What Is Real?

John Streiff

Osher Lifelong Learning Institute

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What Do We Know?

How Do We Know What We Know?

Most of us would agree that we know what we know because we have subjective personal experiences. We learn everything as a result of experiencing the world around us in various ways.

Clearly we are born with autonomic functions that don’t require learning. But everything else we know we must in some way first experience. We have no knowledge and therefore no beliefs without experience.

Limits to What We Know

There are limits to our perceptions. In our species, cognitive abilities compensate for our limited perceptual abilities. But even these cognitive abilities have their limits. We can misperceive and we often misremember.

Nature’s Limits

Light Speed

The speed of light is the fastest thing in the known material universe. Nothing can accelerate beyond the speed of light at 186,000 miles per second. This means that we always experience everything on delay.

Quantum Uncertainty

Quantum uncertainty is a feature of Quantum physics. It limits our ability to peer with confidence into the depths of reality.

Our Cosmological Scale

Some people believe that either the universe was created for us, or that we are probably the most important things in the universe. This is a statement of the philosophy of “anthropocentrism”.

If we believe what Nature shows us daily, we actually live in a second-rate galaxy at the edge of the universe in an insignificant solar system. While we do seem to be somewhat unique in our visible region of the galaxy and it is statistically possible we are not alone in the universe, the fact is that we are not at the center of anything, except our egos.

Indeed a belief in anthropocentrism leads to some interesting ideas. For example, American physicist Fred Alan Wolf in the 1970s suggested that when we stare at the sky at night we might actually be creating the distant galaxies. Such are the rabbit holes that await us if we accept anthropocentrism too literally.

What Do We Really Know?

We apparently live inside the universe. Physicists and cosmologists tell us stories about the birth of the universe and guess as to its age and size. But these are necessarily assumptions. We don't know if the start of the universe was really a 'bang', but it fits the story nicely and – for the most part – there is little evidence to the contrary.

A fish in a fish bowl reasonably believes the whole world is made of water. It has no knowledge and no reason to believe otherwise. In like fashion, we are ensconced in the known universe. Our entire experience of reality is confined to our experiences of that universe.

Because we are constrained to the universe as our cosmic fishbowl, there are necessarily things we cannot and do not know about reality. It would be foolish to believe otherwise. Not only are our perceptions and memories flawed, we observe reality from within our cosmic fishbowl with no knowledge of what might be outside.

It should be no surprise that we continually have questions and encounter numerous paradoxes in science and philosophy.

Despite these limitations, our amazing technology advancements of the last few centuries suggest we must know something. Science is in the business of enabling technology advancement and there is no doubt that enterprise has been highly successful.

Consensus

Given our individual limits, we collect our knowledge into consensus beliefs and realities; we do this with religion, politics, philosophy and science for example. Most of us trust scientific consensus because the barriers to acceptance of a new idea are higher in science.

Indeed religion is based solely on faith while philosophy introduces logic and reason and science is based on empirical experimental verification of philosophical ideas. So indeed science has the ability to produce the most refined knowledge in the appropriate contexts.

But all consensus realities and beliefs are at the end of the day collections of individual subjective experiences and beliefs. And that consensus is no better than its weakest ideas.

We form consensus beliefs and realties because we want to survive. We want to survive physically, emotionally and intellectually. We still have that deep survival instinct. We live and die by these beliefs in some cases. The news abounds with examples daily.

We Don’t Know What We Don’t Know

All this leads to the inescapable conclusion that *We Don’t Know What We Don’t Know*.

As a species, both as individuals and as groups, we are too ignorant about reality as a whole to know the limits of the possible.

We can understand this situation by thinking about a flower like the Grandiflora Magnolia. The flower only lives for about a week. And inside that flower live microbes who live only a few days. Those microbes are only able to explore a tiny area of the flower during their short lives. They are entirely unware of the nature of the flower, of the fact the flower is attached to a larger tree or that the tree occupies a world of mountains, streams, animals, people, sky and stars.

We are very much in the same situation in our universe as the microbes inside the flower. It is no surprise that we are, in actual fact, so encumbered and limited in our actual knowledge.

Our Limit of Knowledge

We live in a fishbowl we call the known universe, making observations constrained by our perceptual limitations and biases. We have many questions and encounter many paradoxes and routinely overestimate our limited understanding of the universe despite our limited successes.

We don’t know what we don’t know.

Science

If we truly know so little about reality, how have we have been so successful technologically? The answer is in the application of the Scientific Method.

Scientific Method

A statement is scientific because it meets three requirements. It is testable, the test is falsifiable and it is repeatable. Only if all three of these are true can a statement be considered 'scientific'.

An hypothesis or experiment is falsifiable if it can be shown to be wrong. Scientific statements must describe how they can be shown wrong. This is usually not required in common discourse, and is often not required in philosophical discussions.

It must be possible for anyone with suitable equipment and knowledge to repeat the experiment and get the expected results. The degree to which this replication is possible is a general judge as to the quality of the scientific proposal.

Experiments

Scientists realize that experiments don't prove anything in the sense of mathematics and logic. Proofs are possible in mathematics and logic because the operators and operands behave in predictable ways. But experiments can contain unknown degrees of flaws and errors. Social and behavioral science experiments often involve living organisms, from plant life to humans with attendant unknown complexities that affect experimental outcomes. Quantum physics suggests that every experiment is potentially in contact with the entire universe in principle. It seems these contacts rarely affect experimental outcomes, but the potential exists nevertheless.

Hidden Variables

Think about the simplest experiment, an experiment you have done thousands of times; it involves two molecules of hydrogen and one of oxygen. In other words, water. The experiment is boiling water. There was a time when no one knew why water boiled; they had not yet discovered the importance of heat. But at some unknown time in history, after the importance of heat to boiling water became known; it was discovered that altitude (or more correctly, atmospheric pressure) also contributed to the boiling point of water. This new variable had been "hidden". No one knew or cared until they observed the anomaly that altitude seemed to matter. The point is that hidden variables can exist in any discipline. Later we will discuss hidden variables in the context of Quantum physics, but they can appear anywhere in our observations.

Philosophies of Reality

There are many competing philosophies of the nature of Reality. The two philosophies that live at the extreme ends of the spectrum are Realism and Idealism.

Realism goes back centuries, and essentially says that “What you see is what you get”. That Nature is showing the real world as it actually is, subject to our perceptual distortions of course. That even if we weren’t looking, the objective reality is always there. Our observations have no direct impact on the reality of the universe; they only impact our knowledge of the universe.

Idealism was born in the mid-19th century as a reaction to a rising tide of philosophical “Materialism”, a form of Realism. Idealism holds that Consciousness is primary and fundamental to everything in Reality. That the universe and all its contents emerge in some unspecified way from that primary Consciousness. Idealism is untestable scientifically; it is purely Metaphysical in nature. Proponents of Idealism often point to its inherent simplicity and parsimony in their defense of this worldview.

For many centuries scientists were primarily Realists and indeed many are so today. Many philosophers held onto views similar to Idealism. In the early 20th century an intermediate view emerged called Panpsychism. Panpsychism claims that matter exists independently of Consciousness and that Consciousness in some way pervades the universe; that consciousness is everywhere. In other words, that Consciousness is ubiquitous as opposed to primary as in Idealism. Many scientists in the 20th and 21st centuries, who have for various reasons abandoned Realism and its variants, are more comfortable with Panpsychism than Idealism precisely because the former does not stipulate the creation of matter from Consciousness.

Truth

At the end of the day most of us seek “Truth”. But is there an “objective truth”? Is there an “objective reality”? Many philosophers have come to the conclusion that in fact there may be no objective truth, and many scientists are beginning to likewise believe there is no objective reality.

It is possible these rather radical ideas in science and philosophy are based in an incomplete understanding of reality itself. If in fact we are insulated from whatever is beyond the universe, it might simply be the case that our lack of perspective – our lack of knowledge in other words – has led us to these conclusions.

One of the goals of this course is to explore what “truths” various people have brought to the discussion of the nature of Reality. To see if there is a reasonable possibility that some important facts have been missed along the way. And if so, how might these missing pieces of the story change our point of view were they better known.

Comparing Philosophies

A brief comparison of the extreme philosophies on the nature of Reality, namely Realism and Idealism reveals some interesting things.

Realism claims that matter is fundamental while Idealism claims that mind is fundamental.

Realism claims that mind emerges from matter while Idealism claims that matter emerges from mind (consciousness).

Realism claims that mind cannot influence matter, while Idealism claims that matter cannot influence mind.

But in our everyday experiences, all of these things actually happen. It is as if neither Realism nor Idealism completely capture the nature of Reality. It seems that something more fundamental may exist and that both these apparently extreme positions in some way arise as special cases of a more fundamental, deeper aspect of reality. This idea of fundamentalism is captured in the philosophy of Neutral Monism with a departure point of claiming that we don't know what we don't know and that something more fundamental than we know is the basis of everything.

To form a coherent model of Reality, we must examine the data from scientific theories and research. And in doing so, remembering that We Don't Know What We Don't Know, accept any well-done scientific research as reasonable inputs to a set of requirements for a new model of reality.

The Goal

To achieve our goal of developing a potential model of reality that offers plausible explanations for what is real, we will consider evidence from reliable research in the field of physics and consciousness. In physics we will discuss relativity and quantum theories. In consciousness research we will discuss scientifically established anomalies of mind and matter.

Relativity Theories

There are two modern theories of Relativity, both attributed to Albert Einstein: the Special theory was published in 1905 and the General Theory was published in 1915. But the idea of relativity dates back to Galileo in 1632.

The basic idea is that we can never know what is absolutely true. We only know what is true relative to ourselves. Each of us only know what we observe. And we make all observations in relation to our locations in space and time. Galileo further stated that the laws of physics are the same from all perspectives and in all places.

