

Nonduality

A Scientific Perspective



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That eternal and infinite being we call God or Nature, acts from the same necessity from which it exists.

Spinoza

The eternal mystery of the world is its comprehensibility.

Everyone who is seriously involved in the pursuit of science becomes convinced that a spirit is manifest in the laws of the universe.

Since our inner experiences consist of reproductions and combinations of sensory impressions, the concept of a soul without a body seems to me to be empty and devoid of meaning.

Albert Einstein

The spirit of the Lord, indeed, fills the whole world, and that which holds all things together knows ever word that is said.

Book of Wisdom

There is that in me - I do not know what it is - But I know it is in me

Walt Whitman

Truly, I have attained nothing from total enlightenment.

Buddha

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Life is but a walking shadow, a poor player
That struts and frets his hour upon the stage
And then is heard no more. It is a tale
Told by an idiot, full of sound and fury
Signifying nothing

Shakespeare

To fear death, my friends, is only to think ourselves wise
Without being wise
For it is to think that we know
What we do not know

Socrates

They see only their own shadows, or the shadows of one another, which the fire throws upon the opposite wall of the cave. To them the truth would be literally nothing more than the shadows of the images. See what will naturally follow if the prisoners are released and disabused of their error. See the reality of which in his former state he had seen the shadows; and then conceive some one saying to him, that what he saw before was an illusion. His eye is turned towards more real existence, he has a clearer vision. The prison is the world of sight, the light of the fire is the Source, and you will not misapprehend me if you interpret the journey upwards to be the ascent of the soul into the world of intellect.

Wouldn't he remember his first home, what passed for wisdom there, and his fellow prisoners, and consider himself happy and them pitiable? And wouldn't he disdain whatever honors, praises, and prizes were awarded there to the ones who guessed best which shadows followed which? Were he to return, wouldn't he be rather bad at their game, no longer being accustomed to the darkness?

In the world of knowledge the idea of good appears last of all, and is seen only with an effort. When seen, its also inferred to be the universal author of all things beautiful and right, parent of light and of the lord of light in this visible world.

They are wrong when they say that they can put knowledge into the soul which was not there before, like sight into blind eyes. Our argument shows that the power and capacity of learning exists in the soul already; and that just as the eye was unable to turn from darkness to light without the whole body, so too the instrument of knowledge can only by the movement of the whole soul be turned from the world of becoming into that of being.

Plato

That eternal and infinite being we call God or Nature, acts from the same necessity from which it exists.

Spinoza

Preface

This book is about the meaning of science. There is a great deal of confusion about what science actually means, and an important goal here is to clear up that confusion. The science that is discussed here is the standard science of our day, which includes relativity theory, quantum field theory, complexity theory, and some of our most advanced science, such as inflationary cosmology and string theory. String theory is the best candidate for a theory of quantum gravity, or a “theory of everything”, which allows for unification of all the laws of the universe, and is the main focus of attention, especially as it demonstrates the holographic principle of quantum gravity. The reason to understand the holographic principle is because it allows for a scientific understanding of the nature of nonduality. This kind of scientific explanation of nonduality began when Plato wrote the Republic, continued when Spinoza wrote the Tractatus, but lately has fallen out of favor.

Science is the beautiful weapon that will guide us in this journey of discovery, by destroying false knowledge, which is the only process that ever allows for a clear conceptual understanding of the nature of nonduality. That false knowledge is inherently about the nature of the knower. This is false knowledge the knower apparently ‘knows’ about itself. The knower ‘knows’ something about itself that is untrue. We call this kind of false knowledge a false belief, or a delusion, which is only possible because the knower ‘believes’ something about itself that is untrue.

Scientific explanations can never really give the experience of nonduality, just as a map or travel guide can never give the experience of a journey to a foreign land, but they can indicate the nature of that unknown land, typically by metaphor or analogy with what is already known. They can also point out travel directions that allow one to make the journey to that terra incognita, about which nothing is known. All possible scientific explanations about the nature of nonduality are only like a map, and are best understood in that spirit. The one that makes the journey to terra incognita can only make that journey for themselves, but they can come back and give a testimony of their journey to those who have not yet made the journey. There are many testimonies that can be read about, but this is not one of them. This work only has the nature of a map. It can only describe the final destination of the journey in terms of metaphors, and can only give

travel directions about how the journey is made. There are really only two good reasons to have such a map. One is to satisfy your curiosity about the nature of the final destination without the need to make that journey for yourself, and the other is to make the journey.

Notes

There will probably never be a better description of the subjective experience of nonduality than *I Am That* by Nisargadatta Maharaj, which is to say this report is as good as it gets. The basic message of Nisargadatta can be summarized with the deceptively simple statement “Nothing but the subjective ‘I am’ is true”, or to paraphrase Shankara “The world is an illusion, the source of existence is the only truth, and ultimately there is no difference between the true nature of what ‘I am’ and the source of existence”. This book is only an attempt to give a reasonably accurate and complete scientific explanation of the illusory nature of the world, and to explain how the world is created from the source of existence.

In the beginning God created the heaven and the earth
And the earth was without form and void
And darkness was upon the face of the deep
And the Spirit of God moved upon the face of the waters
And God said 'Let there be light'; and there was light
And God saw the light, that it was good
And God divided the light from the darkness

Genesis

The non-existent was not; the existent was not at that time
An unfathomable abyss
There was neither death nor immortality
There was not distinction of day or night

That One thing, breathless, breathed by its own nature
Apart from it, there was nothing
Darkness was hidden by darkness in the beginning
All that existed then was void and formless

That which becomes, was born through the power of heat
Upon that desire arose in the beginning the first discharge of thought
Sages discovered this link of the existent to the non-existent
Having searched in the heart with wisdom
Their line of vision was extended across
What was below, what was above?
Who knows truly?
Whence this creation came into being?

He, the first origin of this creation
Whether he formed it all or did not form it
Whose eye controls this world in highest heaven
Surely he knows, or perhaps he knows not

Rig Veda

Brahman is the only truth, the world is illusion, and there is ultimately no
difference between Brahman and Self

Shankara

The whole universe is a dream, dreamed by a single dreamer.
The dreamer is Brahman.

Joseph Campbell

Brahman: the ultimate impersonal reality, underlying everything
in the universe, from which everything comes and to which it
returns.

Dictionary

The Nature of Inflationary Cosmology

Inflationary cosmology is a theory about the origin of the universe, or big bang event. It is a theory that is experimentally well confirmed from observations of the background microwave radiation left over from the big bang event. The nature of the theory is quite complex, and involves complicated aspects of quantum field theory and relativity theory, but the important point about inflationary cosmology is that its basic assumption is that the entire universe arises as a spontaneous eruption of energy from the void. That spontaneous eruption of energy, which is the big bang event, is understood as a quantum fluctuation in the energy level of the vacuum state, which of course is zero, since there is nothing in the void of empty space. The vacuum state is an inherent property of quantum field theories, like quantum electrodynamics, and a quantum fluctuation in the energy level of the vacuum state is possible because of the virtual creation of particle-antiparticle pairs, like a virtual electron-positron pair. But the big bang event is also described by relativity theory, and inherently involves the curvature of space-time geometry.

To have a consistent theory of the big bang event along the lines of inflationary cosmology requires relativity theory be unified with quantum field theory. That unification allows for a clearer conceptual understanding of how the universe is created from the void. The problem of how relativity theory is unified with quantum field theory is discussed later. Even without an understanding of the nature of that unification, it is clear from inflationary cosmology that the void is the primordial nature of existence that exists 'before' the universe is created in a big bang. The word 'before' is not used in the sense of linear time, as in a linear sequence of events, but in the sense of 'being outside' or 'in the presence of'. In some sense, the void is 'outside' or 'in the presence of' the world. An important goal of any explanation about how the world is created from the void is to explain how the void is 'outside' the world, or the world is 'in the presence of' the void.

When we speak of 'presence', we inherently imply the nature of perception. The nature of creation and perception are intrinsically related. Whatever the things are in the universe that are perceived, they must be created 'before' they can be perceived. Before the physical universe is created in a big bang event, before any perceivable things are created in the universe that can be perceived, before there is any matter, energy, information,

behavior, or even the dynamical nature of the space-time geometry of the universe, the primordial nature of existence, which is the void, must exist. Existence is 'prior to' creation and perception.

This is a powerful argument about the primordial nature of existence. If you accept inflationary cosmology, then there is no escaping the conclusion that the void is the source of existence, and 'before' anything is created, 'before' anything is perceived, the void exists. This is the standard theory of the creation of the physical universe, well accepted in the physics world, but few physicists want to contemplate what it actually means, and when they do they're often confused about it. What does it mean that the void is the primordial nature of existence?

This question cannot be answered unless we also understand the nature of consciousness. Everything that is created in the physical universe, the nature of all matter, energy, space and time, everything that can be perceived within the physical universe, is perceived by whatever the nature of consciousness is. The nature of consciousness is an aspect of existence, just as the nature of matter, energy, space and time are aspects of existence. The source of everything in existence within the physical universe is the void. Since consciousness is also an aspect of existence, it then logically follows that the void must also be the source of consciousness that perceives everything in the physical universe. Inflationary cosmology tells us how everything in the physical universe arises from the void, as a spontaneous eruption of energy that is understood as a quantum fluctuation in the energy level of the void. But can any scientific theory tell us anything about how consciousness arises in the world as a universe arises from the void? Does consciousness somehow arise from the information or behavior it perceives, or is its nature in some way fundamental, 'outside' whatever information it perceives?

Is consciousness somehow derivative of matter, energy, space and time, or is its nature in some way primordial, an inherent aspect of the nature of the void? The nature of whatever is perceived in the world constantly changes, but everyone has their own private experience that the nature of their consciousness, whatever 'it is' that perceives whatever appears to happen in the world, is always present, and it is always the same presence. That potentiality to perceive does not seem to change as whatever is perceived in the world constantly appears to change.

The private experience of consciousness is often described as the ‘theater of consciousness’. Whatever appears to happen in the world is presented on the ‘stage’ of consciousness, and the nature of consciousness belongs to the ‘one’ that is present in the ‘audience’ for that ‘play’. Consciousness is only the potentiality of the one that is present to perceive and give meaning to what is presented on that stage. Simply stated, the nature of consciousness is that which knows what it all means. With this view of things, even the mind is only a part of that stage. The nature of all sensory perceptions, emotional body feelings, thoughts, memories, forms of imagination, and mental concepts are presented on the stage of consciousness. Consciousness is the nature of that which knows what all perceptions mean. The nature of consciousness belongs to the ‘one’ that is present for all perceptions. The physicist Stephen Hawking says it as well as anyone: “Consciousness is not a quality that one can measure from the outside”, which can be rephrased as ‘consciousness is always outside any quality of the world that one can measure’. Can any theory explain how consciousness is ‘outside’ whatever is measured in the world?

Notes

A discussion of the nature of the void, inflationary cosmology, and how the entire universe is created from nothing, is found in *The Void* by Frank Close, which is also published in an edition called *Nothing*.

In all ten directions of the universe there is only one truth

Ryokan

All things arise from Tao
They are nourished by the energy of Tao
They are formed from matter
They are shaped by environment

Tao-Te-Ching

Tao follows what is natural

Tao-Te-Ching

Look deep into nature and then you will understand everything better.

Albert Einstein

No law can be sacred to me but that of my nature

Ralph Waldo Emerson

Nothing is sacred

Zen saying

The Tao that can be told is not the eternal Tao
The name that can be named is not the eternal name
The nameless is the beginning of heaven and earth
The named is the mother of ten thousand things

Tao-Te-Ching

A human being is part of a whole, called by us the Universe, a part limited in time and space. He experiences himself, his thoughts and feelings, as something separated from the rest—a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires.

Albert Einstein

The individual feels the futility of human desires and aims and the sublimity and marvelous order which reveals itself in nature. Individual existence impresses him as a sort of prison and he wants to experience the universe as a single significant whole.

Albert Einstein

The universe is sacred
You cannot improve upon it

Tao-Te-Ching

Everyone who is seriously involved in the pursuit of science becomes convinced that a spirit is manifest in the laws of the Universe

Albert Einstein

The Unification of the Laws of the Universe

About a century ago, physicists made a remarkable discovery. The laws of the universe are not arbitrary, but all arise from the nature of symmetry. For example, conservation of momentum arises from translational symmetry of empty space, and conservation of angular momentum arises from rotational symmetry of empty space. With quantum theory, momentum is quantized. The conserved quantum number called 'spin' angular momentum is simply a quantized consequence of the rotational symmetry of empty space. All the conserved quantum numbers, like electric charge, arise from some kind of symmetry. The laws of the universe, like electromagnetism and gravity, are not arbitrary, but all arise from symmetry.

Those laws can all be mathematically expressed as field theories. Fields like the electromagnetic field can be quantized. The quantized energy levels of those fields can be calculated from the field theory, and are experimentally measurable. The empirical evidence in support of quantum field theory is quite impressive. The magnetic moment of the electron can be measured, but its value can also be calculated with quantum electrodynamics. The agreement in the measured and calculated values is one part in 10^{11} , which is a remarkable degree of accuracy, similar to the precision required to measure the distance from New York to Los Angeles to less than the thickness of a hair.

Quantum field theory explains how energy is quantized in the universe. Relativity theory is the field theory that describes gravity, or the curvature of space-time geometry. The problem of the unification of the laws of the universe, which is the problem of how to unify relativity theory with quantum field theory, is inherently related to the problem of how gravity is quantized, or how space-time geometry is quantized. Quantization of space-time geometry is the problem of how the energy of the gravitational field is quantized.

The nature of electromagnetism is the electromagnetic field, which are lines of force that arise from electric charges. Positive electric charges are the sources of the field lines, and negative electric charges are the sinks of the field lines. A charged particle, like an electron, experiences a force because of those field lines, and the movement of the charged particle is determined by those forces. But the charged particle also gives rise to its

own electromagnetic field, and so any system of charged particles and electromagnetic field lines is inherently coupled. The electromagnetic field can be quantized, and the result is the point particle called the photon. The reason the electromagnetic field can be quantized is because the photon is a spin 1 particle. The photon carries intrinsic angular momentum that is quantized, which is called spin. That angular momentum is measured when we measure the polarization of light. The electromagnetic field lines can form waves, and those waves are the nature of light. The nature of the photon is a localized or quantized 'wave-packet' of electromagnetic field lines, and just like water waves, those field lines appear to travel through space over time. But water waves in the ocean are only a localized disturbance in the motion of the ocean that is otherwise at rest if not for that wave action, and those water waves only appear to travel through space over time. Is there a similar 'medium' that electromagnetic waves are a disturbance within? The answer is the void.

