? How waves evolve, how big this g value is. But we're seemingly leaving out one big question that constitutes most of our intuition of the world. The why question? For example, why we live in a three dimensional space? Why does time only move forwards not backwards?

And these questions may seem really invaluable, because after all, what is answering them gonna help us? It doesn't really give us anything. We also don't ask these questions such as why we live in a three dimensional space, because we do live in a three dimensional space. We are born into a three dimensional space that gives us the intuition of everything we are born into it. But every once in a while, you see something incredibly strange that destroys everything you understand. And that's that's what it was, for example, like the quantum mechanics. It's nothing like you've ever seen before.

Now, the question of why it becomes incredibly important, because we don't understand it. And quantum mechanics says a ton of peculiar things. It says nothing is deterministic anymore. Everything is governed by this wave function. All of us are probabilities. Nothing is deterministic anymore. And it also says that only when we observe something like this quick observed, I observed you, so you exist. But that does mean that if you guys don't see me or I don't interact with any of these lights and these ways and all of these things, I don't exist. I'm not a flesh going anymore.

Now that is ridiculous, right? If you think about how can I just not exist if nobody sees any? These are the questions.

So now we ask, why is it that way? Why is quantum mechanics so strange? And if that sounds too distant, how can we understand this entire thing about it? But how can you understand that waves just fluctuate like this? This really ties to the door, ties us back into the start of this talk, where I said, we don't know yet, but the answer to this question is we don't understand it.

And you also see here what we ask. When we ask about nothing, what is nothing? We don't really just ask about how these wave functions move, how these waves evolve, how fun field theory can't explain all of this thing, how to explain what is nothing. Right? Just give us a picture of this thing. And we're done. No. We have to ask ourselves, why is it that way? How does it make sense of it? And, in fact, just the ability to calculate is very contemptible for a lot of physicists. They think if we are able to predict the future, describe everything, we don't need to understand the theory. And that is very important to predict things. And that is really what physics is all about. Right? We try to find a pattern.

We try to fit it with things in the future, and we try to predict things. We try to describe things, and we try to fit everything inside these tiny equations. That would be right, the thought that we don't need to understand what quantum mechanics means. We don't need to understand what quantum field theory means. But we don't understand everything. We don't have the ability to describe everything. In fact, there are things like quantum gravity where we try to accommodate the differences between the continuous wave functions in gravity, the discrete energies in quantum mechanics, there are dark energy, dark matters that we have not seen yet. At all in our modern observatories, right? These things we don't understand. So it is, in the end, important that we do look at the why question, understand why these things work, why quantum mechanics, why this and that. Sadly, we don't at the current stage, we just we just don't.

At the start of this talk, we encountered this idea that light can just pass through a sea of nothingness. Einstein said, we don't have to worry about it. It's just the way it is. Light just passes through nothing. And there's the ether theory who asked the direct opposite. Why can't you like pass the receive of nothingness? It shouldn't be that way. There should be a medium. And Einstein's theory was right, actually, because even with all these fluctuations, even with all these quarks and glue ONS, these are not medium for light. Light don't travel in these things, because they're not light particles, right? There are just other particles moving in and out of existence.

There is no medium for light. But does that mean that the ether theory doesn't work out? Well, it actually turns out that it is only because we ask the wise that we do understand so much about quantum mechanics. And we do understand so much about quantum field theory today. It is particular because we asked why, although we didn't get the exact answer, we were hoping for, right? The medium theory, we didn't get that. But we get some other astonishing things that were really great as well. And perhaps it can be said about the same thing to our current dilemma. How we can figure out this strange thing about quantum field theory and quantum mechanics, how we can make sense of that. It's only when we make our first step to ask these questions and to understand that we do not actually understand them. Can there be progress? And that is really what I want to share with you.

Today in this talk. I'll just end this entire thing with a little story that I heard and or read from. This famous physicist named Richard Feynman, where he explained to his students, what the nature of subtraction is. Imagine a few thousand years ago, there were two Mayans who wanted to learn how to subtract numbers. They go to find their priest. The priest says subtraction is very easy. You just take a drawer out, then you count, for example, if you want to do 533 minus 285, you just first count, 580 583 beans and then put all those beans inside a jar. Then you take out 285 beans, the remaining amount of beans is your answer.

Now there is no way that we can actually do, for example, 1 million - 1 million using this method. But that's not the point. The point is that at the end of the day, after all, the fancy tricks counting beans outside of the jar, what subtraction really is. And that is what people hope. We can do the same for complexities and complex things, such as quantum field theory, all those things that are extremely complex that give us extremely sophisticated equations and predictions. To just look back. Turner has at some point and look back and ask the question, what does it all actually mean? What is all of this? And that is all I have for you today. Thank you.