To this Galilean notion of relativity Einstein added to measurements the impact of the constancy of the speed of light. Constraints to measurement imposed by the admission of the speed of light had implications had implications to measurements in the universe. Specifically Einstein was eventually able to show that earlier ideas from Newton regarding so-called "absolute space" and "absolute time", central to Newton's explanation of gravity, were simply not required. Einstein's theories exposed previously unknown predictions regarding measurements of space, time, mass and velocity in the universe.

No Privileged Reference Frame

The first key assumption in Einstein's relativity theories is that there is no place in the universe that is a point of reference for everything else. When you understand the implications of the assumptions that will be presented, you will be tempted to ask "okay, but what is really going on?" This question is an appeal to what is called a "privileged reference frame". But Einstein realized in a purely relativistic universe such a privileged frame of reference is unnecessary. This does not mean there is no privileged frame of reference in all reality; simply that relativity theories don't need one.

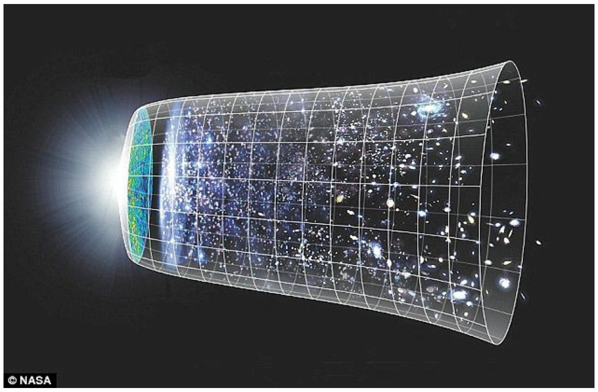
Consistent Laws of Physics

As with Galileo, Einstein further stipulated that the laws of physics should the same everywhere in the universe. While this seems so obvious it does not need to be stated, this stipulation leads to some very strange, non-commonsense predictions in Special Relativity theory.

Consistency of Measurements

Another assumption is that all measurements should be consistent although not necessarily identical. This is the first hint we are no longer in Kansas. While two people may measure the same thing, for various reasons having mostly to do with the geometry of spacetime, their measurements need not agree. And yet from each observer's perspective, the apparently different measurements are both valid. This is the kind of prediction that causes people newly encountering Einstein's Relativity to ask "what is ***really*** going on?"

Spacetime



In 1908 Einstein's mathematics professor, Hermann Minkowski, said in a speech at a German technical conference that: "*The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth, space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.*"

In effect Minkowski proposed for the first time that the concepts of space and time could be unified mathematically. This was possible, he said, because the two are mathematically equivalent. There is no limitation in the mathematics that prohibits combining space and time into a common structure called "spacetime".

Of course we do not perceive the universe on a 4D spacetime basis. We perceive a 3D space changing in time. But repeated verifications by experiments have shown the predictions of Einstein's relativity theories are indeed correct; it meets the gold standard in science, a theory whose predictions never fail an experimental test.

What Minkowski proposed was a four-dimensional spacetime as opposed to three-dimensions of space changing over time. *This is the central reason that the predictions of Einstein's relativity theories are so strange* and were so radical in the early 20th century when they were proposed. We never consider that we are moving through both space and time for example. And that fact has a profound impact on measurements and motion.

Light Speed

Mass is a measure of resistance to force. Einstein famously wrote that "*the fastest thing in the material universe is a zero mass particle travelling unimpeded through a perfect vacuum.*" Particles of light, or photons, are such particles. They are the fastest thing in the universe; anything with mass has resistance to force and must travel at slower speeds through space.

Most particles have mass and therefore travel slower than light. Sound particles – phonons – travel at 600 miles per **hour**. By contrast light particles – photons – travel at 186,000 miles per **second**, lightspeed.

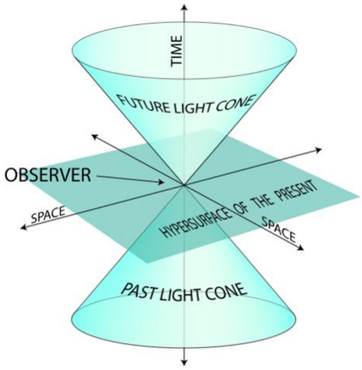
To understand the implications of the speed of light, and to begin introducing the effects of mass and spacetime, assume a bullet is fired from a stationary gun. Presume the gun's muzzle velocity is 100 MPH. Someone observing from the sidelines will clock the speed of the fired bullet itself at 100 MPH. But if the gun is in motion at 40 MPH, a bullet fired in the direction of motion of the gun will be the sum of the two velocities or 140 MPH to the same observer.

If instead the gun is substituted for a lit flashlight and the flashlight turned in any direction under any conditions of motion, the light will always travel at light speed. Neither accelerating the flashlight nor changing its direction will impact the speed of light.

Light Cones

Minkowski proposed Light Cones to visualize the implications of the constancy of the speed of light.

Since we cannot comprehend a four dimensional structure directly, one or two spatial dimensions are discarded in light cone diagrams. This is done purely to make the illustrations more understandable.



The light cone diagram is typically rendered either as two triangles in two dimensions or as two cones in three dimensions, one inverted over the other meeting at their tips. The observer is at the center of the light cone where the two structures meet. Time from the observer's past flows toward the observer from the bottom of the light cone and time from the observer's present flows upward in the light cone into the observer's future. (The light cone can be oriented at any angle, but for simplicity we discuss here only a light cone oriented such that time is represented vertically from bottom to top).

The boundary of the light cone is a 45 degree angle and represents the constant speed of light. This light cone boundary is called the "light-like region" of the light cone. The area inside the boundary represents trajectories of objects travelling slower than light. This is called the "time-like region". The area outside the boundary represents trajectories travelling faster than light, so-called "superluminal" particles, and is called the "space-like region".

For any given point in spacetime, the area on the light-light region and the time-like region of the light cone is called by physicists the "local" region. When physicists speaks of "locality" they are referring to these regions of the light cone for a specific point in spacetime. When they speak of "nonlocality" they are speaking of the space-like region beyond the light cone.

Retrocausality

Minkowski's spacetime allows for the possibility in principle to run experiments backward in time; they will work as well as forward in time. The mathematics of physics does not preclude such things.

Our normal experience of the world around us violates this prediction. But as we shall see, scientific experiments from multiple disciplines strongly suggest that this idea, called "retrocausality", or influence from the future, in some sense is actually a real effect.

When physicists talk about retrocausality, they mean that the present influences the past. And it is generally believed in science that this is the limit to retrocausal influences. It is not a suggestion, according to mainstream science, that the future can influence the present. But this argument is not as sound as it might first appear. We shall see evidence later that retrocausal influence may in fact be even broader. And we can make the reasonable argument that a truly complete model or theory of reality must accommodate both notions of retrocausality.

Simultaneity of Relativity

Everything that happens necessarily involves motion through spacetime. Even if you believe you are sitting perfectly still you are still travelling uncontrollably through time. So when you measure something for example, you are doing so through both spacetime.
It takes time to make measurements, and you are moving through spacetime as you do so.

Since measurements are made in spacetime, what appears to be “now” for one observer can agree with another observer’s past or yet another observer’s future provided they are each in different reference frames. Again this is a natural consequence of living in what appears to be a 4D spacetime.

Simultaneity is the notion that two events in spacetime occur at the same moment; put another way, that there is no distance in time between two events. According to Special Relativity theory, any observers who are at rest with respect to each other will agree on when and where events they share in common occur. However, since time and motion enter into the definition of where and when an event happens, if observers are in motion with respect to each other they can, under the proper conditions, disagree on the simultaneous occurrence of events they would otherwise agree are simultaneous if they weren’t moving with respect to each other. In other words, relative motion matters. They will agree on what happens but may disagree when things happen.

Special Theory Time Dilation

The Time Dilation hypothesis states that for an observer at rest, time as measured by that observer passes more slowly for events occurring in another reference frame that is apparently in motion relative to the observer at rest.

The best example is an actual series of experiments demonstrating Time Dilation. Two highly accurate clocks are set to the same time as they sit side by side in the same location. They are in the same reference frame at this point. One clock is left behind while the other is flown around in an airplane. As a result, the second clock is in motion relative to the first clock left behind on the ground. In other words, the second clock is in a second, moving reference frame relative to the first clock. When the plane lands and the two clocks’ times are compared, the second clock that was in motion relative to the first clock indicates that time for the second clock progressed more slowly while it was in motion, consistent with the Time Dilation hypothesis of Special Relativity.

Another example originates in experiments detecting almost massless particles called muons. These are produced above the atmosphere by cosmic radiation. They have a rest lifetime of microseconds. Yet they are detected after they passed through the Earth atmosphere long after their decay time should have expired. The reason is time dilation; their “lifetime” is extended because time slows down for them as the fall through the atmosphere.

Special Theory Length Contraction

he Length Contraction hypothesis is perhaps even stranger than the Time Dilation hypothesis. It is important to remember that all these predictions, verified by experiment, can be understood simply by remembering that the underlying geometry assumed in Einstein's Relativity theories is 4D spacetime.

There have been many attempts to explain Length Contraction. Here I shall use a very simple example to illustrate the principle. Remember, this is a natural consequence of a 4D spacetime geometry.

Assume you and a friend are standing together and that your friend in holding a ball of some size. You have your friend move a distance away, say 100 feet. The actual distance does not matter as long as you can see him. You now measure the size of the ball he is holding at the distance, since there is a distortion in your measurement of the ball due to the fact he is now at a distance from you. This is the same effect that causes a mountain to look smaller at a distance. You now have an accurate measurement of the ball he holds as he stands 100 feet distant. Next you ask him to maintain a constant distance of 100 feet from you as he goes into motion. Effectively, he will traverse a circular path with you at its center. By his maintaining a constant distance you can potentially accurately detect any Length Contraction effects.