The modern concept of the electromagnetic field is that it arises as an excitation of energy from the vacuum state, or void. The vacuum state is the state of zero energy, which is to say there is nothing in the void of empty space. The photon is a quantized excitation of electromagnetic field energy that arises from the void. That quantized energy is quantized out of the vacuum state. All elementary particles, like the electron and the positron, are quantized excitations of some kind of field energy. In the case of the electron and positron, that field is called the Dirac field. The electron is a quantized excitation of Dirac field energy, which also can undergo wave motion. The electron only appears to move through space over time because of that quantized wave motion. The electron and the photon appear to be localized in space and time only because that wave motion is localized as a quantized 'wave-packet' of field lines. The void of empty space is the motionless background 'medium', or empty 'background space', that all quantum fields are a localized disturbance within.

The nature of the vacuum state as conceptualized in quantum field theory is somewhat confusing, since the vacuum state is characterized by the virtual creation of particle-antiparticle pairs. There are two equivalent ways to look at virtual particle-antiparticle pair production. The virtual particle and antiparticle can both be considered to carry positive energy, but the amount of energy ΔE they carry is limited by the uncertainty principle in terms of the amount of time Δt that they are created for, as $\Delta E \Delta t \geq h$, where h is Planck's constant. Virtual particle-antiparticle pairs are continuously

created out of the vacuum state, but only to annihilate each other in a short period of time. This process is called a vacuum fluctuation, and is represented as a closed-loop process. In some sense, the closed-loop process is like a particle that travels forwards in time 'half of the time', and then travels backwards in time the other 'half of the time', which is how the closed-loop process is completed. In some sense, the antiparticle of the virtual particle-antiparticle pair is just like an ordinary particle that travels backwards in time. The other way to look at the virtual antiparticle is as a particle with negative energy that travels forwards in time, in which case the total energy of the virtual process adds up to zero because energy is conserved. In this sense, virtual particle-antiparticle pair production requires no energy, since the virtual antiparticle carries an equal and opposite amount of energy as the virtual particle, and the total energy of this virtual process adds up to zero, as if nothing actually happens. Virtual particle-antiparticle pairs are created out of nothing, and annihilate back into nothing.

Particle creation and annihilation are inherent properties of all quantum field theories, and describe how particles are quantized excitations of field energy. All particles are quantized out of the vacuum state. All particle excitations of field energy are relative to the vacuum state. Particle creation and annihilation are referred to as the source and sink of those particles, or as 'disturbing' the vacuum state. In some sense, particle creation and annihilation are a form of causality, as it is always necessary to create 'before' you annihilate. The vacuum state is the 'ground state', or state of zero energy, even though it appears to be full of virtual particle-antiparticle pairs. The vacuum is often described as a 'stormy sea' of quantum fluctuations. Although the vacuum state appears to be full of virtual particle-antiparticle pairs, the vacuum state still has a total energy of zero. The nature of the void is empty space, even though there is an appearance that the vacuum state is full of virtual particles. To fully understand how the vacuum state can appear to be full of virtual particles requires the holographic principle of quantum gravity, which explains how space-time geometry is quantized, and that ultimately explains how the entire physical universe is created from the void.

The concept of fields is inherently related to the interpretation of quantum theory. All fields are understood in quantum theory to determine the probability with which some physical property of the point particle that arises from that field can be measured. The nature of the electromagnetic field is

understood to determine the probability with which the point particle called the photon can be measured at some particular point in space and time. All quantum fields are understood as probability amplitudes that determine the probability with which the point particle that arises from that field can be measured at some particular point in space and time. The fundamental nature of all fields determines the probability with which some quantized physical property of the universe can be measured, whether that quantized physical property has the nature of matter, energy, space or time.

Angular momentum is a physical property of the universe that is quantized, just like the nature of energy is quantized. When the earth orbits the sun in a nearly circular orbit, the earth moves with a momentum $p = Mv$, and orbits the sun with a radius R , where M is the mass of the earth and v is the velocity of the earth in its orbit. We say that the earth has an orbital angular momentum of $pR = MvR$, which is a conserved value as the earth orbits the sun. For simplicity of description, a perfectly circular orbit is assumed. Angular momentum is a vector quality that points in some direction, just like ordinary momentum is a vector that points in some direction. That direction is related to the plane of rotation, and points in opposite directions if the rotation is clockwise or counterclockwise. But the earth also has another kind of angular momentum due to the fact that it spins around an axis of rotation, just like a spinning top. Spin angular momentum is also a conserved value. In a very similar way, as an electron orbits an atomic nucleus in an atom, it has orbital angular momentum. But the electron is a point particle that also has an intrinsic kind of spin angular momentum called 'electron spin'. The photon is another point particle that has intrinsic spin angular momentum, which is related to the polarization of light. The nature of the quantization of momentum means the orbital angular momentum of the electron, as it orbits the atomic nucleus, is quantized in units of Planck's constant. The spin angular momentum of the electron and the photon are also quantized. But unlike orbital angular momentum, spin angular momentum can be quantized in integer units, or in half-integer units.

The photon is a massless spin 1 particle that arises from the quantization of the electromagnetic field. The photon carries no electric charge, but the photon interacts with particles that do carry electric charge, like the electron, and that interaction is the nature of the electromagnetic force. The electron is also characterized by a field, called the Dirac field. The quantization of the Dirac field results in the point particle called the electron,

which is a spin $\frac{1}{2}$ particle. The nature of gravity is also a field theory. The nature of gravity arises from the curvature of space-time geometry. The gravitational field is called the metric, which gives a measure of the curvature of space-time geometry. The nature of space-time geometry is curved because of matter and energy, which give rise to the gravitational field the same way electric charges give rise to the electromagnetic field. All matter and energy are the sources of the gravitational field. Those field lines are lines of force that determine the movement of all the matter and energy acted upon by the gravitational field, and so any system of matter, energy and gravitational field lines is coupled, just like any system of charged particles and electromagnetic field lines. But gravity is different than electromagnetism. If the gravitational field could be quantized, it would correspond to a spin 2 particle called the graviton. The problem is that there is no logically consistent way to quantize a spin 2 field theory in a 3+1 dimensional space-time, with three spatial and one time dimensions. This is the fundamental reason the concept of higher dimensions came into theoretical physics. The unification of the laws of the universe is only possible if there are more dimensions than the usual ones we are familiar with.

There is a natural way to unify the electromagnetic field with the gravitational field, called compactification. If there is a fifth dimension that is rolled-up into a small circle at each point of conventional 3+1 dimensional space-time, then the electromagnetic field naturally arises with the gravitational field. The part of the metric that corresponds to the compactified fifth dimension is the electromagnetic field. Compactification of an extra dimension is like the surface of a garden hose with an extended dimension along the length of the hose and a rolled up dimension around the circumference of the hose. Electromagnetism arises from relativity theory with a compactified fifth dimension at every space-time point. Conservation of electric charge is due to conservation of momentum in the fifth dimension, which is due to translational symmetry in the fifth dimension, but with compactification that translational symmetry becomes a rotational symmetry. The quantization of momentum in the fifth dimension gives rise to quantization of electric charge, just as quantization of angular momentum gives rise to spin. The remarkable thing is that all the fundamental forces can be unified with gravity if there are ten dimensions and six of those dimensions are compactified.

The concept of compactification seems deceptively simple, but quite remarkably, it explains how the electromagnetic field is a disturbance in

the void, just as water waves are a disturbance in the ocean. The usual three spatial and one time dimensions that we are familiar with are not the only dimensions. At every point of 3+1 dimensional space-time, there is a fifth dimension rolled-up into a small circle. Momentum can be directed in that fifth dimension, like any other direction. That momentum is quantized, and because the fifth dimension is compactified, that momentum takes on discrete integer units at every point of 3+1 dimensional space-time. Momentum is quantized into positive integer values 0, +1, +2, +3 ... when directed in the positive direction, and negative integer values -1, -2, -3, ... when directed in the negative direction. If a point of 3+1 dimensional space-time has a +1 unit of fifth dimensional momentum at that point, we say there is a quantized unit of positive electric charge at that point. Quantized fifth dimensional momentum is what we call electric charge. That fifth dimensional momentum inherently carries energy. Matter and energy are the sources of the gravitational field that measures the curvature of space-time geometry. The fifth dimensional momentum, which we call electric charge, also results in the curvature of space-time geometry. But the field that measures the curvature of space-time geometry that arises from electric charge is not called the gravitational field. It is called the electromagnetic field. Electric charge is the source of the electromagnetic field just as matter and energy are the source of the gravitational field. Both of those fields give a measure of the curvature of space-time geometry.

There are two other fundamental forces besides electromagnetism that need to be unified with gravity. The weak nuclear force is responsible for radioactive decay, and the strong nuclear force is the force that holds an atomic nucleus together the same way the electromagnetic force holds an atom together. Atoms are bound together because charged electrons exchange photons with atomic nuclei. Quarks inside an atomic nucleus are bound together because those quarks exchange point particles called gluons that give rise to the strong nuclear force the same way photons give rise to the electromagnetic force. Like the electromagnetic force, the strong nuclear force arises from extra dimensions.

All the fundamental laws of the universe naturally arise with compactification of extra dimensions. If there are ten dimensions and six of them are compactified, one for the electromagnetic force, two for the weak nuclear force, and three for the strong nuclear force, then ten dimensions allows for the unification of all the laws of the universe. The six compactified components of the metric correspond to the fundamental forces of electro-

magnetism and the strong and weak nuclear forces, while the four non-compactified components of the metric give rise to gravity. The compactified quantum field parts of the metric give rise to the spin 1 particles, like the photon, while the non-compactified parts of the metric give rise to the spin 2 graviton. The conservation and quantization of charges, like electric charge, arises naturally because of symmetry in the extra six dimensions. With ten dimensions, all laws of the universe arise from the symmetry of empty space.

There is another kind of symmetry besides the usual translational and rotational symmetries we are familiar with, called super-symmetry. The concept of any kind of symmetry depends upon geometrical concepts. The conventional way that space is conceptualized is to locate a point in space with a position coordinate x . If space is ten dimensional, then there are ten independent components labeled as $x = (x_1, x_2, \dots, x_{10})$ that represent the concept of translation in each of the ten independent directions. The concept of translation is that of movement in a straight line, while the concept of rotation is that of circular movement in a plane. Empty space is symmetric because nothing changes with either a translation or a rotation in empty space. Each component of the spatial coordinate x is allowed to take on numerical values. The allowed numerical values are called the real numbers. The real numbers include the natural counting numbers, ratios of natural numbers that are called fractions, irrational numbers like π , and the negative values of all these numbers. The counting numbers are only 'natural' because we are able to count distinct objects in the world. The very idea of a quantum number is that of an observable property of physical reality that can be counted, like the quantized units of electric charge. In some sense, the concept of all the 'natural' counting numbers arises naturally with the process of quantization and countable quantum numbers. The quantized nature of electric charge is in countable units, such as 0, +1, +2, +3, ..., and the negative values of these countable units, -1, -2, -3, ... The quantized nature of spin is also in countable units, which is why spin is labeled as spin 0, spin 1, spin 2, ..., but with the added wrinkle that spin can also take on half-integer units, such as spin $\frac{1}{2}$.

The concept of the natural counting numbers is inherent in the process of quantization, but the concept of all the real numbers is inherent in the concept of empty space itself. The nature of all the real numbers can be understood in terms of idealized geometrical concepts, such as the number π , which is the ratio of the circumference of a circle to its diameter. The con-

cept of all the real numbers arises from the concept of the symmetry of empty space. Those idealized geometrical concepts are referred to as Platonic ideals. They do not refer to the actual perceivable physical objects that can be perceived in physical reality, but to the perfectly symmetric nature of empty space itself.

All mathematical concepts arise from the concept of symmetry of empty space. But there is another kind of number that is not a real number but still allows for another kind of symmetry of empty space called super-symmetry. That number is called an anti-commuting number, and is labeled as θ . The number θ is the square root of zero, which simply means $\theta^2 = 0$. The solutions to the equation $\theta^2 = 0$ define the anti-commuting numbers. More generally these numbers obey a relationship of the form $\theta_1\theta_2 + \theta_2\theta_1 = 0$. A point in super-symmetric empty space is labeled with a spatial coordinate x and an anti-commuting number θ . In some sense, super-symmetry is a kind of translational symmetry in the super-space defined by a spatial coordinate x and an anti-commuting number θ . This symmetry underlies the quantized nature of spin angular momentum, and extends the concept of rotational symmetry that underlies the nature of orbital angular momentum. The reason for super-symmetry is that it allows for the spin $\frac{1}{2}$ particles, like the electron, to naturally arise through the process of compactification of extra dimensions, and naturally relates particles with different values of spin. Without super-symmetry, only the whole-integer spin particles, like the spin 1 photon, can arise.

Relativity theory is the field theory that describes gravity. Gravity is understood to only represent the curvature of space-time geometry. But the gravitational field carries energy, just like the electromagnetic field. We are aware of that energy when something falls in a gravitational field. The laws of the universe can only be unified if the energy carried by the gravitational field is quantized. The inherent nature of the quantization of the gravitational field is how space-time geometry is quantized. Unification of the laws of the universe is only possible if space-time geometry is quantized, which is the problem of how gravitational energy is quantized.

The gravitational field is quantized in the form of a particle called the graviton that carries spin angular momentum, just like the photon of the electromagnetic field. The quantum number 'particle spin' carried by point particles is a consequence of the rotational symmetry of empty space. A point in 3+1 dimensional space-time is labeled as (x, t) where x now only

has the usual three components. Point particles are defined in 3+1 dimensional space-time and carry 'particle spin' as conserved quantum numbers. But if empty space has a larger dimensionality, then there are more conservation laws. This is the reason a theory of quantum gravity with extra dimensions can be a "theory of everything". All the fundamental physical forces are included in quantum gravity. The laws of electromagnetism are inherent within relativity theory if there is a fifth dimension rolled up into a small circle at each point of 3+1 dimensional space-time. With a compactified fifth dimension, Maxwell's equations of electromagnetism naturally arise from Einstein's equations. Conservation of electric charge is simply a consequence of the conservation of momentum in the fifth dimension. Point particles carry electric charge as conserved quantum numbers, just as they carry spin.