When you measure the diameter of the ball you find that as his speed increases the ball he is holding flattens in the direction of motion; it begins to resemble a pancake as he speeds up. When he slows down, the ball grows larger in the direction of motion. And when he stops, the ball returns to its original diameter. There is no impact on his height during motion since he is travelling on a horizontal path relative to you. This is Length Contraction.

You cannot actually perform this experiment because the effect at most speeds slower than light is too small to observe. But if you had a sufficiently accurate measuring device (which does not exist currently) you could actually perform this test and observe these results.

General Theory and Gravity as Spacetime Curvature

Einstein's General Theory of Relativity, published in 1915, introduced the idea that the effect of gravity is actually due to spacetime curvature. Bodies with mass curve spacetime and that spacetime curvature produces the effect we call 'gravity'. Everything with mass curves spacetime. More massive bodies, like planets and stars, curve mass more and produce larger gravity effects than things much smaller, like pencils, dogs, cats and people.

Since gravity is the product of curved spacetime, mass produces distortions in spacetime. And since the predictions of Simultaneity of Relativity, Time Dilation and Length Contraction are based in the geometry of 4D spacetime, that curvature has an effect on the calculations involved in those predictions. In other words in the presence of mass and curved spacetime, the effects of Time Dilation and Length Contraction change.

There are two forms then of Time Dilation, one due to motion as expressed in Special Relativity and an additional form due to gravity known as Gravitational Time Dilation. The latter applies only in the presence of mass, such as on the Earth. For this reason most physics experiments are impacted by both forms of Time Dilation.

A notable example of this is in the GPS satellite system you use to track your location in your smartphone or car. Those GPS systems depend on satellites that orbit the earth. The satellites are in motion relative to the earth and experience Time Dilation as a result. The onboard computers that generate time-based data used by the GPS receivers to tell you where you are must be corrected to compensate for the very real effects of Time Dilation due in part to the effects of gravity and spacetime curvature.

However, in deep space where there are no bodies with mass, only Relativistic Time Dilation occurs.

General Theory, the Cosmological Constant and Galactic Expansion

When Einstein formulated the General Theory of Relativity it was believed the universe was static. That is, that the galaxies sat unmoving in the universe while their contents, like stars and planets, moved within them on orbital paths. Einstein was therefore surprised when his equations of General Relativity predicted the galaxies should be in motion and not standing still since this violated the received wisdom of the then-current cosmology. To compensate for this situation, Einstein inserted a new term in his equations known as the “cosmological constant”.

In 1931 astronomer Edwin Hubble discovered evidence that distant galaxies were moving away from our Milky Way galaxy. He suspected the galaxies are not static and in fact are moving apart in the universe. The rate of expansion discovered by Hubble was precisely the value of the cosmological constant. When Einstein removed this constant from his equations, General Relativity precisely predicted this newly discovered galactic expansion. Nevertheless, Einstein would label this event “my greatest blunder”.

Energy, Mass and Momentum

Perhaps the most famous equation in physics, at least to the public, is $\boldsymbol{E = mc^2}$. It relates energy (E) to Mass (m) through a conversion constant related to the speed of light (c). Einstein, integrating existing knowledge at the time, was arguably the first to write down this relationship in mathematical form.

This equation reflects a commonly known fact that “energy cannot be destroyed”. Rather it is always transformed into mass. Mass can be thought of as a resistance to force. All matter has mass. Due to the immensity of the conversion factor c^2, the amount of energy locked up in matter can be immense, if it can be released. This is the basis of combustion and of atomic energy.

The term mc^2 represents energy due to mass otherwise known as “potential energy”.

In 1926, physicist Paul Dirac extended Einstein’s equation to add energy due to motion which is known as “kinetic energy”, expressed as pc. This equation is called the energy-momentum-mass equation and is written as $\boldsymbol{E = pc + mc^2}$. It says that the total energy in anything, be it a particle or the universe, is the sum of kinetic energy (pc) and potential energy (mc^2). Anything in motion has kinetic energy. Anything with mass has potential energy. For example, a log sitting in the fireplace burns, releasing its potential energy, due to its inherent mass. A log hurled across the room strikes with force due to its kinetic energy. By contrast, a light beam has no mass and so has no potential energy; it only has kinetic energy.

The origin of momentum and therefore kinetic energy is not known in physics. This is one of the great mysteries. But it may be the case that the answer to this age-old question is actually before us now as we shall see as we next turn to Quantum Physics.

Unification of Electromagnetism and Gravity

One of Einstein's goals in his later career was to unify the two well-known forces at the time, electromagnetism and gravity. The atomic forces, namely the strong and weak nuclear forces, were not well understood at the time since atomic physics was still emerging.

Einstein knew that Newton's gravity theory, developed in the 17th century, explained the effect of gravity as a sort of "action-at-a-distance" or a nonlocal theory in that there was no causal chain that led from a clear cause to the effect of gravity at a point in spacetime. As with most physicists, Einstein held a strict "locality bias" ; he preferred local theories – theories that operated on the basis of a causal chain of cause and effect. Maxwell's electromagnetic theory was local in this sense as are most other theories in modern physics.

When he realized that his newly developed theories of motion involving spacetime curvature also predicted the effects of gravity better than Newton's gravity theory, Einstein knew he had found a local theory of gravity. In time Einstein's gravity theory actually explained more about gravity than had Newton's. In other words, Einstein's gravity theory embedded in General Relativity had greater *explanatory power* than Newton's gravity theory. In fact, Einstein's model of gravity held up to experimental tests throughout his lifetime. Only in the late 20th century did more precise measurements eventually show the theory to be somewhat incomplete.

Einstein believed he should be able to unify the equations of electromagnetism and gravity now that he had produced a local theory of gravity. But he failed in the attempt by the time he died in 1955. Now an explanation is possible although not well known. The story begins with Maxwell and the publication of electromagnetic theory in 1862.

One of Maxwell's original equations predicted something called a "magnetic monopole"; a magnet with only one pole. All magnets ever found have two poles however, so the prediction seemed to be wrong. But the other Maxwell equations of electromagnetic theory worked perfectly, so this equation – known as the Gaussian Magnetic equation was simply ignored.

Shortly after Maxwell published, a well-respected English mathematician named William Kingford Clifford commented that the existence of a magnetic monopole would imply the need for a fourth direction of space. In other words, move from a 4D spacetime to a 5D spacetime. But since a magnetic monopole has never been observed this idea was forgotten.

At least it was forgotten until the beginning of the 20th century when American physicist Theodore Kaluza rediscovered the idea and suspected the fourth direction of space could be used to unify electromagnetism and gravity. It would be undetectable, thought Kaluza, if that fourth direction of space were somehow curled up and very tiny. He wrote to Einstein with his idea which Einstein called brilliant and admitted that he would never have thought of it.

For several years Einstein and colleagues worked on the idea but finally came to believe the fourth direction of space had to bigger than Kaluza had proposed. Einstein couldn't explain how this extra direction of space could go undetected and so they gave up on the approach.

We now know this was the reason Einstein failed to unify electromagnetism and gravity. And that is the unknown history. It is not in physics textbooks, physics professors don't teach it and physicists don't know about it for the most part.

In the late 20th century, around 1982, West Virginia professor of physics Dr. James Beichler rediscovered Kaluza's proposal and took it seriously. Beichler interpreted the fourth direction of space as the mathematical point dimension which, for Plato, was the source of all Platonic forms. You learned about this in elementary school when you were told that a point is zero-dimensional and that extending a point forms a one-dimensional line, sweeping the line produces a two-dimensional surface, and spinning the surface forms a three-dimensional volume. The story usually stops there since it is quite difficult to visualize 4D objects, although geometers do so mathematically all the time.

Beichler was eventually able to write down equations unifying to two forces, succeeding where Einstein and colleagues had failed. Most physicists and mathematicians have apparently not seen these equations. However when compared to the mathematical equations involved with the unification of electricity and magnetism into electromagnetism from Maxwell, and the equations describing the unification of the strong and weak nuclear forces with electromagnetism (from the early-mid 20th century) one finds a striking symmetry. This suggests that all forces, including gravity, emerge from a common source; they simply behave differently under different conditions and circumstances. And that is consistent with the hypothesis of a **produced universe** which is important to us in our quest for a model of reality.

Requirements from Relativity Theories

Thus far, here are the requirements imposed on any potentially successful model of reality by Relativity theories. It must explain:

- The existence of lightspeed as a speed limit to causality in the Universe
- Time dilation and length contraction effects, especially their durable nature
- The effect of gravity
- The geometry of the Universe

Of course, there are still many open questions. We move next to Quantum theories in an effort to understand those.

Quantum Theories

If the hypotheses of Einstein's Relativity theories seemed strange, the predictions and implications coming from quantum physics are downright weird. However, for the public, there is far more confusion and misunderstanding of quantum physics and its meaning than necessary. And some of this is coming, surprisingly, from the academic scientific community.

There are three major theories in physics: Newton's classical theories, Einstein's relativity theories and the Quantum theories. All three are equally trusted because all three have been rigorously tested and have survived many, many attempts to falsify their predictions.
The gold standard in scientific research is continuous success when theories are tested to falsify their conclusions. Such theories are considered the most trusted and reliable in science.

The Quantum theories are believed to represent the most fundamental aspects of the known universe because they seem to describe an aspect of reality that is not considered either by Newton's or by Einstein's theories.

Primacy of Quantum State

A key assumption in quantum theory is that there is a quantum state of some kind and that classical states begin in this quantum state. The form this quantum state actually takes is not known. But the assumption of the existence of a quantum state is entirely consistent with all experiments and is a central theme in all interpretations of quantum theory.