Relativity theory reflects the symmetry of empty space. Translational symmetry results in the conservation of momentum and energy, while rotational symmetry results in the conservation of angular momentum. But relativity theory also reflects the principle of relativity, which states that the laws of the physical universe are identical in all frames of reference that move relative to each other with constant velocity. This means that those laws appear to be the same laws for all observers in constant velocity motion that observe them from any observational point of view. Those laws appear to be the same for all observers no matter how those observers appear to move relative to each other with constant velocity. An example of such a law is the constancy of the speed of light. The speed of light is the same velocity for all observers at all points of view, no matter how those observers appear to move relative to each other with constant velocity. This may seem strange, but simply reflects that the speed of light is a constant of nature, and takes on the same value for all observers no matter how those observers appear to move relative to each other with constant velocity, just as Planck's constant and the gravitational constant take on the same value for all observers.

Relativity theory reflects another symmetry of empty space, which is called the principle of equivalence. This principle states that there is no way to distinguish the effects of a gravitational field from the effects of an accelerating frame of reference. An apple that falls in a gravitational field, like that experienced on the surface of the earth where the acceleration due to gravity is g , will experience the same kind of motion as an apple dropped inside a space-ship that accelerates through empty space with an accelera-

tion rate $a = g$. There is no way to distinguish the effects of a gravitational field from those of an accelerating frame of reference without gravity. The principle of equivalence simply reflects the symmetry of all observational points of view, no matter what their relative states of motion. All observers, no matter what their states of motion relative to each other, have equal claim to the validity of their observations. All observers may claim that they are at rest, or stationary, and that the rest of the world moves past them, as long as they include a gravitational field in the description of their local environment. An implication of the principle of equivalence is that from the point of view of an observer in 'free fall' through empty space, the gravitational force disappears, since the effect of gravity is exactly cancelled out by the effect of acceleration. All observers, at all points of view, observe the same laws of the physical universe, which always appear to be the same laws no matter the apparent state of motion of those observers. Those laws appear to be the same no matter the apparent state of motion of the 'eye of the beholder'. At its most basic level, the principle of equivalence reflects that there is no preferred frame of reference, which reflects the symmetry of all observational points of view in empty space. There is a deep connection between this symmetry and the symmetry inherent in all the other fundamental forces unified with gravity through compactification of extra dimensions. The gravitational field arises from this symmetry as the metric, which measures the curvature of space-time geometry.

In conventional relativity theory, the space-time metric, $g_{\mu\nu}(x, t)$, measures the curvature of space-time geometry, and describes the 'shortest distance' between two points in a 'curved' 3+1 dimensional space-time geometry. Einstein's field equations for the metric determine the nature with which matter and energy 'curve' space-time geometry, and point particles follow paths that minimize the 'distance' between two space-time points. That minimized 'distance' between two space-time points is mathematically expressed as a principle of least action. In the sense of relativity theory, least action simply means the 'shortest distance' between two space-time points in a curved space-time geometry. This is just like the curved line between two points on the surface of a sphere, which is called a geodesic, and describes the shortest distance between two points on that sphere.

With a compactified fifth dimension, the electromagnetic potential, $A_\mu(x, t)$, is directly related to the extra components of the five dimensional

space-time metric, $g_{\mu\nu}(x, t)$, and obeys Maxwell's equations that are inherent in Einstein's equations. With a ten dimensional super-symmetric empty space, the fundamental laws of electromagnetism and the strong and the weak nuclear forces are inherent within quantum gravity if six of those dimensions are compactified. Those compactified extra dimensions are the only known way to unify all the laws of the universe in a mathematically consistent way.

Quantum field theories like quantum electrodynamics give a point particle description of physical reality. That description is inherently in the nature of fields. In the case of quantum electrodynamics, the Dirac equation and the Dirac field give a point particle description of the electron, and Maxwell's equations and the electromagnetic field give a point particle description of the photon. Why are these equations called wave equations? How can a point particle be described by a wave function? The wave function, $\Psi(x, t)$, is a probability amplitude that mathematically specifies the probability of measuring the point particle at a particular space-time coordinate (x, t) . A wave function is a probability amplitude that obeys the wave equation. That probability amplitude is determined at every space-time point by the wave equation and specifies the probability of measuring the point particle at that space-time coordinate. The electromagnetic field is a probability amplitude that specifies the probability of measuring the photon, and the Dirac field is a probability amplitude that specifies the probability of measuring the electron. Point particles are localizable in space-time because the probability amplitudes are localized. Field lines are localized in a 'wave-packet', which is a quantized field excitation. What is the classical limit of a quantum field theory? In the classical limit the probability amplitude specifies a particular path through space that the point particle follows over time. That classical path is parameterized as a particle trajectory $x = x(t)$, and obeys a classical equation of motion inherent in the quantum field equations through a principle of least action.

Even Einstein's field equations of general relativity are a quantum field theory. The space-time metric $g_{\mu\nu}(x, t)$ is a probability amplitude that specifies the probability of measuring the point particle called the graviton. The gravitational force between all point particles is a consequence of the exchange of gravitons, just as the electromagnetic force between charged particles is a consequence of the exchange of photons. But Maxwell's equations and Einstein's equations were not initially recognized to be quantum field theories because they do not explicitly contain Planck's constant. The

photon and the graviton are both massless particles, and so Planck's constant 'cancels out' on both sides of the equation, unlike the case for the Dirac equation for a massive electron. The reason for this can be seen in the relativistic relationship between energy and momentum for a point particle, $E^2 = p^2 c^2 + m^2 c^4$, and with the quantum correspondence between energy and frequency, $E = h\nu$, and between momentum and wavelength, $p = h/\lambda$. For the massless photon this means $c = \lambda\nu$. For a massive particle in the non-relativistic limit, where mc is much greater than $p = mv$, and we ignore terms that involve powers of $1/c^2$, the relationship between energy and momentum is given by $E = mc^2 + p^2/2m$, and Planck's constant does not cancel out of this equation.

Different field equations also appear different because they describe point particles with different values for 'particle spin'. The electron is a spin $\frac{1}{2}$ particle, the photon is a spin 1 particle, and the graviton is a spin 2 particle. Even an atomic nucleus is a bound state of point particles called quarks and gluons described by their own field equations, but those particles are not observable other than in bound states because of the phenomenon of quark confinement. The strong nuclear force does not allow for unbound quarks. All of these field equations give a point particle description of physical reality. They all determine probability amplitudes that specify the probability of measuring a point particle at a particular space-time coordinate. The probabilistic nature of quantum fields is not just a theoretical nicety. It has direct physical implications that we all experience, such as the perceivable experience that matter occupies space.

Atoms only appear to occupy space because of the probabilistic nature of quantum fields, which is usually stated as the uncertainty principle. A hydrogen atom is a bound state of an electron and a proton. The electron orbits the proton in a similar way to how the earth orbits the sun. The electron is a charged particle that radiates electromagnetic radiation as it moves around, just like the electrons in a radio antenna. Without quantum uncertainty, the electron would radiate away all of its kinetic energy, lose velocity, spiral down its orbit, and collapse at rest on top of the proton. Without quantum uncertainty, the state of lowest energy is for the electron to collapse at rest on top of the proton. This is just like a satellite in orbit around the earth that loses velocity through friction with the atmosphere and crashes to the ground. The only thing that keeps the electron in orbit is quantum uncertainty. The closer the electron gets to the proton, the less uncertainty there is in its position, but by the uncertainty principle there is

more uncertainty in its velocity, and it must move away. The resistance to atomic compression is purely a quantum effect. The electron and the quarks inside the proton are all point particles that by themselves occupy no space. Atoms only occupy space because of quantum uncertainty, and without it would collapse down to nothing.

Point particles only appear to occupy space because of quantum uncertainty, and without it, all bound states of point particles would collapse down to nothing. Without quantum uncertainty, we would not have the perceivable experience that matter occupies space. The reason our feet do not fall through the floor as we walk around is because of quantum uncertainty. If the atoms in our feet occupied the same space as the atoms in the floor, that certainty in position would result in uncertainty in momentum, which is what pushes them away. The atoms in our feet cannot occupy the same space as the atoms in the floor because of quantum uncertainty, and that is the only reason the floor holds our feet up.

How does the uncertainty principle work in practice? An electron, with electric charge $-e$, is bound to a proton in a hydrogen atom. The electron moves through space with a momentum $p = mv$, and orbits the proton in a circular orbit of radius r . The electron has kinetic energy $KE = \frac{1}{2}mv^2$ and a potential energy of attraction to the proton of $PE = -e^2/r$, which gives it a total energy of $E = \frac{1}{2}mv^2 - e^2/r$. To calculate the ground state orbit of the electron, which corresponds to the ground state energy level of the hydrogen atom, we use $p = h/\lambda$, and recognize that the ground state energy level corresponds to a single wavelength of the electron's wave function. This means that exactly one wavelength of the electron's wave function fits into the circumference of the orbit, or $2\pi r = \lambda$, which means that the electron's orbital angular momentum is quantized as $pr = h/2\pi$. This allows us to write $E = \frac{1}{2}m(h/2\pi mr)^2 - e^2/r$. This gives the total energy expressed only in terms of the radius r . For very small values of r we find E is very large because of quantum uncertainty, while for large values of r we find E becomes small. But there is an intermediate value of r where E is minimized. To find the ground state energy, we look for the minimum value of E as a function of r , which means we solve the equation $dE/dr = 0$, since the minimum value of E as a function of r is where the slope of the curve is zero. This gives us the radius of the ground state orbit as $r_0 = h^2/4\pi^2 me^2$, which is about half an angstrom, or half of 10^{-8} cm. This also gives us the ground state energy level as $E_0 = -4\pi^2 me^4/2h^2$, which is about 14 electron volts.

These are the measured values of the ground state energy level and ground state radius of the hydrogen atom. The ground state energy is a negative value because it is a bound state. To find the excited energy levels of the hydrogen atom, or the excited states, means to fit more wavelengths of the electron's wave function into the circumference of the circular orbit, or to equate $2\pi r = n\lambda$, where $n=1, 2, 3, \dots$ is an integer that labels the excited state. This gives all the excited energy levels as $E_n = E_0/n^2$, and the orbital radius of an excited state as $r_n = n^2 r_0$. These quantized energy levels are all negative in value because they correspond to bound states. As an electron makes a transition from the n th to the m th energy level, a photon is emitted with a quantized energy of $E = h\nu = E_n - E_m$, which is a quantized excitation of the electromagnetic field. A photon is emitted as an electron makes a transition to a lower energy level. The collection of all such quantum transitions specifies the spectral emission lines of the hydrogen atom.

What if the total energy of the electron is positive? Then the electron is not bound to the proton, but only scatters off of the proton as it moves around. The electron scatters off the proton the same way two billiard balls scatter off each other if they collide into each other. They exchange momentum as they bounce off each other, and momentum is always conserved in any scattering event. We understand that the exchange of momentum between the electron and proton occurs through the exchange of a photon, which is a quantized excitation of the electromagnetic field. If the total energy of the electron is positive, we say the electron has greater than escape velocity and is not bound to the proton, just like a rocket ship fired into outer space from the surface of the earth with escape velocity that is free of the earth's gravitational attraction.

Quantization of momentum is confusing because of the different nature of bound states and scattering states. Bound states only form because potential energy is negative, which is why the energy of the hydrogen atom $E = p^2/2m - e^2/r$ can take on negative values. Escape velocity for the motion of the electron is determined by $E = 0$. For a bound state, $E_n = E_0/n^2$ and $r_n = n^2 r_0$, which is possible because the total energy is negative. The wavelength of a bound state is determined by $p = h/\lambda$ and $2\pi r = n\lambda$, but since the excited states are found by minimizing the total energy with respect to r and setting $r = r_n$ for those quantized bound states, this means for larger values of n the wavelength is actually longer and behaves like $\lambda_n = 2\pi n r_0$, and the quantized values of momentum behave like $p_n = h/2\pi n r_0 = nh/2\pi r_n$. We find that angular momentum

increases for an excited state because $p_n r_n = nh/2\pi$, but an excited state actually has less momentum and a longer wavelength since we find $r = r_n$ for the orbital radius of a quantized bound state with negative energy.

The scattering states all have positive energy, and describe unbound motion. To find the scattering states, we assume r is very large, and that the electron moves in a 'box' of length L , where the size of the box, L , is the size of the universe. For very large values of r we ignore the potential energy term, which gives the total energy as $E = p^2/2m$. To quantize the scattering states, we fit an integral number of wavelengths into the box, and set $L = n\lambda$, which gives the quantized momentum states as $p_n = nh/L$. For a fixed value of L , this means that a scattering state with a higher value of momentum has a shorter wavelength and a positive energy $E_n = n^2 h^2 / 2mL^2$. These positive energy scattering states merge into the negative energy bound states, since a bound state with a large value of n is just like a scattering state with a small value of n , and those states merge together at $E = 0$.

Even these scattering states do not really represent 'free' unbound motion, since the particle is bound within a 'box' the size of the universe. There really is no such thing as unbound motion, since everything in the universe is bound within something larger than itself, and there is 'nothing' larger than the universe. That nothingness of empty space is called the *void*, which is the empty 'background space' that the physical universe is created within. That creation of the universe is called the big bang event. The reason to understand the unification of the laws of the universe is to understand the relationship of the void to the universe. That relationship is inherent in the holographic principle of quantum gravity, which we will come to shortly, once the problem of unification is dealt with.

The exclusion principle is another principle, related to the nature of spin, that also explains why atoms appear to occupy space. Spin is the conserved quantum number that specifies the amount of quantized angular momentum carried by point particles like the electron. The electron is a spin $\frac{1}{2}$ particle, and that spin can only point 'up' or 'down'. This is just like a spinning top that can only spin clockwise or counterclockwise. The exclusion principle says two electrons cannot occupy the same state, or have all the same quantum numbers. The exclusion principle explains why electrons must fill up quantized atomic orbits in pairs with opposite directions of spin, and that explains the nature of the periodic table of the elements. The

periodic table results because each quantized atomic orbital can only be occupied by a pair of electrons with opposite directions of spin. One spin points 'up' and other points 'down'. The nature of chemical reactions, the stability of matter, and the solid state properties of matter depend on the exclusion principle, since it determines how electrons are arranged in space. It also explains the quantized nature of atomic and molecular orbits, and the observed spectral lines of atoms and molecules that arise as electrons make transitions from one orbit to another and emit quantized electromagnetic radiation. Quantum field theory predicts the measured spectral lines of the hydrogen atom to an incredible accuracy of eight significant figures. This kind of accuracy is strong evidence that the mathematical description of the world in terms of quantum field theories is fundamentally a correct description.

Is it possible to explain why the nuclear and gravitational forces are attractive while the electrical force is repulsive? You bet it is. The point particle nature of the strong nuclear force is explained by quarks and gluons, but those particles can only bind together into composite nuclear particles like protons and neutrons. The quarks and gluons carry 'color charge' that comes in three varieties, unlike 'electric charge' which only comes in one variety. Free color charge cannot be observed because of the phenomenon of quark confinement, which means that quarks and gluons can only bind together into color neutral bound states.