Quantum State Transition

Another key assumption in quantum theory is that some form of transition occurs which moves a quantum state to classical state. After this transition, the event in question is in "classical" state at which time it is irreversible and can be observed and measured using classical apparatus. It is generally accepted that the quantum state cannot be examined prior to the state transition.

The state transition goes by various names depending upon the interpretation of quantum theory. It is variously called the "state transition", "state reduction" and "wavefunction collapse". Most quantum theory interpretations suggest the existence of such a transition either implicitly or explicitly.

Quantum Entanglement

One assumption in quantum theory that is very foreign to the classical world is called "quantum entanglement". This is the notion that two or more particles, once in proximity in some way, remain correlated in terms of any later observed or measured values. The interaction seems instantaneous across any distance of spacetime, quite in contradiction to Einstein's assumption of lightspeed as a speed limit in the universe. This was one reason Einstein derisively called quantum entanglement “spooky action at a distance”.

Ironically however, quantum entanglement would form the basis of the experiments that ultimately verified quantum theory to the global physics community.

Copenhagen Interpretation

The first interpretation of quantum theory and quantum physics was published in 1927 by a team headed by Danish physicist Neils Bohr. Members of the Copenhagen team included Erwin Schrödinger, Werner Heisenberg, Eugene Wigner and Paul Dirac among others.

Heisenberg Uncertainty Principle

One central prediction of the Copenhagen interpretation is that of quantum uncertainty. Uncertainty is not a unique idea to quantum physics. We experience uncertainties every day. For example, as you read this you have no idea what is actually going to happen in that next ten minutes. That is an uncertainty.

However, there is sort of determinism in the everyday classical world. If you roll a ball or fire a gun, the trajectory of the ball or the bullet can be calculated quite accurately. You can therefore predict exactly where that ball or bullet will be at any future time; that future is said to be “deterministic”. Of course this assumes there are no external influences such as the ball or bullet encountering an unexpected obstruction.

In the quantum physics, uncertainty refers directly to the process of measurement. It is necessary to expend energy to make a measurement. To see where something is – to determine its position for example – it must be illuminated. That illumination requires photons which impact on the object to be measured. In the classical world, the objects being measured are massive compared to photons. So the light illuminating the measurement has negligible impact on the measurement accuracy and there is virtually no uncertainty in the measurement. In the quantum world however, particles are influenced by any forces exerted upon them to observe them. This results in the quantum uncertainty as expressed in the Heisenberg Uncertainty Principle.

Wavefunction *Collapse*

A central prediction of the Copenhagen interpretation is the collapse of the quantum wavefunction. As said, this is the Copenhagen quantum state transition prediction.

The wavefunction in quantum physics is a mathematical description of the quantum state of a quantum system. The wavefunction is a probability amplitude, and the probabilities for the possible results of measurements made on the system can be derived from it.

The wavefunction may be taken to be a function of all the position coordinates of the particles or the momenta of all the particles. Spin and charge can be observables for some particles, like electrons and photons.

It is not known what form the wavefunction actually takes. There have been experiments conducted in recent decades, known as “weak measurements”, which suggest the wavefunction actually exists in reality in some as yet unknown form. That it is not simply a mathematical representation used in equations with no parallel in the physical world.

The key issue is that no one knows why the wavefunction collapse occurs.

Measurement Problem

The “Quantum Measurement Problem” in quantum physics is due to two factors. One is the quantum uncertainty already mentioned that is a feature of quantum physics. The other is due to our lack of understanding as to the nature of the wavefunction collapse (or state transition).

The reason no one knows why the wavefunction collapses is that there is no mention of the collapse in the mathematics of the Copenhagen interpretation. This is a very unusual situation in physics.

Most predictions in physical theories are supported by their underlying mathematics. It is generally possible to point to specific equations and variables or variable configurations within those equations that support the theory predictions. This is not the case with the wavefunction collapse prediction in the Copenhagen interpretation.

This ambiguity is the **actual** root cause of the so-called quantum measurement problem.

Heisenberg Cut

The Heisenberg Cut in the Copenhagen interpretation represents the hypothetical boundary between quantum state and the classical world. It is not known where this boundary actually lies.

Since there is no explanation of the predicted wavefunction collapse in the mathematics of the Copenhagen interpretation, an alternative explanation had to be found.

Quantum entanglement produces an unusual situation. A quantum system must collapse to classical state before a measurement can be made. Prior to that collapse all the components ultimately involved in the measurement or observation are in principle quantum entangled.

If, for example, there is a particle’s quantum state that is to be measured, the apparatus brought in to perform the eventual measurement will in some sense become entangled with the quantum state of that particle prior to collapse and subsequent measurement.

Likewise, the experimenter conducting the experiment in some sense is could also be quantum entangled with the quantum state of the particle. If another person is witnessing the experiment, this second person will likewise become quantum entangled and so on ad infinitum. This chain of entanglement came to be known as the "Von Neumann Chain".

German physicist John Von Neumann was the first to realize the importance of this chain of entanglement and that it was the key challenge that had to be understood. A possible solution had to do with something being involved in the experiment which could not become entangled and could therefore break the chain of entanglement thus collapsing the wavefunction. But nothing could be found that served this purpose in the real world. Thus Von Neumann made a decision that might be a fatal mistake. It represents a logic error that a first year Logic student would not make. It involved explaining one unknown with another. It suggested that one unknown, namely the wavefunction collapse, could be explained by another unknown, the consciousness of the first observer.

This guess, attributed to Von Neumann, is one solution to so-called Heisenberg Cut in the Copenhagen interpretation. It is the **sole basis** for the philosophical claim that "consciousness collapses the wavefunction and thereby creates reality". There is no unique experimental support for this claim, and as said, there is no support in the Copenhagen mathematics.

Implications of Consciousness Collapsing the Wavefunction

The idea that consciousness collapses the wavefunction produces some strange outcomes. For example, as far as is known, wavefunction collapses have been going on since the dawn of the universe. If that is correct, who or what was the first observer? Humans clearly were not in existence. It is believed that in the early universe there were no living organisms: no matter, no molecules, no atoms, no particles, nothing.

One solution is to invoke a "super-observer", which is code for "deity". But in the early 20th century no scientists wanted to declare to colleagues that their new theory required the intervention of a deity. The philosophy of Idealism provided a solution with its notion that primary Consciousness creates the universe and its contents.

As a result, several physicists of this early period became converts to Idealism. This included Max Planck himself, the acknowledged father of quantum physics, who famously wrote in 1931: "*I regard consciousness as fundamental. I regard matter as derivative from consciousness. We cannot get behind consciousness. Everything that we talk about, everything that we regard as existing, postulates consciousness*". This quote is often cited by proponents of Idealism and Panpsychism in support of their philosophical assertions. But the clear question remains, did Planck and others get it wrong?

In fact as the decades progressed, many physicists converted to Panpsychism which preserves the idea that matter exists independently and that Consciousness is ubiquitous throughout the universe.

The Solvay Conference of 1927

Albert Einstein was one scientist at the time who was not enamored with the new Copenhagen interpretation. A Realist, Einstein put no stock whatsoever in the idea that consciousness in any way creates reality. At the 1927 Solvay conference in Brussels, Belgium, Einstein famously asked Neils Bohr "*do you really believe the moon is not there when no one is looking?*" reflecting his contempt for the idea that consciousness creates reality.

Bohr's reply to Einstein, as it would be to any critic in the coming decades, was to remind everyone that the goal of a scientific theory is to make accurate mathematical predictions. It was not, Bohr said, to explain the observed phenomena but to accurately predict experimental outcomes. Technically, Bohr was correct. But Einstein was unsatisfied. He proposed that perhaps there were "hidden variables" yet undiscovered in the Copenhagen interpretation that might clarify matters.

John Von Neumann also attended the Solvay Conference. He was a supporter of Neils Bohr and the Copenhagen Interpretation. Shortly after the conference, Von Neumann wrote a paper critical of Einstein's hidden variable proposal. As it turned out, Von Neumann's paper was flawed. He made an erroneous initial assumption which led to the false conclusion that hidden variable theories such as Einstein proposed would not work. But this was ignored at the time due to Von Neumann's stature. He was more famous at the time than Einstein. His paper would not be challenged until 1962, when Irish physicist John S. Bell would discover Von Neumann's fatal error. But physicists of the time uncritically accepted Von Neumann's false claim due to his fame; a situation far too common in academia even today.

Von Neumann Implications

Von Neumann had his own ideas about interpretations of quantum physics. Rather than allege that consciousness creates reality "out there" in the objective world, Von Neumann believed that the quantum physics might be more about changes in knowledge "in here"; about changing the state of our knowledge.

Von Neumann believed we are free to ask Nature whatever question we want and Nature will respond consistently provided we ask the same question irrespective of who is asking. This, Von Neumann asserted, was why replicable experiments are possible.

In the late 20th century, American physicist Henry J. Stapp took up Von Neumann's original ideas.

These concepts lead to an interesting possibility that has been contemplated by a few philosophers of science, namely the idea that Nature has global visibility to the universe; that Nature knows everything that is going on everywhere.

If this were true, Nature could influence any outcome of any endeavor to avoid critical paradoxes. This does not mean that paradoxes could not occur; clearly they do. But it does suggest that Nature can prevent critical paradoxes that would alter the history of the materialized universe.

For example, it is often said that time travel is likely not possible because if one could do so, they could go back in time and kill their grandfather before he met their grandmother, thus putting the time traveler's existence in jeopardy. But this scenario would be mitigated if Nature had global visibility across all spacetime. In that situation, the attempted assassination of the grandparent would fail because Nature would in some way intervene. It may be that the hypothetical "Grandfather Paradox" could never occur.