The proton and the neutron are similar composite particles called nucleons, and are composed of bound states of quarks and gluons. Each nucleon carries one unit of 'nuclear charge', which is also called nucleon number and arises from color charge, but different values of electric charge. The nature of the nuclear force can be conceptualized as the exchange of another composite nuclear particle called the pi meson between nucleons. The pi meson is a spin 0 particle. The nature of quantum field theory for the exchange of a spin 0 particle is that 'like charges' attract. The pi meson has a mass and that explains why the attractive nuclear force is limited to the distance scale of an atomic nucleus. The strength of the nuclear force falls off exponentially over distance, with a distance scale set by the mass of the pi meson. The potential energy of attraction between two nucleons takes the form $PE = g^2 \exp(-\mu r)/r$, where g sets the strength of the nuclear force, r is the distance between the two nucleons, and μ is a parameter related to the mass of the pi meson that sets the distance scale of the strong nuclear force. The parameter $\mu = 2\pi mc/h$, where m is the mass of the pi

meson. This gives the distance scale of the strong nuclear force as $1/\mu$, which is about 10^{-13} cm. The electromagnetic force is due to the exchange of spin 1 photons between electrically charged particles. The nature of quantum field theory for the exchange of a spin 1 particle is that 'like charges' repel and opposite charges attract. The potential energy of attraction between an electron and a proton takes the form $PE = e^2/r$, where e is the charge of the electron. An interesting fact about the charge of the electron is that the fine structure constant, $\alpha = 2\pi e^2/hc$, is approximately $1/137$. The photon is a massless particle and so the strength of the electromagnetic force has no exponential fall off over distance. The graviton is also a massless particle and so gravity also has no exponential fall off. The gravitational force is due to the exchange of spin 2 gravitons between all particles. The nature of quantum field theory for the exchange of a spin 2 particle is that 'like charges' attract. The nature of 'gravitational charge' is the nature of all matter and energy. The potential energy of attraction between two masses, m and M , takes the form $PE = GmM/r$, where G is the gravitational constant.

Where does the potential energy of attraction come from? The potential energy of attraction is due to the exchange of point particles like gravitons, photons and pi mesons between other particles, like protons and electrons. The potential energy of attraction is a solution to the wave equation for the wave function that describes the behavior of the point particle of interest, which are Einstein's equations for the graviton and Maxwell's equations for the photon. Even the behavior of the pi meson is described by a wave function that obeys a wave equation called the Yukawa equation. The essential nature of this kind of solution can be seen in the relativistic relationship between energy and momentum for a point particle $E^2 = p^2c^2 + m^2c^4$, and with the quantum correspondence between momentum and wavelength $p = h/\lambda$. For an attractive force that can form bound states, like the bound state of a hydrogen atom as an electron orbits a proton in a circular orbit of radius r , the wavelength of the electron's wave function behaves like $\lambda = 2\pi r$. But the electron is only bound to the proton because of the exchange of photons, and the photons that are exchanged also have a wavelength that is determined by the size of that orbit. In three spatial dimensions, the photons exchanged between the proton and the electron are contained within a sphere with surface area $A = 4\pi r^2$. This means that the force of attraction must behave like $1/r^2$, and the potential energy of attraction must behave like $1/r$, but with a distance scale that is set by $\mu = 2\pi mc/h$, which is zero for the massless photon.

The nature of a force is better understood if we imagine that the photons that are exchanged between the proton and the electron are composed of field lines, or electromagnetic 'lines of force', which exert forces on those charged particles. Those lines of force have a certain amount of 'flux', which we can imagine as the total amount of field lines 'emitted' from the positively charged proton per unit of time. The proton is the 'source' of the field lines, and the negatively charged electron is the 'sink' that absorbs those field lines. If the flux is constant, then the total amount of field lines that cross the surface of a sphere of radius r that is centered at the position of the proton is constant. As we look at larger spheres, the surface area $A = 4\pi r^2$ of those spheres increases. Imagine that the electron is located on the surface of that sphere. The force the electron experiences due to the field lines 'emitted' by the proton in some sense is like the flux of those field lines per unit of surface area, which is why the electromagnetic force falls off as $1/r^2$. If the same number of lines of force cross the total surface of the sphere per unit time, then the number per unit surface area per unit time falls off as $1/r^2$. This is just a consequence of a point source for the lines of force and three spatial dimensions. The force of attraction between the proton and electron is related to the potential energy of attraction as a gradient in space, which is mathematically written as $F(r) = -dV(r)/dr$, and is why the potential energy $V(r)$ behaves like $1/r$.

What is the nature of nuclear fusion and fission? The strong nuclear force is much stronger than the electromagnetic force, but only operates over the short distance scales of an atomic nucleus, while the electromagnetic force operates over all distance scales. As two protons get very close together, they fall into a very deep well of nuclear attraction, which overcomes the electrical repulsion of two protons for each other. Two protons must get very close together before they can bind together in the atomic nucleus and overcome their electrical repulsion. The two protons fuse together as they fall into a deep well of nuclear attraction.

But there is a limit to how many protons can be added to an atomic nucleus because the nuclear force is short ranged and limited in the distance scale that it operates over. If the nucleus becomes too large, then electrical repulsion wins out over nuclear attraction, and the protons repel and fly apart. Nuclear fission is due to the weak nuclear force that turns a neutron into a proton, an electron, and a neutrino. The electron and the neutrino fly away, but the extra proton hangs around inside the atomic nucleus. That extra proton is the reason the nucleus is too large to hold together and

falls apart. What is the nature of the energy released in nuclear fission? That energy is electromagnetic energy that is released as electrically charged protons repel and fly apart.

The point particle explanation for the energetic nature of the physical universe is inherent within quantum field theory. The exchange of a massive spin 0 particle, the pi meson, results in a short range attractive nuclear force; a massless spin 1 particle, the photon, results in a long range repulsive electromagnetic force; and a massless spin 2 particle, the graviton, results in a long range attractive gravitational force. Spin 2 drives the universal direction of gravitational collapse, and allows the bound states of galaxies, stars and planets to form. Spin 1 allows electrically neutral atoms and molecules to form, and for atoms and molecules to bind together into larger bound states because of the uneven distribution of electric charge within atoms and molecules, which is the nature of all chemical bounds. Spin 0 allows nucleons to fuse together into atomic nuclei, and for stars to burn their nuclear furnaces and radiate electromagnetic radiation. There are also two massive spin 1 particles, the W and Z particles, which mediate the weak nuclear force, and allow for radioactive decay and nuclear fission.

The fundamental forces of the universe are all due to symmetry, but the nature of that symmetry is super-symmetry of ten dimensional empty space with six rolled-up dimensions. The nature of 'charge' is the nature of momentum quantized in those extra compactified dimensions. The reason electric charge is quantized, with positive and negative values, is compactification, with the fifth dimension rolled-up into a small circle at each point of 3+1 dimensional space-time. To see how this is possible, use the fundamental relationship between momentum and wavelength, $p = h/\lambda$, and recognize that if the fifth dimension is rolled-up into a circle of radius r , then the circumference of that dimension is $2\pi r$. Quantization of momentum means we fit an integral number of wavelengths into the length of the circumference, or $2\pi r = n\lambda$, where $n=0, 1, 2, \dots$ are the allowed quantized integer units of electric charge, and the quantized values of momentum are $p_n = nh/2\pi r$.

Quantized momentum in the fifth dimension, directed in the 'positive' or 'negative' direction, is the nature of electric charge. The three 'color charges' of the strong nuclear force, carried by quarks and gluons, correspond to another three rolled-up dimensions, and the two 'weak charges' of the weak nuclear force, carried by the W and Z particles, correspond to another two rolled-up dimensions. Ten dimensions is the only possible

way all the fundamental forces can be unified. In the language of group theory, the symmetry of the 3+1 non-compactified dimensions is represented by $SO(3, 1)$, and the symmetry of the six compactified dimensions is represented by $U(1)$, $SU(2)$, and $SU(3)$, but the source of all these symmetries is ten dimensional empty space.

Unification of all the laws of the universe is possible with tens dimensions, if six of those dimensions are compactified. The remarkable thing is a ten dimensional theory can be quantized, but that theory is no longer a field theory that describes the behavior of point particles. That theory is a string theory that describes the behavior of one dimensional objects, called strings. The absolutely remarkable thing is that string theory can only be quantized in ten dimensions. There is no logically consistent way to quantize a string theory except in ten dimensions.

But the most remarkable thing about string theory is that it is not a theory of one dimensional objects at all. String theory is a theory of two dimensional surfaces. The two dimensional surfaces that naturally arise from string theory are surfaces of quantized space-time. That describes how space-time geometry is quantized, and solves the problem of how the energy of the gravitational field is quantized. String theory gives a logically consistent mathematical algorithm that describes how surfaces of quantized space-time are constructed from a larger empty space. The surfaces constructed from that empty space are embedded within that empty space. The nature of the algorithm, as it starts with the fundamental equations of string theory and ends up with the surfaces of quantized space-time, is a little hard to decipher, but the end result is the surfaces of quantized space-time encode quantized bits of information in a way analogous to spin variables.

The nature of spin variables is to encode quantized information. For example, a spin $\frac{1}{2}$ variable can either point 'up' or 'down', which is analogous to a '1' or '0', or a switch in the 'on' or 'off' position. A spin $\frac{1}{2}$ variable encodes information in a binary code, just like a sequence of 1's and 0's encodes information in a binary code. Spin is quantized angular momentum that can only point in certain quantized directions, such as a spin $\frac{1}{2}$ variable that can only point 'up' or 'down'. There is a tendency for different spin variables to align with each other. Spin alignment is a quantum phenomenon that allows spin variables to 'point' in the same direction, and is the fundamental quantum process that allows angular momentum to add together. There is a subtlety about the nature of spin alignment that has its

origin in the nature of symmetry, and is reflected in the exclusion principle. A spin $\frac{1}{2}$ variable behaves like an anti-commuting number $\psi_1\psi_2 + \psi_2\psi_1 = 0$, while a spin 1 variable behaves like a commuting number $\phi_1\phi_2 - \phi_2\phi_1 = 0$. That difference in behavior is expressed in the tendency of spin $\frac{1}{2}$ variables to anti-align with each other, or point in opposite directions, while the tendency for spin 1 variables is to align together and point in the same direction.

The problem of how to unify gravity with the other fundamental forces is the problem of how to quantize the gravitational field, which is the problem of how to quantize space-time geometry. The gravitational field is the metric, which gives a measure of the curvature of space-time geometry. String theory fundamentally answers the question of how space-time geometry is quantized. Space-time geometry is quantized on surfaces. The fundamental unit of space-time geometry is called the Planck area, which is about 10^{-65} centimeter squared. Each surface of quantized space-time geometry is composed of fundamental Planck areas. String theory also demonstrates the holographic principle of quantum gravity. Each fundamental element of quantized space-time geometry, or Planck area, encodes one bit of quantized information. Information is encoded on each Planck area with a quantized bit of information that is analogous to a spin variable.

String theory demonstrates that space-time geometry is quantized on surfaces, and each fundamental element of quantized space-time geometry encodes a quantized bit of information, which is analogous to a spin variable. String theory is a theory of surfaces of quantized space-time geometry. Those surfaces all encode information, with one bit of quantized information per quantized Planck area, which is like a pixel on a viewing screen. The information encoded on the surface defines everything that appears to happen in the three dimensional world bounded by that two dimensional bounding surface. String theory is holographic because everything that appears to happen in that apparent three dimensional world is like a holographic projection from the viewing screen.

The nature of a hologram is a two dimensional surface that coherently encodes information. The holograms we are familiar with are pieces of photographic film that coherently encode information for three dimensional holographic images. Coherent means to cohere, or hold together, as a bound state. The information for the three dimensional image encoded on the two dimensional film is encoded in a coherent way, as a bound state

of information. There is no actual image on the film, but rather a coherently organized interference pattern. That coherently organized interference pattern is produced by the coherent light emitted from a laser. That coherent light arises from a phase transition inside the laser. The laser emits quantized electromagnetic radiation that is coherently organized due to a quantum transition that results in all the light waves aligned with each other. The quantum transition inside the laser occurs as a large group of electrons all make the same transition from one quantized energy level to another energy level, and results in the emission of quantized electromagnetic radiation that is coherently organized because all the electromagnetic waves are aligned with each other.

That alignment is inherently the alignment of spin carried by spin 1 photons. The coherent organization of the behavior of the photons is reflected in the interference pattern that develops on the photographic film, which is also coherently organized. There is no image on the film, only an interference pattern. If the film is cut in half, it still projects the same holographic image, but the image is degraded because half the information for the image is lost. The information for the image is encoded everywhere on the film, which is what coherent means. If part of the film is lost, some of that information is lost, but the remainder of the film still projects the same, although degraded image. The microscopic level at which information is encoded on the film is about a micron, or 10^{-4} centimeters, which is about the wavelength of visible light, or the distance between distinct lines of the interference pattern. A piece of holographic film encodes information with a density of about one bit of information per 10^8 centimeter squared. That is the big difference between a conventional hologram and a surface of quantized space-time, which encodes information with a density of about one bit of information per 10^{65} centimeter squared. The density of information is the only reason why conventional holograms look fuzzy compared to the 'real' world.

String theory demonstrates the holographic principle, and directly shows how a two dimensional surface of quantized space-time encodes all the information for the three dimensional world that is bounded by that surface. All the information for the world is encoded on the surface by some kind of 'matrix' variables, which are analogous to spin variables. Matrices give a mathematical representation of spin. The surface of quantized space-time acts as a holographic viewing screen and holographically encodes all the information for the three dimensional world bounded by

that surface. The laws of that three dimensional world, expressed in terms of relativity theory and quantum field theory, arise from the way information is holographically encoded on the surface. Holographic means all the information for the three dimensional world is encoded on the bounding surface. Whatever forms are perceived in that three dimensional world are analogous to holographic images that are projected from the surface of quantized space-time, and are perceived at a point of view. To quote Leonard Susskind: "In a certain sense the world is two dimensional and not three dimensional as previously supposed".

Quantum field theory in 3+1 dimensional space-time only gives a point particle description of physical reality that holographically corresponds to the viewing screen description of quantum gravity defined on two dimensional surfaces of quantized space-time. That holographic description is only possible because each fundamental element of quantized space-time geometry, or Planck area, encodes a quantized bit of information defined in a way similar to a spin variable. All of those quantized bits of information are coherently organized on the viewing screen. Coherent organization allows for the projection of holographic images.