This leads to the interesting idea that we can imagine things which never need materialize in the universe. Ideas may not all lead to material outcomes.

Bohmian Interpretation

Motivated by Albert Einstein's argument that the Copenhagen Interpretation must contain hidden variables, American physicist David Bohm examined the mathematics of that interpretation. Bohm indeed discovered something hiding in the Schrödinger equation.

Bohm published the Bohmian Interpretation of quantum theory in 1952. He had discovered another variable hiding in the Schrödinger equation. He named the new variable the "quantum potential".

Bohm found the variable that Schrödinger and others had missed. In doing so, Bohm established several things about quantum physics, the quantum state and its transition.

He discovered the nature of the state transition was a momentum/energy transfer. Prior to this time no one actually knew what was entailed in the transition. Since the transition represents an energy transfer from the quantum to the classical realm, Bohm reasoned this could explain the outstanding question in particle physics on the origin of kinetic energy.

Since Bohm located the transition variable in the Schrödinger equation as the quantum potential, one could argue that in fact there is no "measurement problem". It had been the ostensible existence of a measurement problem that motivated Von Neumann. And it was the same measurement problem that motivated Ed Witten in 1952 to develop the "Many Worlds" interpretation of quantum physics which ultimately led to the "Multiverse" theory decades later. But as there may be no measurement problem, the ideas that consciousness collapses the wavefunction or that “many worlds” exist are unnecessary.

Bohm’s Inspiration

David Bohm was inspired by a simple classical hydraulics experiment which demonstrates drops of oil suspended in glycerin as they enfold and unfold. The experiment is not a quantum physics experiment per se, but the ideas of enfolding and unfolding of information as demonstrated in the experiment motivated Bohm’s thinking in terms of quantum physics.

The Bohmian Interpretation

Bohm suggests that there exist two aspects of Reality: an invisible Implicate Order and a visible Explicate Order. Bohm believed that active global information in the Implicate order is used by the quantum potential to create the content of the material universe, located in the Explicate Order. This is how, according to Bohm, our material universe is continually manifest into existence. This dynamic process based in the holonomic relationship of the Implicate and Explicate orders was called by Bohm a “*holomovement*”. Today, Physicist Yakir Aharanov and colleagues are currently exploring the implications of this idea in terms of a constantly regenerating universe. This represents a revival of interest in Bohm in modern physics.

There is no concept of consciousness collapsing a wavefunction in the Bohmian Interpretation. Rather all particles have known positions in the material universe at all times and are altered as necessary based on the active global information in the Implicate Order.

Bohm invoked the “pilot wave” concept to explain the motion of particles and their trajectories in quantum physics experiments. Bohm derived the pilot wave from an earlier idea of Prince Louis de Broigle called “matter wave theory”. For this reason, the Bohmian Interpretation is otherwise known as the “de Broigle-Bohm Pilot Wave Theory”.

The Bohmian Interpretation is an objective model of reality. In other words, it states that the universe is always “out there” and we are simply observers. This is in contrast to the Copenhagen Interpretation which is a subjective model of reality, implying that observations create reality in some sense.

Reaction to the Bohmian Interpretation

Many physicists and professors of physics are woefully under-informed as to this history of quantum physics. The reason lies what happed in the early 20th century in the field.

Von Neumann's flawed paper, falsely claiming the unworkability of any hidden variable interpretation of quantum theory, was still very much alive in 1952 when Bohm published his interpretation. Most physicists working at the time were aware of Von Neumann's paper and believed it to be accurate even though it would later be proved incorrect. So Bohm's proposal was generally rejected at that time and later generations of physicists were accordingly taught that the Bohmian interpretation was flawed when in fact this is not the case.

There was another reason though that the Bohmian Interpretation was not better known. That had to do with an innovation in physics called "field theory". In the mid-1950s, classical physicists began discussing field theories. The field theory is an attempt to deal with the "wave particle duality" which will be discussed later. The quantum theorists jumped on the field theory bandwagon as they developed various quantum field theories (QFTs). These included quantum chromodynamics, quantum electrodynamics, and later various String theories and Symmetry theories. These various quantum field theories occupied quantum theorists during the late 20th century.

As a result, they stopped thinking about nuances of the more orthodox aspects of the quantum theory. The Copenhagen mathematics worked. The calculations never failed an experiment. Theorists and experimentalists alike were enamored of the new quantum field theories and were unconcerned that the Copenhagen interpretation gave little guidance to the basics of quantum physics.

Later objective comparisons of the Copenhagen and Bohmian interpretations generally are favorable to the Bohmian approach. Both interpretations give the same mathematical results. Both provide complete accurate experimental predictions of all known quantum physics experiments. But only the Bohmian Interpretation offers any insights as to the actual nature of the quantum reality.

Prof. Basil Hiley was Bohm's collaborator from 1960 onward and has continued publishing in physics journals showing how the Bohmian Interpretation explains all known quantum physics experiments. David Bohm died in 1992, but his influence continued.

Bell on Bohm

Irish physicist John Stuart Bell was drawn to the Bohmian Interpretation. Bell watched its development as he was engaged in other critical physics projects elsewhere in the world.

Bell found Von Neumann's paper on hidden variables when he began to develop a mathematical model that would enable empirical testing of quantum entanglement.

Bell came to realize that Von Neumann had made false initial assumptions and had arrived at false conclusions in that paper. In other words, Bell showed that Bohm's approach was actually valid contra Von Neumann's assertions. Bell was quite vocal in his criticisms of Von Neumann in the 1960s. Here is what he had to say about it:

"The proof, when you come to grips with it, falls apart in your hands. There's nothing to it! It's not just flawed. It's just silly."

Bell's work on entanglement in the form of what came to be called the "Bell Inequalities" led him to believe that the universe must be either nonlocal or retrocausal. By nonlocal, it was meant that some form of actions must be occurring outside the Minkowski light cones of observers; that everything was not "local" as Einstein had conceived things. By retrocausal, it was meant that influences from the present could influence events in the past. Bell was concerned that retrocausality might imply philosophical "fatalism"; that we had no free will. So he chose to believe the universe is nonlocal. Most physicists of the late 20th century chose to follow Bell's thinking.

Post Quantum Mechanics – PQM

Australian Rod Sutherland was inspired by the Bohmian interpretation and its objective view of the universe. But unlike Bell and others, Sutherland rejected Non-locality and accepted Retrocausality instead.

In doing so, Sutherland maintained that all interactions could be explained if we accept that interactions or influences from our own future light cones actually occur. By eliminating nonlocality, Sutherland could explain the universe in an entirely local way to the observer but to do so he had to accept that some things happen because of future events. Retrocausality also aligns better with Relativity theory.

Retrocausal Influence from the Future

For a physicist, "retrocausation" means that events in the present affect events in the past. The implication is that causality does not always flow forward as we experience it from past through the present into the future. There is the possibility that, under specific conditions, history is not written at the time we think it is. Strangely, this thinking is consistent with some reliably observed effects in quantum physics demonstrating what are sometimes called "consistent histories".

Commenting on Sutherland's mathematics, American physicist Jack Sarfatti has noted that this retrocausal back action is restricted only to certain structures in the universe. According to Sarfatti, retrocausal back-action only occurs with specific structures believed to have evolved late in the history of the universe. Other earlier evolving structures do not produce the retrocausal influences. The early evolving structures are inanimate things like rocks, well-described by physics. The later evolving structures are more animate things like weather systems and living organisms. Thus only these later evolving structures are capable of this retrocausal influence. Sarfatti suggests this is a key aspect of consciousness; that in fact we may be in contact with our future selves. These ideas also support the notion that only living things are conscious. They confirm that there was no need for consciousness in any form in the early universe in contradiction to the dogmas of Idealism and Panpsychism.

Quantum Entanglement

Quantum Entanglement seems to involve some form of Interaction among particle states at potentially vast distances of space and time. Such interactions seem to violate Einstein's notion that lightspeed is a universal speed limit and that nothing can exceed the speed of light.
But what Einstein may have missed is that his physics of Relativity theory only apply within the universe in general and specifically within the light cone of an individual observer. Indeed, the mathematics of Relativity theory actually often breaks down beyond the light cone barrier.
This suggests that Relativity and its predictions are restricted to observations within the light cone and not beyond. Einstein seems to have believed this was because all interactions are local (within the light cone only). He seems not have realized or considered that local effects within the light cone might be due to influences external to the light cone or even from beyond the universe itself.

Physicists' understanding of entanglement matured during the 20th century as more and different experiments were conducted. Early on it was believed that entanglement could only occur in cold dry environments, and only particles could be quantum entangled. Over time newer experiments demonstrated entanglement could occur closer to room temperatures and that larger structures could also be quantum entangled in what has come to be called "Macro entanglement". The largest particles entangled to date are "Buckey Balls".

It has been found by experiment that entanglement occurs both across space and time. In other words, multiple quantum states can be correlated simultaneously in time at different locations in space apparently without limits and multiple quantum states can likewise correlate across time.

The first formal statement of an entanglement experiment was formulated by Einstein, Podalsky and Rosen (EPR) in a 1935 paper criticizing the Copenhagen Interpretation.
EPR offered a thought experiment in that paper which formed the basis for later practical experiments that verified quantum entanglement. Ironically, the authors of the paper did not believe such experiments would succeed. And yet experiments of this type continue, reliably demonstrating quantum interactions, to this day.

The first entanglement experiment was performed at Birkbeck College in London shortly after Einstein’s death in 1955. It was repeated with some loopholes by American physicist John Clauser in 1962. Those loopholes were closed by the work of Irish physicist John S. Bell. Based on that work, French physicist Alain Aspect and colleagues, working in Europe, confirmed entanglement to the global physics community in 1982. Nobel prizes have been awarded in recognition of these accomplishmets.