The nature of any quantum field theory, $\psi(x, t)$, only mathematically specifies the probability of measuring the quantized physical properties of a point particle at some 3+1 dimensional space-time coordinate. The quantized nature of 'particle spin' that is carried by point particles holographically corresponds to the coherent organization of some kind of fundamental spin variables defined on the viewing screen. As empty space is quantized into surfaces of quantized space-time, the rotational symmetry of empty space is broken, and that is why each fundamental element of quantized space-time encodes information as a spin variable. The symmetry of empty space is broken as each fundamental spin variable points in some particular direction, and as the spin variables tend to align together. All the information for any three dimensional world described by a quantum field theory is defined on a bounding surface of quantized space-time, and obeys the laws of the universe, which in their most fundamental form are the computational rules of quantum gravity. Those point particles can bind together into the bound states of macroscopic objects, but all the information for those objects is defined upon the viewing screen, with one bit of quantized information defined per Planck area. A Planck area encodes a bit of information, and acts just like a pixel on the viewing screen.

A macroscopic object is only a bound state of information defined on a surface of quantized space-time that is a bounding surface that defines an apparent three dimensional world. All information for that world is defined on the viewing screen, and is encoded with some kind of fundamental spin variables. The only reason information binds together on the viewing screen is because of the tendency for spin alignment. The tendency for spin alignment is the very same tendency that results in the nature of the coherent light emitted from a laser, which allows for the physical phenomena of holography. The viewing screen is holographic only because of the tendency for spin alignment, which is the basis for all coherent organization. The formation of any bound state of information is holographic in nature. The surface of quantized space-time is just like a holographic viewing screen that holographically defines everything that appears to happen in the apparent three dimensional world bounded by that two dimensional surface. Whatever forms are perceived in that apparent world are like holographic images that are projected from the viewing screen and are perceived at a point of view.

Notes

The laws of the universe, the problem of unification, and string theory are all discussed in *The Elegant Universe* by Brian Greene. The holographic principle is discussed in *The Black Hole War* by Leonard Susskind. Quantum field theory, symmetry, and symmetry breaking are discussed in *Quantum Field Theory in a Nutshell* by A. Zee.

To see a world in a grain of sand
And a heaven in a wild flower
Hold infinity in the palm of your hand
And eternity in an hour

William Blake

There was a time when meadow, grove and stream
The earth and every common sight
To me did seem

Appareled in celestial light
The glory and the freshness of a dream

William Wordsworth

Never the spirit was born
The spirit shall cease to be never
Never was time it was not
End and beginning are dreams

Bhagavad-Gita

Before Abraham was, I am

Gospel of John

I am satisfied with the mystery of the eternity of life and with the awareness and a glimpse of the marvelous structure of the existing world, together with a devoted striving to comprehend a portion of the Reason that manifests itself in nature.

Albert Einstein

All the world's a stage
And all the men and women merely players
They have their exits and their entrances
And one man in his time plays many parts

Shakespeare

We are such stuff as dreams are made on
And our little life is rounded with a sleep

Shakespeare

To sleep: perchance to dream: ay, there's the rub;
For in that sleep of death what dreams may come
When we have shuffled off this mortal coil

Shakespeare

If the doors of perception were cleansed
Everything would appear as it is, infinite

William Blake

The Holographic Principle

Second Law of Thermodynamics

String theory demonstrates the holographic principle. Space-time geometry is quantized on surfaces, with one bit of quantized information encoded by some kind of fundamental spin variable per Planck area, the fundamental element of quantized space-time geometry. But string theory is not necessary to understand the nature of the holographic principle, which is already inherent in the nature of relativity theory, quantum field theory and the second law of thermodynamics.

The second law is all about how energy flows in the universe from more ordered states to less ordered states of information, or how entropy increases. Entropy is a measure of the amount of disordered information in any state. The nature of the flow of energy through the universe is for entropy to increase as energy flows, which is to say energy flows from more ordered to less ordered states. The most ordered state of the universe is the big bang event, which is characterized by a uniform distribution of matter and energy. As that matter and energy falls together under the influence of gravitational attraction, the universe becomes more disordered, with more entropy. The most disordered bound state of the universe is the black hole, which is a state of maximal gravitational collapse, and maximal entropy. The flow of energy through the universe is always directed from the big bang event to the black hole, which is what the second law is all about.

The nature of entropy is simply that of disordered states of information. The nature of disordered information is inherently related to the nature of energy. Energy always has a kinetic aspect and a potential aspect. For example, as a water molecule moves around it has kinetic energy because of its velocity. In non-relativistic physics, the kinetic energy of an object with a mass of m and a velocity of v is expressed as $KE = \frac{1}{2} mv^2$. If we have a system of water molecules that are moving around very fast, that system takes the form of hot water vapor. The water molecules act like little billiard balls, and tend to scatter off of each other as they collide into each other. Since the water molecules tend to scatter off of each other randomly, they tend to scatter into random directions of motion.

The entropy of that system of water molecules is a measure of their random motions. Since they collide into each other randomly, they tend to

scatter off of each other into random directions of motion. A hot collection of water vapor that appears to be at rest is not really at rest, since all the water molecules move around very fast in random directions of motion. We cannot perceive the movement of each individual water molecule, but we can perceive the heat of the water vapor, and that heat is a reflection of that random molecular motion.

Even the apparent random motion of the water molecules is not really random, but only reflects our ignorance about the motion of all the water molecules. The movement of the water molecules is determined by the same laws of motion that determine the movement of everything else in the physical universe, and those deterministic laws of motion are not random, but our knowledge of that complex motion is incomplete. In some sense, entropy is a measure of the information that we are ignorant about, which is the detailed nature of that molecular motion. That molecular motion can occur in many different ways and we will still perceive the gas of hot water vapor in the same way. In a similar sense, entropy is a measure of all the different ways that complex motion can occur at a microscopic level in order that the gas of hot water vapor appears to be the same at a macroscopic level of observation. That is the nature of the disordered information that we are ignorant about.

The absolute temperature, T , of the water vapor is defined in terms of average kinetic energy of each water molecule as $KE = \frac{1}{2}mv^2 = 3kT/2$, where k is called Boltzmann's constant, and relates the average kinetic energy of each molecule to absolute temperature. The factor of three arises from the three independent directions of motion in three spatial dimensions. The velocity vector is written in terms of those three components as $v = (v_1, v_2, v_3)$, and $v^2 = v_1^2 + v_2^2 + v_3^2$. Each independent component of the velocity vector contributes an amount $\frac{1}{2}kT$ to the total kinetic energy of molecular motion measured by temperature, and so three independent directions of motion results in the factor of three. The entropy of the water vapor, which is a measure of the disordered movement of the molecules as they tend to move in random directions, is also related to the temperature. The entropy is a measure of the total amount of disordered kinetic energy, or heat, in the system of water molecules. The definition of heat is disordered kinetic energy, which is what we perceive when we perceive the heat of the water vapor.

The water molecules have another kind of energy besides their kinetic energy, which is called potential energy. If two water molecules get close

enough to each other, they have the potential to stick together because of electromagnetic interactions. If two water molecules get too close together they repel each other, which is why they tend to scatter off of each other like billiard balls if they collide. The only reason the water molecules appear to repel each other is because of quantum uncertainty. Without quantum uncertainty, the lowest energy level of the water molecules would be for all the electrons to collapse at rest on top of the atomic nuclei as they radiate away photons of electromagnetic radiation, and in that case the system of water molecules would collapse down to nothing. The water molecules only appear to occupy space because of quantum uncertainty, and that is also why they appear to scatter off of each other like billiard balls.

If the molecules are too far away from each other they hardly interact with each other at all, and they tend to move around freely. But there is an intermediate distance where the two water molecules attract each other. Each water molecule is electrically neutral, but it is a bound state of electrons and atomic nuclei, and so there is an uneven distribution of electric charge in space. As two water molecules approach each other, the electrons in one water molecule tend to exchange photons with the atomic nuclei in the other water molecule, and because of the uneven charge distribution, there is a net electrical attraction between the water molecules, just as there is an electrical attraction between an electron and a proton. The nature of the electrical force is that like charges repel and opposite charges attract, and that is the reason the electric charges arrange themselves in space in such a way as to minimize the electromagnetic energy of that spatial arrangement. We recognize that spatial arrangement in crystals, such as when water freezes into crystalline ice and the water molecules take on relatively fixed positions in that crystal arrangement. The attraction of two water molecules for each other, separated by an intermediate distance where attraction can occur, is their potential energy of attraction, which tends to bind the two water molecules together, just as the electromagnetic force tends to bind an electron to a proton to form a hydrogen atom. That potential energy of attraction determines an escape velocity, which is similar to the escape velocity a rocket ship fired from the surface of the earth requires to break free of the earth's gravitational attraction and escape into outer space.

If one object attracts another object, those two objects can bind together, like the rocket ship that is bound to the surface of the earth by the earth's gravitational attraction. The only way an object can break free of the

attraction of another object is if that object acquires escape velocity, which is the velocity required to break free of the attraction. If the potential energy of attraction is called PE, then the velocity required to break free of that attraction, which is the escape velocity, is determined by zero total energy $E = KE + PE = 0$, or $KE = -PE$. This means that if the kinetic energy of the object is greater in magnitude than the potential energy of attraction, the object moves freely. If the kinetic energy of an object is greater than the potential energy of attraction to another object, then that object is unbound to the other object and moves freely because it has greater than escape velocity. But if the kinetic energy is less than the potential energy of attraction to another object, then that object is bound to the other object, and it does not move freely because it has less than escape velocity. The potential energy of attraction of a rocket ship on the surface of the earth is given by $PE = -GmM/R$, where G is the gravitational constant, M is the mass of the earth and R is the radius of the earth. Since $\frac{1}{2}mv^2 = -PE$ determines the escape velocity of the rocket ship, this gives $v^2 = 2GM/R$. Escape velocity from the surface of the earth does not depend on the mass, m , of the rocket ship, but only on the strength of the earth's gravitational attraction. Another example is an electron bound to a proton in a hydrogen atom. For an orbit of radius r , potential energy of attraction is $PE = -e^2/r$, and escape velocity for the electron is determined by $\frac{1}{2}mv^2 = e^2/r$. In a very similar way, the escape velocity of two water molecules depends on the strength of their electromagnetic attraction for each other. The escape velocity simply represents where the total energy of the system is zero, since it is determined by kinetic energy equal to the magnitude of the potential energy of attraction. The reason total energy can be zero is because potential energy takes on negative values for attractive forces like gravity. We write the total energy as $E = KE + PE$, but with an attractive force, we inherently imply that the potential energy of attraction is a negative value, and so $E = 0$ determines an escape velocity.

If the two water molecules have greater than escape velocity, they move freely. But if the two water molecules have less than escape velocity, they are bound together, just like an electron that is bound to a proton in a hydrogen atom. The phenomena of water molecules binding together is called a phase transition, and explains how water vapor condenses into liquid water. If the average velocity of a water molecule in a system of water vapor is greater than escape velocity, then the water molecules are unbound and move around freely. If the average velocity of a water mole-

cule is less than escape velocity, then all the water molecules bind together and condense into liquid water. The transition of the system of water molecules from water vapor to liquid water is called a phase transition, and only depends upon the balance between kinetic energy and potential energy in the system. If the amount of kinetic energy in the system is greater than the amount of potential energy, which is a hot system with a high temperature, then the water molecules tend to move around with greater than escape velocity. They move around freely, and the system remains in the state of water vapor. But if the amount of potential energy in the system is greater than the amount of kinetic energy, which is a cooler system with a lower temperature, the water molecules tend to move around with less than escape velocity and bind to each other, and the system condenses into the state of liquid water. The determinate factor is the temperature, or average amount of kinetic energy, in the system. The phase of the system is determined by the balance between potential energy and kinetic energy, and as that balance is altered, a phase transition can occur. The amount of kinetic energy in the system is related to the entropy of the system because the movement of all the water molecules in the system tends to be randomly directed, which means the kinetic energy is disordered.

Atoms are in constant motion due to the kinetic energy of atoms, which is related to absolute temperature as $KE = \frac{1}{2}mv^2 = 3kT/2$. A gas is considered to be a collection of atoms or molecules that are unbound to each other, and so they move around freely. For example, hot water vapor is a gas of water molecules. The reason the water molecules move around fairly freely is because they move so fast that their motions overcome any electromagnetic attractions between the molecules. The hotter the temperature of an object, the faster the molecules move at an atomic level. Hot water vapor is a gas because it is hot, which means all the molecules move around with a lot of kinetic energy. The amount of kinetic energy in the gas of hot water vapor is greater than the amount of potential energy that defines an escape velocity for the water molecules to bind together and condense into liquid water due to their electromagnetic attractions for each other, which is to say the total energy $E = KE + PE$ in the system of water molecules is positive. Of course, if the system of water vapor is bound to the surface of the earth due to gravity, there is also the negative potential energy of gravitational attraction, which is why the water vapor in the atmosphere cannot escape from the earth's gravitational attraction. The total energy of an object as it moves around under the influence of some force is a constant, which is to say that the total energy is conserved.

This means that as potential energy increases, the kinetic energy of the object must decrease. This is as much the case for the total energy of the earth as it orbits the sun in the sun's gravitational field as it is for the motion of a molecule as it moves in the electromagnetic field generated by other molecules. Those fields are 'lines of force' that exert forces on the charged particles, like the electrons and atomic nuclei, that those molecules are composed of.

The potential energy of the object is energy that can be converted into kinetic energy by virtue of the force applied to the object. For example, as an object of mass m falls in the earth's gravitational field it moves faster and faster as gravitational potential energy is converted into kinetic energy. For the earth's gravitational field, the gravitational potential energy is $PE = - GmM/r$. The total energy of the object as it falls is then given by $E = \frac{1}{2}mv^2 - GmM/r$. This total energy is constant until the object hits the ground, and the kinetic energy of the object is transferred to the earth. This is referred to as the conservation of energy. As the object falls toward the ground, its distance from the center of the earth becomes smaller and so the term GmM/r becomes larger. Since this term is subtracted from the kinetic energy term, for the total energy E to remain constant means that the kinetic energy must increase. This means the object's velocity must increase. As the object falls it moves faster and faster. If we let x equal the height of the object above the surface of the earth, then we can write the distance of the object from the center of the earth as $r = R + x$, where R is the radius of the earth. Since R is much larger than x , we can approximate

$$\frac{1}{r} = \frac{1}{(R+x)} = \frac{1}{R(1+x/R)} = \{1 - x/R + \dots\} / R,$$

and the total energy of the object is given by $E = \frac{1}{2}mv^2 - GmM/R + mgx$, where the acceleration due to gravity on the surface of the earth is given by $g = GM/R^2$. As the object falls, gravitational potential energy is converted into kinetic energy.

At this point, it's worth a brief remark about the relationship of mathematics to science. It is just not possible to have an accurate scientific understanding of the world without mathematics, which includes both geometry and the calculus. The world is inherently geometrical in nature, and the world changes over time. That change is described with the calculus. Geometry means things like the nature of the x - y plane and the Pythagorean theorem. Calculus means how a function of a variable

changes. If we have a function $f=f(x)$, then the derivative of that function is defined

$$\frac{df}{dx} = \lim_{\Delta x \rightarrow 0} \frac{\{f(x + \Delta x) - f(x)\}}{\Delta x}.$$

If $f(x) = c$, then $df/dx = 0$. If $f(x) = ax$, then $df/dx = a$. If $f(x) = bx^2$, then

$$\frac{df}{dx} = \lim_{\Delta x \rightarrow 0} \frac{b \{(x + \Delta x)^2 - x^2\}}{\Delta x} = 2bx.$$

In a similar way, if $f(x) = x^n$, then $df/dx = nx^{n-1}$, which is simply an expression of the binomial theorem. The meaning of the derivative is the slope of the curve defined by the function. If we draw the curve $y = f(x)$ in the x - y plane, then the slope of that curve at every point is given by df/dx . The whole thing is based upon geometry and calculus.

Why is energy conserved? If we have a particle that moves in some potential $V(x)$, the total energy of that particle is given by $E = \frac{1}{2}mv^2 + V(x)$. To say energy is conserved over time means $dE/dt = 0$. But by simple differentiation,

$$\frac{dE}{dt} = m\mathbf{v} \left(\frac{d\mathbf{v}}{dt} \right) + \left(\frac{dV}{dx} \right) \left(\frac{dx}{dt} \right)$$

But $v = dx/dt$, and so we find that $mdv/dt = -dV/dx$, which simply says $F = ma$ if we identify $F(x) = -dV/dx$. The gravitational force that acts on an object of mass m at the surface of the earth is $F = -mg = -GmM/R^2$, which corresponds to a potential $V(x) = mgx$. Conservation of energy means the total energy of an object that falls in the earth's gravitational field is constant until that object hits the ground and transfers its kinetic energy to the earth with one big thump. Energy is conserved in that transfer, and momentum is also conserved.

The same kind of thing happens in atomic gases, and energy is conserved as the atoms move around and bump into each other. The atoms or molecules move around because they have kinetic energy. In a gas they move around fairly freely because the attraction of the electromagnetic force is so weak. This is because the atoms and molecules are far away from each other and the electrical force falls off with distance just as the gravitation-

al force does. It actually falls off faster because from a long distance away an atom appears to be electrically neutral as the positive charge in the nucleus cancels out the negative charge of the orbiting electrons. The atoms in a gas move around fairly freely because there is a long distance between separate atoms. That is until they bump into each another.

When they bump into each other they repel. Atoms repel each other not because of the electrical force, but because they 'squeeze' space out of each other. They repel each other because of quantum uncertainty, which means they cannot occupy the same space. Without quantum uncertainty, all the electrons would collapse at rest on top of the atomic nuclei, and the atoms would collapse down to nothing and occupy no space. Atoms only occupy space because of quantum uncertainty, and that is why they repel. Atoms collide into each other like billiard balls and scatter off of each other. Momentum and energy are always conserved in any scattering event. In between collisions each atom moves freely and has a total energy given pretty much just by its kinetic energy $\frac{1}{2}mv^2$. But this is only the case for a hot gas with a lot of kinetic energy.

What happens to a gas as the temperature is lowered? The molecules in the gas slow down. They still bump into each other, but as they collide and bump off of each other there is more of a chance that they will stick together because of the electromagnetic attraction between molecules. As two slowly moving molecules gently bump off of each other, they may find themselves stuck together because of the electromagnetic attraction for each other. Each molecule falls in the other molecule's electromagnetic field. But they can only fall so far because of the repulsion experienced if they begin to occupy the same space. If they move slowly enough they might not have enough kinetic energy to escape from the pull of each other's electromagnetic attraction, and they are bound together because they do not have escape velocity. This is like a rocket ship that does not acquire escape velocity on lift-off, and so it falls right back to the earth.

As the gas cools, more and more of the molecules will pair up with each other because of the electromagnetic attraction between molecules. First bound pairs, then bound triplets, and then bound quadruplets of molecules will form. Some of the quadruplets stick together to form eight member groups of molecules. If two of these stick together a sixteen member group is formed. As the gas cools, there are bigger and bigger of these groupings of molecules. If the gas is water vapor, these molecular group-

ings begin to form tiny water droplets. The water droplets coalesce together, and form liquid water. As water vapor cools it condenses into liquid water. The condensation of liquid water out of water vapor is called a phase transition. The phase transition only occurs because the average velocity of each water molecule falls below an escape velocity determined by the potential energy of electromagnetic attraction of the water molecules for each other. The same kind of process happens when water cools to its freezing point and water freezes into crystalline ice. The molecular structure of ice has more order than the molecular structure of liquid water. Every water molecule lines up in a precise order that is described by the crystalline structure of ice. The reason snowflakes have their geometrical shapes is because of this crystalline structure. But even in ice there is constant molecular movement. The electrons and atomic nuclei continue to move around. There is still kinetic energy in the system.

The nature of the phase transition, as water vapor condenses into liquid water, occurs at constant temperature, which is the boiling point of water. The phase transition can only occur because heat is removed from the hot water vapor, which lowers the temperature of the water vapor. But once the system of water vapor reaches the boiling point of water, more heat must be removed from the system of water vapor at constant temperature for the water vapor to condense into liquid water. The amount of heat that must be removed from the system of water vapor at the constant temperature of the boiling point of water for the phase transition to occur is called the heat of condensation. The reason for this phenomena is that more disordered kinetic energy must be removed from the system of water vapor at the boiling point of water for the water molecules to bind together and condense into liquid water. The average velocity of each water molecule in the system only falls below escape velocity if that extra disordered kinetic energy is removed from the system. Water vapor only condenses into liquid water at the boiling point of water because that extra heat is removed from the system. The other way to look at the phenomena of the phase transition is that water vapor only condenses into liquid water because heat energy, which is disordered kinetic energy, is radiated away from the system.

The bound state of liquid water only forms because disordered kinetic energy is radiated away from the unbound state of water vapor. As the bound state of liquid water forms, the motion of water molecules becomes more ordered as they are bound together, but the price of that order is the disordered kinetic energy that must be radiated away from the water vapor

for the bound state to form. Radiation of disordered kinetic energy away from the system of water molecules, as the bound state of liquid water forms, is the essential nature of the second law of thermodynamics, which says energy always flows from more ordered to less ordered states. The only reason the bound state of liquid water can form is because disordered kinetic energy is radiated away from the system of water molecules. Even though the liquid water appears to be more ordered with lower entropy, the only reason this process can occur is because disordered kinetic energy is radiated away from the system. As liquid water forms there is an overall increase in entropy because of the disordered kinetic energy radiated away from the system. An increase in entropy occurs because disordered kinetic energy must be radiated away from the system of water molecules for the average velocity of each water molecule to fall below escape velocity. The same kind of phenomena occurs with the formation of all bound states. The bound state of a hydrogen atom can only form, as an electron is bound to a proton, because a photon is radiated away. Some of the excess kinetic energy of the electron is radiated away, which is why the electron moves with less than escape velocity.

The photon tends to be radiated away in random directions, so that overall, there is an increase in entropy as the bound state of the hydrogen atom forms. The bound state of an atomic nucleus can only form because protons and neutrons bind together under the influence of the strong nuclear force. As the protons and neutrons bind together, they radiate away some of their excess kinetic energy in random directions, which is why they move with less than escape velocity. The photons that are radiated away in random directions result in an overall increase in entropy. All bound states only form because the things that bind together move with less than escape velocity as they radiate away some of their kinetic energy in random directions, and that radiation results in an overall increase in entropy.

At this point it's interesting to make a brief digression and discuss the nature of thermodynamic equilibrium, and how thermodynamics relates to quantum theory. These ideas arose from the kinetic theory of gases, and are based upon classical concepts of motion, but those classical concepts led to paradoxes, from which the discovery of quantum theory arose to make sense of the thermodynamic properties of gases. The kinetic theory of gases was initially developed in the nineteenth century, prior to the discovery of quantum theory, in order to explain the observable macroscopic properties of matter that are due to atomic motion.

The kinetic theory of gases is based upon the concept of thermal equilibrium. This assumes that the system of interest is isolated from interactions with all other systems, and that a long enough time has elapsed that whatever the physical processes are in the system, such as the movement of atoms and their collisions, these processes have reached a steady state of equilibrium within the system. Equilibrium means that on average nothing changes over time. This is what it means to say each atom has an average kinetic energy related to the temperature of the system. The system can only be described in a meaningful way by temperature if it has reached such a state of thermal equilibrium. The kinetic theory of gases is based upon the atomic hypothesis, which is the idea that all matter is composed of atoms. The atoms in the system move around and carry kinetic energy. The average kinetic energy of each atom is defined in terms of a parameter called absolute temperature as $KE = \frac{1}{2}mv^2 = 3kT/2$. This is only the case once the gas has reached thermal equilibrium at a temperature T .

The basic idea of an ideal gas is to put a bunch of atoms inside a box. Those atoms have a certain amount of kinetic energy, and move around freely except for random collisions with each other and collisions with the walls of the box. We ignore all interactions except for collisions. If two atoms collide with each other they exchange momentum like two billiard balls that collide and scatter off each other. If an atom collides with the wall of the box, it exchanges momentum with the wall of the box. That exchange of momentum is referred to as the pressure of the gas on the walls of the box. That pressure is equal to the force applied on the walls of the box per unit area. The force applied to the walls of the box arises because of the exchange in momentum as an atom bounces off the wall of the box. The force applied per atomic collision is written as $f = \Delta p / \Delta t$, where $p = mv$ is the momentum of the atom that collides into the wall of the box. This is another way of writing Newton's law of motion $F = ma$, where the acceleration $a = \Delta v / \Delta t$. As an atom bounces off the wall of the box, it suffers a change in momentum Δp in some brief time interval Δt . Let's assume that there are a total of N atoms inside the box, and they move around randomly with an average velocity determined by their average kinetic energy $KE = \frac{1}{2}mv^2 = 3kT/2$.

Let's call the length of the box L , which means the area of each wall is $A = L^2$. The pressure applied to the walls of the box by the hot gas of atoms is $P = F/A$, which is the total force applied per unit area. As an atom moves

in the x -direction and approaches the wall of the box, it moves with velocity v . After the atom bounces off the wall of the box it moves with velocity $-v$, since it reverses direction. We'll assume atoms bounce off the wall of the box like bouncing balls. As an atom bounces off the wall of the box it suffers a change in velocity $\Delta v = v - (-v) = 2v$, since the velocity of the atom is reversed. The force applied to the wall of the box by each atomic collision with the wall is $f = m\Delta v/\Delta t = 2mv/\Delta t$. The total number of atoms that bounce off the wall of the box in the time interval Δt is related to the size of the box, the average velocity of the atoms, and the total number of atoms in the box. In a time interval Δt each atom that moves in the x -direction moves through a distance $\Delta x = v\Delta t$. The average number of those atoms that bounce off the wall of the box in the time interval Δt is $N(\Delta x/L)/2$, since only those atoms within a distance interval of Δx of that wall of the box can bounce off that wall in the time interval Δt , and an atom can move in either the positive or negative x -direction. But there are three independent spatial directions that the atoms can move in, so that the average number of atoms that bounce off any of the six walls of the box in a time interval Δt is given by $N(v\Delta t/L)/6$, which is the total number of collisions with any wall in that time interval. The total force F applied to any wall of the box by all the atomic collisions with that wall in a time interval Δt is related to the force per atomic collision, $f = 2mv/\Delta t$, and the total number of collisions with that wall, $N(v\Delta t/L)/6$, as

$$F = \frac{N}{6} \left(\frac{2mv}{\Delta t} \right) \left(\frac{v\Delta t}{L} \right) = \frac{NL}{3} mv^2.$$

The pressure of the gas on the walls of the box is the force per unit area $P = F/L^2 = mv^2N/3L^3 = NkT/V$, where we can identify $mv^2 = 3kT$ and $V = L^3$ is the volume of the box. This is the ideal gas law $PV = NkT$, which follows simply from classical ideas about the nature of atomic motion. This relationship does not depend upon the detailed nature of the atomic forces, but only on conservation of momentum and the definition of temperature.

It's actually pretty amazing that the ideal gas law, $PV = NkT$, arises just from the conservation of momentum and the definition of temperature, as long as we assume that gases are composed of atoms. But there is another even more remarkable relationship that describes the way matter is organized and the thermodynamic properties of matter called the Boltzmann probability factor. For any system in thermal equilibrium at temperature

T , the dynamical organization of that system is determined by a certain probability factor. This probability factor depends only on the temperature and the energy of that system. If the system can become organized into two different states of organization characterized by a difference in energy $\Delta E = E_2 - E_1$ then the probability at thermal equilibrium that the system is organized in state 2 relative to the probability that it is organized in state 1 is given by the expression

$$P_2/P_1 = \exp(-\Delta E/kT).$$

Boltzmann's law of probability does not replace Newton's laws of motion but only simplifies them. If a bunch of particles, like a large number of electrons and atomic nuclei that compose some state of matter, move around and interact with each other through some kind of force, like the electromagnetic force, then it is still possible to solve Newton's equation $F = ma$ for each of those particles and exactly determine their motion. That motion will be described as a path through space that depends on time, or as a particle trajectory $x = x(t)$, for each of those particles. What Boltzmann's law says is that if there are a large number of particles at thermal equilibrium, like the electrons and atomic nuclei that compose some state of matter, then their average motions and the average way that they arrange their spatial organization is determined by the Boltzmann probability factor

$$P_2/P_1 = \exp(-\Delta E/kT).$$

At thermal equilibrium it is not necessary to know all the complex individual particle motions, but only their thermal average motions. The Boltzmann law of probability only applies to thermal equilibrium. The system of particles that move around has to be isolated from its environment, and there has to be a lot of particles so that the individual motions of particles average out to give an average thermal motion. The system has to be in a steady state.

How did Boltzmann discover the probability law? The simplest case to consider is the distribution of gas molecules in the atmosphere. Assume the temperature is constant throughout the atmosphere and write $n = N/V$ as the number of gas molecules per unit volume. Then the ideal gas law gives $P = nkT$. But the air pressure higher up in the atmosphere is lower than the air pressure down below, so write $P = P(x)$ where x is the height above the ground.