This experiment is easily replicated in any reasonably well-equipped modern physics laboratory. It is routinely demonstrated to second-year physics students as part of their introductory quantum physics training, since most students don’t believe quantum entanglement until they actually witness it.

An Entanglement Experiment

A basic entanglement experiment involves creating two new particles from a single particle, influencing those particles at some later point in time and subsequently measuring the particle states, comparing the results. If it is intended to demonstrate the nonlocal nature of the quantum realm, the influences and measurements must be done in such a way that they happen only after the particles are in a so-called “nonlocal” condition.

In this context, nonlocal means beyond the reach of a signal travelling at lightspeed. In other words, the experimental outcome cannot be explained by conventional local or lightspeed interactions.

For example, one might begin with a particle of light passed through a beam splitter to create two new entangled photons. The photons are entangled because they are created from a single parent photon. The two entangled particles are allow to travel through spacetime until they are far enough apart that they are in a nonlocal condition. Once this happens, one of the two particles is influenced in some way. Since these are photons, one might be passed through a filter. When either particle is tested, both demonstrate they have been affected by a filter, even though one never went anywhere near a filter.

Electrons might be influenced by changing the spin state of one particle. In these cases the other electron, when observed, shows predictable changes in its spin as well, even though it was never in any way directly classically influenced during its travel.

An important feature of all quantum experiments is that experimenters are free to choose any of the possible types of measurement they like. This suggests that free will exists, at least in terms of measurement choices. But there is a debate as to the implications of this apparent fact. In a nonlocal world the choices could be free because some form of interaction could occur at speeds faster than light. However in a retrocausal world all interactions would involve backward in time influences suggesting that the decisions made during measurement preparation were not entirely free at the time.

Dual Slit Experiment

The dual slit experiment is one demonstration of quantum entanglement. But this was not suspected when the experiment was first performed by British polymath Robert Young in 1800, a century before Max Planck proposed the quantum of action that eventually led to the development of the quantum theories and quantum physics.

This is a description of the early dual slit experiments that were similar but not identical to Young's initial experiment.

Young's initial question regarded the actual nature of light. It was thought at the time that light was particle-like. Young wished to confirm this by experiment. His findings began a long series of surprises in physics that continue to this day.

The basic setup consists of a source of light and a sheet with two narrow slits through which the light must pass. In the original experiment light was first passed through a single slit. This produced a single line of light, consistent with particle behavior. But when the same light was passed through two slits at the same time, wave-like behavior was observed in the form of what is called an "interference pattern".

At the time it was believed that multiple light particles were interacting with each other, much as waves from rocks simultaneously thrown into a body of water interact. This idea could not be tested until the late 20th century however.

Technology improvements in the 20th century made testing the interaction hypothesis possible. The new tests only allowed single particles in the apparatus at any given time. Thus interactions of multiple particles were precluded. When the dual slit experiments were repeated with the new apparatus, the same identical results were observed as before. With a single slit, particle behavior was observed and with two slits, wave behavior was observed. Clearly the result was not due to particle interactions. Something else had to be happening.

The next attempt was to determine in various ways through which slit the particles travelled. These attempts to discover "which path" information resulted in a loss of wave behavior in all cases. Any attempt to discover the actual paths taken by particles inhibited evidence of wave behavior.

American physicist John A. Wheeler proposed a "delayed choice" version of the dual slit experiment. In this version, the choice as to whether to determine which path information was made only after the particles were known to have cleared the slits. Thus whatever was happening had to occur once the particles were inside the apparatus and not before. But, no matter what precautions were taken, the particles behaved as if they were aware of the eventual intentions of the experimenters. The new protocol had only deepened the mysteries of quantum physics.

This first test of Wheeler's was conducted in outer space using a distant celestial body and an intervening "gravity lens". The gravity lens bends light from a more distant celestial body enroute to observers on the Earth. The light so bent appears as two distinct points in the night sky. Since both points of light originate from a common distant celestial source, they replicate the dual slits in the dual slit experiment. When each point in space is viewed through a telescope and selectively imaged onto a photographic plate, the results are identical to the other dual slit experiments. Of course the light in question had been travelling through spacetime for anywhere from millions to billions of years, which means that all decisions involved occurred well after the light from the distant celestial body had passed the gravity lens out in space.

One variation of Wheeler's delayed choice experiment resulted in even more bizarre findings implying that not only could a human mind influence the which path information, but could do so even when the equipment involved was powered off and unplugged. This experiment has been replicated and published. We will consider this experiment in more detail in the section on Consciousness Research.

Quantum Eraser Experiment

The quantum eraser experiment was conceived at the end of the 20th century in a final attempt to understand the true underlying working variables responsible for entanglement effects.

In this experiment, a pair of particle paths were configured with beam splitters and mirrors leading to detectors such that detector pairs would either be guaranteed to detect the particles or known not to do so. This took advantage of consistencies in the predictions of the Schrödinger equation.

In certain configurations of the apparatus, the quantum information was effectively "erased" because in those configurations it was known that specific detectors would never detect particles. This apparent paradox actually influenced not the particles directly but the underlying quantum state. Thus the quantum eraser experimental apparatus configuration seems to influence the information that underlies that quantum behavior. It is essentially using the quantum physics behaviors that had been reliably documented to influence an aspect of reality to which we apparently do not have direct access in any other way.

Influencing quantum information in this unique way suggests the working variable in all these experiments is quantum information.

This strongly implies that quantum information, whatever that might actually be, is what is governing these experimental outcomes. Put another way, it appears the universe is the way it is because of the state of information.

So it seems that reality at its most fundamental is some form of information. This suggests that neither mass/energy nor consciousness are actually fundamental to reality.

In some ways therefore, the quantum eraser experiment in particular and quantum entanglement experiments in general may be the most significant physics experiments conducted thus far.

Requirements from Quantum Theories

The summary requirements for a model of reality may be summarized as follows.

Non-Locality

In some sense the quantum reality is likely beyond the scope of the light cone of the observer, and may exist outside the known physical universe. The model must therefore accommodate these notions of nonlocality. It must specify the source of the content of the universe and at least suggest a mechanism by which this source is transferred or manifest within the universe.

The model must explain how nonlocal interactions are possible whether as apparent forces, signals, or something else entirely.

Retrocausality

The model must accommodate influences and / or signals from the present into the past and additionally potential influences and/or signals from the future of an observer.

Entanglement

A mechanism must be provided in the reality model that explains the quantum entanglement phenomena both across time and space. It must be shown how multiple particles' observed states can be correlated in a manner consistent with observations in quantum experiments.

Guidance

The model must suggest or explain how matter and energy manifests in the material universe. The model must provide an explanation for the interfaces between the universe and the more fundamental reality that might exist.

Field Theories

One set of theories in theoretical physics concerning the structure and origins of the universe is known as “field theories”. In its modern form these are the quantum field theories.

Field theories stipulate that there exists throughout the universe an unseen ever-present background known as a “vacuum”. This would imply that what we perceive as empty space is in fact not empty. In many field theories it is believed that particles either emerge from the vacuum or that states of particles already present in the universe are influenced by the vacuum.

It has been suggested anti-particles, absent in the universe, may actually reside within the vacuum, and that they can only be coaxed out of the vacuum by various high-energy reactions, such as in particle colliders.

It has also been suggested that the vacuum – sometimes called the “zero point field” – abounds with untapped energy that might one day provide unlimited fuel for the planet or future space travel. While currently highly controversial, the concept of a “polarizable vacuum” has been the subject of intense scrutiny by the U.S. Government and DARPA for many decades.

Holographic Universe

The *Holographic Principle* essentially states that it is possible to project an object of N dimensions from a surface of N-1 dimensions. In the common example of the holographic image, this amounts to a holographic image of 3 dimensions projected from a 2 dimensional surface.

The term “holographic universe” is a mathematical metaphor based on the holographic principle. Theories following the holographic principle (and often referred to colloquially as “holographic universe” theories) are actually projection theories. The basic idea is that the universe in which we live exists because it is a projection from higher dimensional spaces. For example, if we live in a 4D universe of spacetime, it might be projected in some way from higher dimensional structure.

One example of such a projection theory is known as “ADs/CFT” which stands for Anti-Desitter space, Conformal Field Theory. The details are too complex to describe here, but essentially the Anti-Desitter space represents our projected universe and the Conformal Field Theory describes the activities and connections between that dimensional base space representing our universe and the dimensional space from which that universe is projected.

One of the challenges with field theories is that the source of the source of the content of the universe is not specified. In other words, while the vacuum in field theory informs the states of particles in the universe there is no explanation for what informs the vacuum.
Cleary something more is needed.

Consciousness

It is not possible to formulate a complete "theory of everything" or a model of all reality without considering the role of subjective consciousness; that conscious experience we all undeniably possess.

In this course, we shall examine the idea that there might be philosophies that suggest Consciousness may be far more than our subjective experiences. The most prominent of these is philosophical Idealism, mentioned earlier. Another is Panpsychism: the notion that Consciousness is ubiquitous; that Consciousness is everywhere in the universe and in everything. Unfortunately, there is no empirical evidence that supports this assumption.

Consciousness Research

The principle research that informs this body of evidence comes from the science of once known as Parapsychology and now known as Conscious Research. This is the scientific study of phenomena suggestive of non-local consciousness.

The research is conducted by credentialed scientists in research centers all over the world. Many hold doctorate and post-doctorate degrees in research fields ranging from psychology to physics. They are generally senior scientists or tenured professors in academic institutions. The research follows standard scientific practices and methods for the design, execution, data collection and data analysis of the experiments and the research.