The temperature is constant so $P(x) = n(x)kT$. Remember that pressure is force per unit area. Draw an imaginary surface of area A at height x above the ground. The gravitational force that the atmosphere above this surface exerts on the atmosphere below this surface is the weight of the atmosphere above this surface. The atmosphere below the surface has to push back with an equal force to keep things in equilibrium, which means the pressure below the surface is higher than the pressure above the surface because of that weight.

Let's look at some small interval Δx just above the surface. If there was no gravity the pressure would be constant. But there is gravity so the pressure changes as we cross this interval. Let's call $\Delta P(x)$ the change in air pressure as the height rises by Δx . This difference in pressure is due to the weight of the molecules in that small interval. We know how much these molecules weigh from Newton's law of gravity, $\Delta F = -\Delta Mg$, where the total mass of a small volume of area A and height interval Δx is $\Delta M = mn(x)\Delta xA$, and where m is the mass per molecule. This change in weight must balance out the change in pressure. Remember that pressure is force per unit area, $P = F/A$, and so $\Delta P = \Delta F/A$. This gives the relationship $\Delta P(x) = -mgn(x)\Delta x$. But we also have the ideal gas law that gives another relationship $\Delta P(x) = \Delta n(x)kT$. If we eliminate the pressure, we find that $\Delta n(x) = -mgn(x)\Delta x/kT$. Take the limit of the differential and

$$\frac{dn}{dx} = -\frac{mgn(x)}{kT}.$$

What kind of a function $n(x)$ gives itself back when differentiated as $dn/dx = cn(x)$ for some constant $c = -mg/kT$? The answer is the exponential function $n(x) = n(0)\exp(cx)$. This gives the number of molecules per unit volume $n(x) = n(0)\exp(-mgx/kT)$. This is the Boltzmann probability factor. The probability of finding a gas molecule of mass m at height x above the earth's surface relative to the probability of finding it at the earth's surface is $\text{Prob}(x) = n(x)/n(0) = \exp(-mgx/kT)$. This only assumes constant temperature. But we've already seen something like this before. The gravitational potential energy of the molecule relative to the earth's surface is given by $V(x) = mgx$. This means $\text{Prob}(x) = \exp[-V(x)/kT]$. This law is valid for any potential energy function $V(x)$, as can be easily seen since the force applied to the particle is always related to the potential energy function as $F(x) = -dV(x)/dx$. The most general statement of this result is that if there are two configurations or states of matter, which are in thermal equilibrium at temperature T , and that only differ by a poten-

tial energy difference $\Delta E = E_2 - E_1$, then the probability of the second configuration relative to the first configuration is given by $P_2/P_1 = \exp(-\Delta E/kT)$. What about the kinetic energy of those two possible configurations or states of matter? The kinetic energy is represented by the temperature of the system, since each particle in the system moves with an average kinetic energy $KE = \frac{1}{2}mv^2 = 3kT/2$, which only assumes the particle moves in three spatial dimensions.

Why doesn't the atmosphere evaporate into outer space? Each molecule in the atmosphere is gravitationally bound to the earth. Each molecule lacks escape velocity. Escape velocity for a molecule is determined by $v^2 = 2GM/R$ at the surface of the earth. Escape velocity from the surface of the earth is about 12,000 meters/sec, while the average velocity of a water molecule at room temperature is about 300 meters/sec. According to the Boltzmann law, the probability of finding a water molecule high above the atmosphere relative to the surface of the earth is vanishingly small. The temperature at the surface of the earth is not hot enough for the atmosphere to evaporate into outer space.

The Boltzmann law is only valid for thermal equilibrium. This means a system of particles isolated from its environment and allowed to reach a steady state of motion. The most likely configuration of motion that the particles reach depends on how they interact with each other through a potential energy function. The term ΔE only relates the difference in potential energy between different possible configurations of the particles. Average kinetic energy enters into the equation only as kT . This is a remarkable result. At thermal equilibrium matter arranges itself into configurations according to a probabilistic rule that involves some kind of a balance between potential energy and average kinetic energy.

The relative probability a system at thermal equilibrium arranges itself with one particular configuration rather than another configuration depends only on the energy difference ΔE that separates these two states of organization and the temperature of the system. The average kinetic energy of any particle as it moves around at equilibrium is given by $\frac{1}{2}kT$ for each independent direction of motion. It is still possible to solve Newton's laws of motion for each particle and then to take the averages. The Boltzmann law just simplifies the analysis.

The Boltzmann law is a general rule for the way matter organizes itself at thermal equilibrium. A good example is a gas of atoms in thermal equilib-

rium that interact with each other according to the potential energy function $V(r)$. Let's assume $V(r)$ has some minimum value $V(r) = V_0$ at some distance $r = r_0$, and that the potential energy becomes small for large values of r . The probability that any two atoms will be separated by a distance r relative to the probability that they are separated by the distance $r = r_0$ is given by

$$\frac{P(r)}{P(r_0)} = \exp[-\{V(r) - V_0\} / kT].$$

If kT is much larger than the potential energy difference $V(r) - V_0$, then this probability is nearly equal to 1. This means that at high temperatures, the probability that the atoms are separated by any large distance r is about the same as it is that they will be found at $r = r_0$. This is due to the fact that the atoms only weakly attract each other, because their potential energy of attraction is small relative to their average kinetic energy, which is about equal to kT . That means they are free to move away from each other. If their average velocity is much greater than escape velocity, then they are free to move around. Only when the atoms get very close to each other do the atoms repel each other and the probability becomes very small because the potential energy difference becomes large. The state of organization of the gas at thermal equilibrium is spontaneously organized into the state of an ideal gas of atomic billiard balls. But why do the atoms repel each other when they get too close to each other? They repel each other because of quantum uncertainty as they 'squeeze' space out of each other.

Something interesting happens as the temperature is lowered. The potential energy difference $V(r) - V_0$ may then become an appreciable fraction of kT . The probability that the atoms are found at a distance r greater than r_0 then becomes very small. At lower temperatures, the tendency of atoms to attract each other and stick together is greater than their kinetic tendency to move away from each other, and they begin to organize themselves into a state of organization where the average distance between two atoms is at the preferred distance $r=r_0$. This happens because their potential energy of attraction becomes more important than their kinetic energy of random motion. They no longer have enough velocity to escape from each other, or move freely away from each other, but rather become bound to each other.

If all the atoms in the gas attract each other in pairs according to the potential $V(r)$, then at some critical temperature the gas will begin to condense as larger and larger number of atoms clump together. First there are bound pairs, then bound triplets and quadruplets and so on. These clumps of atoms condense out into a liquid phase the same way water vapor condenses into liquid water. Small clumps condense into bigger clumps which condense into even larger clumps until almost all the atoms have condensed out of the gas phase into the liquid phase. This phenomenon is a phase transition, and occurs at a temperature called the critical temperature. For water this critical temperature is the boiling point of water. That critical temperature behaves roughly like $kT = -V_0$. The negative sign indicates an attractive force.

The idea of blackbody radiation is also based upon thermodynamic equilibrium. Equilibrium means that the system is in a steady state, and is completely isolated from its environment. For a blackbody emitting and absorbing radiation in thermal equilibrium, this means the radiation cannot escape. The isolated system is the hot blackbody and its thermal glow of radiation. The idea of a blackbody is a hot object that is put inside a box with reflecting walls. All the radiation the blackbody emits is reflected off the walls of the box, and that radiation is constrained to remain within the box. The radiation cannot escape from the box. The walls of the box can only reflect that radiation. The hot blackbody cannot reflect the radiation, but can only emit or absorb the radiation. The blackbody is hot, so it emits radiation just like a hot light bulb. That radiation bounces around inside the box until the blackbody reabsorbs it. The blackbody and its box are an isolated system, but you can peek into the box and see what the hell is going on in there.

The blackbody is maintained at a certain fixed temperature. Equilibrium means that the blackbody and its box are isolated from everything that happens outside the box. All the radiation inside the box is due to the blackbody's emission and absorption of radiation. The walls of the box only reflect whatever radiation is emitted until it is reabsorbed. The isolated system consists of the hot blackbody and the radiation inside the box. Thermal equilibrium means that the blackbody emits exactly the same amount of radiation as it absorbs, which is the steady state. But radiation comes in different frequencies. Equilibrium means that the blackbody emits exactly the same amount of radiation as it absorbs at each possible frequency. When you look inside the box you see the intensity of radiation

at a particular frequency. The intensity of radiation that is measured is expressed in terms of the frequency of that radiation, which are electromagnetic waves. This is written as $I=I(\omega)$, where the angular frequency ω of electromagnetic waves is related to ordinary frequency of vibration as $\omega=2\pi\nu$.

To go further in the analysis, we have to make a connection between the motion of the atoms that comprise the blackbody, and the electromagnetic radiation that is emitted and absorbed by those atoms. The average kinetic energy of each atom in the blackbody is proportional to the temperature of the blackbody. The hotter the temperature, the faster the atoms move. Each atom can move in three independent directions. The average kinetic energy for each direction is related to temperature as $KE = \frac{1}{2} kT$ for each direction of motion. Each atom is composed of charged particles with a positively charged atomic nucleus and negatively charged orbiting electrons. According to Maxwell's equations, charged particles should radiate electromagnetic radiation as they move around.

Atoms are not just little billiard balls that move around and collided into each other. Atoms have an internal structure with the nucleus on the inside and the orbiting electrons on the outside. Atoms can make chemical bonds and stick together. A gas molecule composed of two identical atoms, such as H_2 or O_2 , is a bound state of those two atoms. Gases of hydrogen and oxygen are composed of such molecules. To form the bound state of such a molecule, the two atoms find an optimal distance between them to bind together through a chemical bond. The two atoms repel each other because of quantum uncertainty if they are too close to each other, and attract each other because of the electromagnetic interaction when they are separated at an optimal distance of attraction. That attraction occurs because of the spatial arrangement of electric charges in space that allows for that electromagnetic attraction.

The force between two atoms separated by a distance r is represented by a potential energy $V(r)$ that arises from the electromagnetic interaction. The force between atoms is weakly attractive at long distances of separation because of the uneven distribution of electric charges in space. The atoms 'repel' at short distances of separation because of quantum uncertainty. But there is an optimal distance of separation $r = r_0$ at which point the two atoms neither attract nor repel each other, and that is the distance that they prefer to occupy relative to each other as the two atoms bind together.

er. If we include the short distance 'repulsion' of quantum uncertainty along with the electromagnetic energy of attraction in the potential $V(r)$, then there is a separation $r = r_0$ that minimizes that potential $V(r)$ as $V(r_0) = V_0$. This potential is not just the electromagnetic potential energy, but is an 'effective' potential that also includes the 'repulsion' due to quantum uncertainty. Two atoms that are chemically bound to each other prefer to keep this position because this minimizes their potential energy. As they try to separate they're pulled back together, and as they try to get closer they're pushed away.

Two atoms are bound together because of the 'effective' potential $V(r)$. A bound state can only form if the atoms have a velocity below escape velocity, defined by total energy $E = \frac{1}{2}mv^2 + V(r) = 0$. The reason total energy can be zero is because potential energy takes on negative values for attractive forces. The atoms move in a potential energy valley defined by $V(r)$, which is positive for small values of r , and is negative but approaches zero for larger values of r . The minimum value, $V(r_0) = V_0$ is negative, and determines an escape velocity as the velocity at the minimum value that gives a total energy of zero, or $\frac{1}{2}m(v_{\text{esc}})^2 = -V_0$. If the atoms have less than escape velocity as they cross the point $r = r_0$, then they are bound together, and their motion oscillates back and forth around the minimum distance value. As the atoms move closer together they repel and slow down. As they move farther apart they attract and slow down. They move the fastest when the effective potential takes on its minimum value, which is when they are at the bottom of the valley. If that maximal velocity is below escape velocity, then the atoms cannot escape from each other. The atoms move toward each other faster as they attract, and they move away from each other faster as they repel. First they move toward each other, then they move away from each other, then they move toward each other again. This kind of motion describes a kind of oscillation.

This kind of oscillation is characteristic of the oscillation of a mass attached to a spring. The nature of an oscillator is two masses m_1 and m_2 separated by a distance x and connected by a spring. When the two masses approach each other the spring is compressed and the masses repel. As the two masses moved away from each other the spring is stretched and the masses attract. There is an equilibrium distance $x = x_0$ between the two masses where the spring neither pulls nor pushes. This potential energy is written as $V(x) = V_0 + \frac{1}{2}K(x - x_0)^2$ and corresponds to a force law $F = -K(x - x_0)$. The number K is referred to as the spring constant, and

characterizes the stiffness of the spring. This kind of potential energy is called a harmonic oscillator. It's called harmonic because the oscillatory motion of the masses about the equilibrium distance $x - x_0$ has some special properties. The oscillations are described as motion with an amplitude A , and a frequency ω . This kind of periodic motion is usually written in terms of a trigonometric sine or cosine function as $x(t) = x_0 + A \sin(\omega t)$, where the angular frequency is defined as $\omega = 2\pi\nu$.

To simplify things a bit imagine that one end of the spring is attached to a wall, and an oscillating mass is attached at the other end of the spring at position x . Let's solve Newton's law of motion, $F = ma$, and show that the motion of the mass is described by the trigonometric sine and cosine functions. The force on the mass is $F(x) = -Kx$, where we let $x_0 = 0$. The acceleration of the mass is given as the differential of its velocity, $a = dv/dt$, and the velocity of the mass is given as the differential of its position, $v = dx/dt$. Let's assume that $x(t) = A \sin(\omega t)$. To solve the law of motion, $F = ma$, we need to know the differentials of trigonometric functions, which are given by

$$\frac{d(\sin \theta)}{d\theta} = \cos \theta, \text{ and } \frac{d(\cos \theta)}{d\theta} = -\sin \theta.$$

We find that for

$$x(t) = A \sin(\omega t), \quad v(t) = \frac{dx}{dt} = A\omega \cos(\omega t),$$

and

$$a(t) = \frac{dv}{dt} = -A\omega^2 \sin(\omega t).$$

$F = ma$ simply gives $KA = m\omega^2 A$ or $\omega^2 = K/m$. The frequency of oscillation only depends on the spring constant K , and not on the amplitude of oscillation. Since the potential energy is given by $V(x) = \frac{1}{2}Kx^2$, the other remarkable thing we find out is that the total energy

$$\begin{aligned} E &= \frac{1}{2}mv^2 + V(x) \\ &= \frac{1}{2}m\omega^2 A^2 \cos^2(\omega t) + \frac{1}{2}K A^2 \sin^2(\omega t) \\ &= \frac{1}{2}\omega^2 A^2, \quad \text{since } \sin^2(\omega t) + \cos^2(\omega t) = 1. \end{aligned}$$

The amplitude of the oscillation A depends on the total energy of the oscillator as $E = \frac{1}{2} m \omega^2 A^2$. The total energy is constant because of the conservation of energy. The angular frequency of the oscillation ω only depends on the mass and the spring constant as $\omega^2 = K/m$. The stiffer the spring or the smaller the mass, the faster the oscillation. This independence of frequency of oscillation with the amplitude of oscillation is what makes the harmonic oscillator harmonic. The harmonic oscillator is unique because it always vibrates at the same frequency of vibration, no matter what the amplitude of vibration, and those oscillations are described by sinusoidal motion. Only the total energy of the oscillator depends on the amplitude of vibration. Independence of frequency of vibration with amplitude of vibration is unique to the harmonic oscillator.