The research ranges from tests of mind-to-mind interactions, sometimes called either 'telepathy' or 'anomalous cognition' to environment-to-mind interactions, sometimes called either 'clairvoyance' or 'remote viewing'. Other psi cognitive phenomena studied scientifically include knowing the future, called 'precognition', and feeling the future, called 'presentiment'.

Overall the statistical findings in all the various tests are stable and statistically significant although the effect sizes are small. The most likely reason for this is that these studies, especially in the past, have focused on general populations since the interest has been in the degree to which these "psi" abilities are found in general populations. An unintended consequence is that the effect sizes are smaller than in studies in the so-called "hard" sciences such as chemistry. However the effect sizes in this research are similar to those in the related field of psychology research.

It is the significant and stable effect sizes that have convinced scientists working in the field that something interesting is really going on.

Critics have been unable to explain these phenomena in any scientific manner. Historically they have pointed to various possible questionable research practices and suggested the possibility of statistical anomalies, or even downright fraud on the part of participants and scientists.

All these allegations have been rigorously examined in the relevant scientific peer-reviewed technical journals, such as The Journal of Parapsychology. No successful skeptical counter-explanations have been offered and all the various criticisms over the decades have been addressed and refuted. Currently, the best counterargument from the most informed skeptical deniers of this research is that the effects observed cannot occur because they violate unspecified laws of physics. But this claim is more of a statement of ignorance on the part of the skeptic of how science works than a statement of knowledge.

Ganzfeld Studies

The Ganzfeld studies use a fixed choice design to examine the evidence for telepathy. Typically a sender views an image or a video for a 30 minute period during which the participant under test attempts to describe the target while in a mildly altered state of conscious known as the “ganzfeld” state. The ganzfeld protocol was pioneered in the 1930s by Gestalt psychologists. The statistical data from thousands of tests worldwide in dozens of research centers and investigators for over 40 years shows a consistent and significant effect size and consistent hit rates averaging 34 percent. The odds of hitting by chance due to the 1 in 4 forced-choice design is 25 percent.

Remote Viewing Studies

There are two classes of remote viewing studies. One group involves a 25 year project run by the U.S. Government beginning in the 1970s ultimately known as Project Stargate. Research was performed at SRI and SAIC on the West coast and the protocols were applied principally at Fort Meade Maryland on the East coast. The remote viewers were mainly military personnel specifically recruited and trained as remote viewers. Most all of the tests, protocols and results are now publicly available.

The statistical findings are very similar to those of the Ganzfeld studies in terms of size and stability. The effect in the remote viewing cases is well-established.

What was learned from the project is that remote viewing is indeed possible, but that it is not reliable. It is not a “silver bullet” for the intelligence community. This is not surprising since all psi phenomena are unreliable. Psychic abilities in real life are not as depicted on television and movies. But significant successes demonstrated that remote viewing might be useful as an adjunct to other intelligence gathering activities, all of which have some degree of unreliability.

Remote viewing is possible; there is also no known defense for a competent remote viewer. At the same time, remote viewing is highly unreliable even with good remote viewers. So the true risk to U.S. Government assets, information and infrastructure is probably low.

The Government program was terminated not for lack of success as critics tried to suggest, but instead because of politics. The bottom line is that it became too hot a topic politically with some managers accused by members of Congress and senior administration officials of being in league with the Devil, among other things.

Another class of remote viewing research is grounded in more commercial applications. One example is a set of studies conducted by Dr. Stephan Schwartz. These studies involved using remote viewing to located and identify archeological sites. Among the successes were locating one of the Seven Wonders of the Ancient World, the Lighthouse at Alexandria, Egypt and locating various archeological sites throughout the Western world and the Mideast.

Precognition and Presentiment

This research tests the hypothesis that we can know or feel the future. The very hypothesis is riddled with skeptical issues. If the future exists, does that mean we don’t have free will, for example? For now, we shall put those issues aside. The operant question here relates to the content of the data.

Various experimental designs have been employed. Most involve testing to see if the autonomic nervous systems of test participants react prior to a stimulus of some kind.

The working hypotheses are that 1) the autonomic nervous system cannot be controlled by participants, and 2) there is an implicit relationship between the unconscious mind and the autonomic nervous system.

The experiments in presentiment (feeling the future) test the ability to respond on the orders of minutes and seconds. Precognition experiments (knowing the future) test on the scale of hours, days or even weeks. On average, all the research shows stable and significant effect sizes in line with the respective hypotheses under test. It is clear the many people have these abilities although they are generally not recognized. Anecdotally, many people have had the experience of premonitions consistent with the predictions of precognition and presentiment.

Requirements from Consciousness Research

Nonlocality of Consciousness

If the data from Consciousness research is to be believed, it seems reasonable that subjective consciousness, our thoughts, emotions, personality traits and memories may not only be shareable but may be outside our bodies and perhaps even beyond the material universe.

Mental Interactions

The data regarding mind-mind interactions (telepathy) and environment-mind interactions (remote viewing) suggest a mechanism exists to permit such interactions. While it was thought for some time that there might be some form of signal responsible, more recent research has demonstrated that neither gravity nor electromagnetism can be that signal. So either there is another kind of signal we have yet to discover, or there is no signal and perhaps our entire concept of signals and energy is wrong.

Mind-Matter Interactions

The data regarding mind-matter interactions (micro-PK and macro-PK) suggest that some mechanism exists to permit phenomena like poltergeists and healing as well as various laboratory experiments suggestive of psychokinesis at various scales. Mind-matter interactions in general, and macro-PK examples in particular, suggest that our understanding of force laws may be inadequate.

Nature of Subjective Consciousness

As illustrated by Chalmer's "Hard Problem of Consciousness", mainstream science has not yet adequately explained even subjective consciousness which we all undeniably experience. Any model of reality must at least tentatively address the existence of subjective consciousness and provide a context to understand that form of consciousness in the broader sense of all phenomena.

Information as Fundamental

Quantum Eraser experiments strongly suggest that quantum information is the variable controlling the macro-physical outcomes of those experiments.

Consciousness research experiments suggest that subjective consciousness may be nonlocal; that it may originate outside our immediate vicinity in spacetime or that it may even originate from beyond the universe.

The inherent incomprehensibility of the quantum realm often mentioned by Bohr and Heisenberg suggests also that something beyond understanding is responsible for our existence.

The existence of uncontroversial acausal anomalies in the known physical universe suggests that causation is actually outside the universe in contradiction with the doctrine of Causal Closure which claims that all effects are produced by causes within the universe.

The success of the Bohmian interpretation of quantum theory suggests that we live in a universe that is actually a dynamical production of a hidden reality. Bohm called this hidden reality the “Implicate Order”. There might be some form of Reality Blueprint from which this production emerges, analogous to Bohm’s concept of active global information.

These findings point in one clear direction: that our universe is a production of a more fundamental reality and that the basis of all things and thoughts in the universe resides in some way in that deeper reality. And that a Reality Blueprint is the true origin of all thoughts and things in the universe.

Thus it is not matter or mind (consciousness) that is fundamental. Instead information in the form of patterns of states of mind and matter represented in the Blueprint may be fundamental to everything. Some process, residing in that hidden reality, may be responsible for realizing the content of the universe that we experience.

The term “information” is used here not in the sense of emergent knowledge as it is normally used today, but instead in the original Latin definition derived from the word “*informare”* which means “to put form into” something. In this case, to put form into the content of the universe.

Thus it may be that we live in an Information-Mediated reality.

Reality

To build a model of reality, we must necessarily speculate a bit about the structure of that underlying reality. This must be done with the clear understanding that there is little empirical basis for this speculation. We must depend on are inferences from observations and experiments from our perspective within the universe. The accuracy of these speculations is entirely dependent on the accuracy of those measurements and observations, the inferences taken from them, and the mathematics subsequently developed describing them.

What follows is one such speculation.

This model is grounded in the ideas of the Bohmian interpretation of quantum theory.

The salient ideas are that there is an information basis to reality from which emerges the content of the material universe that we observe and experience.

The universe is viewed as a continually regenerating, and therefore dynamic, entity. This implies that motion is real and that the passage of time actually occurs. We therefore experience motion and the passage of time due to the dynamic nature of this regenerating universal content and not as an illusion.

The universe seems to be continuously attached to the underlying more fundamental reality. In this sense, the universe is analogous to a parasite in the natural world; it depends upon its host for its existence. Thus we live in a produced universe hosted by a fundamental reality.

On first examination, no other universes need exist. In other words, there is no need for a “multiverse” concept on this view. It may well be case however that there have historically been multiple instances over time of universes of which the current universe is the most recent. This would be sensible if the underlying universal blueprint had been evolving as these various instances of the material universe were born, existed and died.

We see examples of such generational evolution in all species in the natural world.

Reality Blueprint

The Reality Blueprint is a conceptual structure in the model that hosts the patterns of states of matter and mind. These patterns represent states of instances of things and thoughts in the realized universe.

States of Matter and Mind

Consider the original structure of matter before the invention of field theories in modern physics. Any piece of matter consists of molecules which in turn are composed of atoms which are in turn composed of particles. On this original view then, particles are the smallest unit of matter or energy. Of course today modern physicists suspect that particles may not be the smallest unit of matter and energy. There still exists the concept of something that is fundamental to the matter/energy picture of the content of the universe. We simply have no idea what that something is. The closest metaphor in modern physics is the field.

States of Matter and Mind are represented as structures in the Reality Blueprint. We must not become too focused on the way this might be done. This idea is more metaphoric than prescriptive of what is really going on in that hidden aspect of reality.

We can think of states of matter as the observables recognized in quantum physics. Items such as position, momentum, spin and charge for example.

It is less clear as to the states involved in mind. But this is likely because we don’t have direct access to states of mind in the exterior world as we do states of matter. We rely on self-report to establish states of mind. These self-reports are necessarily provided as qualia; how it feels to be in some mental state.

Critics of Realism-based science often claim it is not possible to produce qualia from quanta. Or put another way, to emerge consciousness and mind from matter. But these objections may reflect more our ignorance of fundamental reality than an actual salient argument against the notion of emergence of mind and consciousness. The true nature and capabilities of the hypothesized hidden reality are in fact unknown to us.

Pattern Transformations

The mind and matter patterns within the Blueprint may be continuously modified by rule-based Transformations. It is sensible they are rule-based because most change is regular and in some sense predictable, even in the case of states of mind. The Transformation Rules themselves may evolve over time. This implies the entire system is continually learning. This explains our observations of species evolution over time.

As a reminder, we experience four types of transformations of states.
The less controversial local event transformations are:

. physical-to-physical	such as a falling rock breaking a tree limb
. mental-to-mental	such as spontaneous thought
. physical-to-mental	such as appreciation of art
. mental-to-physical	such as creation of something from an idea

More controversial are the same transformation when they produce nonlocal events:

. physical-to-physical	such as quantum entanglement experimental results
. mental-to-mental	such as mind-mind interactions (telepathy)
. physical-to-mental	such as environment-mind interactions (clairvoyance/remote viewing)
. mental-to-physical	such as mind-matter interaction (psychokinesis and healing)

Notably, the same four types of state transformations produce the less-controversial local events and the more controversial nonlocal events from the same nonphysical information and transformation rules.

Pattern Aggregations

Patterns may aggregate together into collections. Collections could be mind-only, matter-only or matter-mind. The matter-only collections inform the state of non-living matter found in the early universe. In physics such structures are termed ‘closed, non-dissipative, equilibrium-seeking’. They are typified by rocks about which physics has a lot to say.
The matter-mind collections inform the states of later, more complex structures. In physics, such structures are termed ‘open, dissipative, non-equilibrium-seeking’. They are typified by living matter and structures like weather systems. Thus the matter-mind collections are subjectively conscious, suggesting that all living things are conscious. The mind-only structures inform the state of minds without material embodiments. The most obvious interpretation of this structure is that it informs survival and afterlife.

Causality and Retrocausality

In physics, retrocausality does not allow backward in time communications. This is due to a concept in quantum physics called the “no–signaling theorem” thought to be due to thermodynamic restrictions and the inherent uncertainty of certain types of measurements. However, the nonlocal consciousness research data suggests it is possible to feel the future as in the case of Presentiment and to know the future in the case of Precognition.

The obvious question is in what way might the future exist? If the future is materialized, then it would seem we could not change that future. This results in fatalism; the idea that we have no free will.

Unfortunately, “free will” is another concept that is defined in a myriad of ways. For the purposes of this paper, free will is defined as: “the ability to influence the material content of an as-yet unmaterialized part of the universe.”

Following the above definition of free will, it is clear that a fully materialized static universe, where all particles are already in position in spacetime, would have no unmaterialized content and hence would not permit any form of free will as defined here. On the other hand, a dynamic universe – one that is still changing in any given observer’s future – would potentially allow, but not guarantee, free will.

One of the reasons retrocausality is limited in physics is due to thermodynamics and entropy. However this restriction might not exist in an aspect of reality with no notion of thermodynamics – that is, no mass or energy as we know it.

Fundamental Reality

Debates on multiverse theory established it is acceptable in physics to believe that different universes can have completely different physics. This works because there is no requirement for all universes to have the same physics and, in fact, the multiverse theories could fail if different physics in different universes is not allowed. This paper does not endorse multiverse theory, mainly because it is currently scientifically untestable and because it violates a basic premise held here that Nature is inherently simple and elegant. The multiverse is neither simple nor elegant in my view.

However, we can borrow the idea of different physics in different universes or aspects of reality. Thus the deep reality aspect, hidden from us, might well have somewhat different physics or extended physics compared to our known material universe.
Quantum entanglement suggests a different physics from that we routinely observe in the universe.

One of the great issues in unifying classics theories of Newton and Einstein with quantum theory is this remarkably different behavior that is found nowhere else in our observations of the universe. It is as if the quantum realm was based on a modified physics compared to the other physical laws.

In such a situation, limits imposed by concepts of mass/energy like thermodynamics and the constancy of the speed of light might not exist. And in that situation, what appear to be instantaneous interactions might be expected. This is exactly what is observed in quantum entanglement experiments.

Implications of Retrocausality

There are potential deeper implications to the idea that in some sense the future exists in an informational form as opposed to a material form. For example, it may be that both the future and the past are actually not realized; that only the present exists in material form.

If the future exists only in informational form and not yet materialized, then the reality machinery can alter the future right up to the point in time it must be materialized so it can be experienced.

This idea of “just-in-time” realization fits quite well with the idea of state transition by process in quantum physics. On this view, a process transitions the quantum state and in so doing makes classical observables available in spacetime for measurement and observation. This is the objective view of realty: an external process creates observables. Observation itself does not create the classical observables directly.

The just-in-time materialization concept also nicely explains consistent histories in quantum theory.

Nature may defer realizing outcomes until they are needed, for whatever reason including observation and measurement. This is not what we expect when we think about causation; we expect that having done something that a result necessarily immediately occurs.
But this may not be true in all cases. This would explain the strange outcomes of experiments designed specifically to test retrocausation.

Intention

In the nonlocal consciousness research there is a specific question known as the “selection problem”. This issue arises from a series of questions based on the data. These questions include: how a telepathic “receiver” locates a telepathic “sender”, or how a clairvoyant or remote viewer targets an event distant in space and/or time, or how a psychokinetic agent targets a particular object to the exclusions of others either locally or remotely, or – a bit more esoterically – how a medium knows in advance the identity of the sitter that day, or how an apparitional agent targets a percipient.

All these actions seem to involve Intention. In fact, psi abilities may be described in general as goal-seeking and intention-directed.

A bit more conventionally, it is interesting we are able to seek goals and set intentions given our cosmological insignificance. Why should we be able to do such things? It is an interesting question.

It may be that seeking goals and setting intentions are fundamental to the machinery of reality itself. And this is why we can do so.

We can think about the notion of intention by analogy to a computer system. Computer software operates on what are called “service requests”. When you use a computer, you make services requests regularly without realizing it. The computer software in turn makes other service requests as it does its work. Perhaps reality does something similar.

Like computer services requests, intentions may be prioritized. Prioritization assures that the most important requests are serviced before less important requests. The same may be true of intentions. This would explain why all our intentions do not come true. The underlying priority structure would be hidden from us, so we cannot appreciate what might be actually occurring. It may be that the deep reality mechanism has its own prioritized intentions as it too is seeking goals. If our goals and intentions conflict with higher priority goals and intentions in deep reality, we should expect our goals and intentions to go unrealized or perhaps modified or delayed. And this is exactly what happens in real life.

Of course, we can mediate these effects to a degree. Even though we cannot know what might stand in our way, we can use time to improve our chances of reaching our goals. If I intend to do something in the next few minutes, it is quite probable I will succeed, provided my goals are reasonable. But the guarantee becomes less secure if I postpone by goal for hours, days or weeks.

Thus it appears we also live in a Goal-Seeking and Intention-Directed reality.

A Hyperdimensional Reality Model

It is now possible to summarize a potential model of reality based on evidence from research and theoretical data in the fields of Relativity theory, Quantum theory and Consciousness research.

The model is of my own creation. Its principle features in summary:

Goal Seeking

Intention Directed

Information Mediated

Interaction Driven

Retrocausal

This model is derived from observations of Nature and the natural world. These observations are not based on any philosophy. Reliable anomalies are taken seriously, and less reliable anomalies are incorporated. The rationale is that any legitimate model of reality must accommodate any observation. There is no reason to reject any observations, even if they seem unlikely. In fact, a true model of reality potentially would accommodate even the most controversial observations and reports.

The key driving assumptions are: that all observations are equally likely (a departure from usual practices in theory building), that consciousness research must be taken seriously, that Nature provides us with sufficient information to speculate on potentially inaccessible aspects of reality, and that the model should be – consistent with Nature itself – simple, elegant and complete eschewing complexity.

The model is complete in that it predicts and explains all phenomena, experiences, experiments and measurements that have ever occurred or should ever occur.

REFERENCES

This is a brief reading list of books for the non-specialist audience covering the course topics.

A Most Incomprehensible Thing: Notes Toward a Very Gentle Introduction to the Mathematics of Relativity
Peter Collier, 2012

Einstein's Greatest Mistake – A Biography
David Bodanis, 2017

Entangled Minds
Dean Radin, 2006

Fashion, Fact and Fantasy in the New Physics of the Universe
Sir Roger Penrose, 2016

General Relativity from A to B
Robert Geroch, 1978

Parapsychology A Handbook for the 21st century
Etzel Cardena, John Palmer & David Marcusson-Clavertz, 2015

Physics of the Impossible
Michio Kaku, 2008

Quantum Dialogs
Mara Beller, 1999

The Scientist as Philosopher
Freidel Weinert, 2004

Transcendent Mind, Rethinking the Science of Consciousness
Imants Baruss & Julia Mossbridge, 2017

Undivided Universe – An Ontological Interpretation of Quantum Theory
David Bohm & Basil Hiley, 2004/2005

What Is Real? The Unfinished Quest for the Meaning of Quantum Physics
Adam Becker, 2018

ONLINE VIDEOS

These videos represent various levels of sophistication but all are reasonably clear and accurate presentations of the topics.

Fermilab, Dr. Don Lincoln	Fermilab - YouTube
Arvin Ash	Arvin Ash - YouTube
Science TV	ScienceTV - YouTube
Science Cliq English	ScienceClic English - YouTube
Science Cliq Relativity	Relativity - YouTube
Science Cliq Maths General Relativity	The Maths of General Relativity - YouTube