For comparison, let's take a look at the periodic orbits that arise with planetary motion. The earth orbits the sun in a nearly circular orbit. For simplicity, let's assume the orbit is perfectly circular with radius R . We know the force of gravity of the sun on the earth is $F = -GmM/R^2$, where m is the mass of the earth, M is the mass of the sun, and R is the distance between the earth and sun. The force of the sun on the earth is directed along the radius vector toward the sun. For a perfectly circular orbit, we can place the orbit in the x - y plane, with the sun at the origin of the x - y plane. The position of the earth in its circular orbit is located in terms of an angle θ that specifies a radius vector $(x, y) = R(\cos \theta, \sin \theta)$. Let's assume uniform circular motion around the orbit and let $\theta = \omega t$ in terms of an angular frequency. The next step is to solve the equation of motion $F = ma$. The force of the sun on the earth points inward toward the center of the circle. Since the position of the earth in its circular orbit is given as $(x, y) = R(\cos \theta, \sin \theta)$, the velocity of the earth in its orbit is

$$\begin{aligned} \mathbf{v} &= \left(\frac{dx}{dt}, \frac{dy}{dt} \right) \\ &= \omega R (-\sin \omega t, \cos \omega t), \text{ and} \\ a &= \frac{d\mathbf{v}}{dt} \\ &= -\omega^2 R (\cos \omega t, \sin \omega t). \end{aligned}$$

The acceleration vector is proportional to the radius vector, but points in the opposite direction. As the force of gravity pulls the earth toward the

center of the circular orbit it causes an inward acceleration to maintain that circular orbit. The earth falls toward the sun in its circular orbit, just as an apple falls toward the earth. The earth moves tangential to its circular orbit because of its velocity, but falls toward the sun because of the radial acceleration due to gravity. $F = ma$ then gives $m\omega^2 R = GmM/R^2$, or $\omega^2 = GM/R^3$. The period of the earth's orbit, which is one year, is given in terms of this angular frequency as $T = 2\pi/\omega$, and only depends on the mass of the sun and the radius of the orbit.

When an electron orbits a proton in a hydrogen atom, the electron follows a similar periodic orbit, in much the same way the earth orbits the sun. But we know these electron orbits are quantized, and as an electron makes a transition from one quantized atomic orbital to another, a photon is emitted. The photon is a quantized emission of electromagnetic radiation. The orbit of the earth around the sun is also quantized, but the energy levels involved are so large that we cannot detect the quantized nature of that motion. When two hydrogen atoms bind together to form an H_2 molecule, the force of electromagnetic attraction and the repulsion of quantum uncertainty between those two atoms tends to make the atoms vibrate back and forth together like a harmonic oscillator. Those vibratory energy levels are also quantized, and these quantized atomic energy levels result in the emission of quantized electromagnetic radiation.

The important thing about the harmonic oscillator is that any potential energy function that takes the shape of a potential valley can always be approximated near the minimum of that valley as a harmonic oscillator. The effective potential, $V(r)$, between two atoms always has the shape of a valley near its minimum. Near the bottom of the potential energy valley we can always write $V(r) = V_0 + \frac{1}{2}K(r - r_0)^2 + \dots$, where $K = d^2V/dr^2$ evaluated at $r = r_0$, and the minimum is defined by $dV(r=r_0)/dr = 0$. This is the case since the slope $dV(r)/dr = 0$ at the minimum of the valley $r = r_0$. These results are relevant to problems in atomic physics because the effective potential between two atoms, $V(r)$, always takes the shape of a valley, and is approximated as a harmonic oscillator for small displacements from the equilibrium distance $r = r_0$. Molecules that consist of two bound atoms, such as H_2 or O_2 , should vibrate like little harmonic oscillators.

The vibrational energy of a bound pair of atoms that vibrate back and forth like a harmonic oscillator can be broken up into a part for kinetic energy

and a part for potential energy of that harmonic oscillator. In thermal equilibrium at temperature T , the average vibrational kinetic energy of the oscillator is $KE = \frac{1}{2}kT$, just as it was for any other independent direction of motion. The average potential energy of vibration of the oscillator at thermal equilibrium is also $PE = \frac{1}{2}kT$. Just add these two terms together and come up with a total average thermal energy of vibration of $E = KE + PE = kT$, which should equal $E = \frac{1}{2}m\omega^2 A^2$ in terms of the amplitude of vibration of the atomic oscillator.

Let's apply this result to try to explain the nature of blackbody radiation. Atoms are bound to each other like little harmonic oscillators, and so those bound states have vibrational energy. The vibrating atoms are electrically charged with more positive charge on the inside of the atom, and more negative charge on the outside of the atom. According to Maxwell's equations, as these charged atoms vibrate, they should radiate away electromagnetic radiation. This is basically the explanation for why hot objects cool off. A hot object cools off because it radiates away mostly infrared electromagnetic radiation, which we perceive as heat.

According to our results for the harmonic oscillator, we find that the atoms in the hot object vibrate more forcefully and with larger amplitudes when they are hotter, as $E = \frac{1}{2}m\omega^2 A^2 = kT$, and so they have more average energy of vibration. This is just a consequence of the amplitude of vibration increasing with energy, and the average thermal energy directly related to temperature. The hotter object has more average energy per atomic vibration, and so these atomic vibrations are of higher amplitude. These more energetic atomic vibrations then create more electromagnetic radiation, which radiates away from the hot object. If the object is hot enough, then this radiation is seen as visible light, as is the case for a light bulb. Even if this radiation is infrared, and not visible, there will still be electromagnetic radiation radiated away from the hot object in the infrared range of the spectrum. As the hot object radiates this electromagnetic radiation away, it cools. The infrared radiation carries heat energy away from the hot object.

This is the explanation for blackbody radiation, and its based upon the idea of atomic harmonic oscillators. The hot blackbody is enclosed in a box that reflects the radiation back into the box, so that it cannot be radiated away. The radiation is trapped inside the box along with the blackbody. The blackbody is composed of oscillating atoms that vibrate like little harmon-

ic oscillators, and emit radiation as they vibrate. At thermal equilibrium, the same total amount of radiation is absorbed by the oscillating atoms as is emitted by them. That is the definition of thermal equilibrium. The average amplitude of oscillation is a constant because of the conservation of energy. The oscillators emit and absorb exactly the same amount of radiation on average, so their average energy or temperature doesn't change, and their average amplitude of vibration doesn't change. As the atoms vibrate, they emit and absorb electromagnetic radiation. The atomic oscillators are in thermal equilibrium with the electromagnetic radiation inside the box.

To solve the problem of blackbody radiation, we'd like to calculate how much radiation must be inside the box so that the total amount of radiation absorbed by the atomic oscillators equals the total amount emitted by them when the whole system is in thermal equilibrium at a temperature T . This will determine the intensity of radiation, $I(\omega)$, inside the box as a function of the angular frequency ω of the radiation. It turns out from an analysis of Maxwell's equations that the intensity of radiation is related to the average thermal energy of an atomic harmonic oscillator, $\langle E \rangle$, as $I(\omega) = \omega^2 \langle E \rangle / p^2 c^2$. But we've already determined that $\langle E \rangle = kT$ for an atomic oscillator. The problem is this predicts that the intensity of radiation increases at higher frequencies without limit. When we peek into the box there should be so much radiation in the x-ray and gamma ray frequency range that our eyeballs should melt. This obviously does not happen when we peek into a hot oven. When we peek into a hot oven, we are aware of heat energy that is mostly in the form of infrared radiation, but there is no significant x-ray or gamma ray radiation. Where did we go wrong?

The calculation for the average thermal energy of an atomic oscillator goes back to the Boltzmann probability law $P(E) = \exp(-E/kT)$. For the atomic oscillators that we considered, the total energy of the oscillator only depends on the amplitude of oscillation as $E = \frac{1}{2} m \omega^2 A^2$. The hotter the temperature, the larger the amplitude of oscillation. To find the average energy for an oscillator at thermal equilibrium at temperature T , we sum over all possible amplitudes, but with the probability of any amplitude of oscillation given by the probability law. This means that we can calculate the average thermal energy $\langle E \rangle$ as

$$\langle E \rangle = \frac{\sum EP(E)}{\sum P(E)} = \frac{\sum E \exp(-E/kt)}{\sum \exp(-E/kt)} = kT.$$

The energy of an oscillator is related to the amplitude of oscillation. The result we expect is $\langle E \rangle = kT$ if the amplitude of the atomic oscillators are allowed to take on all possible values. The sum over energy is a continuous sum over all possible values of E , and that leads to the above result if we continuously sum over all values of E . But that is our mistake. The atomic oscillators are not allowed to take on any possible value of E . The energy levels of the atomic oscillators are quantized, and only take on discrete values. To solve the problem of blackbody radiation, we have to solve the problem of how to quantize the energy levels of the harmonic oscillator. The atomic oscillators in a blackbody all have quantized energy levels, and the sum over energy is a sum over those quantized levels.

The correct quantum treatment of the harmonic oscillator is a little complicated, but we can use a trick to solve the problem. The trick is related to geometry. To find the quantized energy levels of the harmonic oscillator, we 'double' the oscillator, which allows us to treat it geometrically. Imagine that we have two identical harmonic oscillators that oscillate out of phase with each other but at right angles to each other in the x - y plane, the first along the x -direction as $x(t) = A \cos(\omega t)$, and the second along the y -direction as $y(t) = A \sin(\omega t)$. We can imagine that these two oscillators define a circular orbit of radius r , where $r^2 = x^2 + y^2 = A^2$, and $\omega = \theta/t$ specifies an angle in the x - y plane of a 'particle' that travels around the circumference of that circular orbit. We can imagine that the location of that 'particle' is specified by a vector $z = (x, y) = r(\cos \theta, \sin \theta)$ that is defined in the plane. The momentum of the 'particle' that travels around the circumference of that orbit is also a vector, $p = mv = (p_1, p_2)$, and where $v = dz/dt = (dx/dt, dy/dt)$. This means we can write $p = mr\omega(-\sin \theta, \cos \theta)$, which gives $p^2 = p_1^2 + p_2^2 = m^2 r^2 \omega^2$. We quantize the momentum of that 'particle' if we specify its momentum in terms of a wavelength $p = h/\lambda$. To find the quantized energy levels of that 'particle', we fit an integral number of wavelengths into the circumference of that circular orbit, or set $n\lambda = 2\pi r$, where $n = 0, 1, 2, 3, \dots$. This gives $m^2 r^2 \omega^2 = h^2/\lambda^2 = n^2 h^2/4\pi^2 r^2$. We can solve this equation for the allowed values of r , and find that $r_n^2 = nh/2\pi m\omega$. The energy of the harmonic oscillator is $E = \frac{1}{2}p^2/m + \frac{1}{2}m\omega^2 r^2$, which gives the quantized energy levels of the oscillator as $E_n = nh\omega/2\pi$. Since the

frequency of vibration is given as $\nu = \omega/2\pi$, this gives $E_n = nh\nu$. We can verify that these allowed energy levels correspond to minimization of energy $dE(r)/dr = 0$ for $r = r_n$, where

$$E(r) = \frac{n^2 h^2}{8\pi^2 r^2 m} + \frac{m\omega^2 r^2}{2}.$$

The harmonic oscillator has discrete quantized energy levels labeled as $E_0, E_1, E_1, \dots, E_n, \dots$ according to the rule that $E_n = nh\nu$. The difference between any two adjacent energy levels $\Delta E = (E_{n+1}) - E_n = h\nu$. The average thermal energy of an atomic harmonic oscillator at thermal equilibrium is still calculated using the Boltzmann probability factor. But instead of the result $\langle E \rangle = kT$, the average thermal energy of an atomic oscillator is given by the sum over all the quantized energy levels of an atomic harmonic oscillator, $E_n = nh\nu$, as

$$\langle E \rangle = \frac{\sum E_n \exp(-E_n / kT)}{\sum \exp(-E_n / kT)} = \frac{h\nu}{\exp(h\nu / kT) - 1}.$$

To see that this expression is valid, let $x = \exp(-h\nu/kT)$. The exponential has the property $[\exp(-h\nu/kT)]^n = \exp(-nh\nu/kT)$. This allows us to write

$$\sum \exp(-E_n / kT) = \sum x^n = 1 + x + x^2 + x^3 + x^4 + \dots = S(x).$$

Can we evaluate this sum? Lets guess the result is $S(x) = 1/(1 - x)$. Then the product $(1 - x)S(x) = 1$. Let's check this out term by term inside the sum

$$(1 - x)S(x) = (1 - x) \sum x^n = (1 - x) + (x - x^2) + (x^2 - x^3) + (x^3 - x^4) + \dots = 1.$$

All the powers of x exactly cancel out. How is this possible? The answer is the sum is only defined if $x < 1$ otherwise the sum diverges to infinity. We're lucky since $x = \exp(-nh\nu/kT)$ is always less than 1, and so the sum converges. The net result is that $\langle E \rangle = h\nu / \{\exp(h\nu/kT) - 1\}$. As $h\nu/kT \rightarrow 0$, the average thermal energy approaches kT , which is the expected result if quantum effects are small. But for $h\nu/kT \gg 1$, the average thermal energy of each atomic oscillator has an exponential cutoff, and so the intensity of blackbody radiation does not increase without limit as the frequency increases. That cutoff is purely a quantum effect. The only reason our eye-

balls do not melt when we look inside an oven is because the energy of each atomic harmonic oscillator is quantized. We 'see' these quantum effects when we look inside a hot oven.

Atomic harmonic oscillators emit electromagnetic radiation in discrete units of radiation we call photons. Electromagnetic radiation is also quantized as $E = h\nu$. The atomic harmonic oscillators cannot continuously emit radiation, but only in quantized 'wave-packets' of energy. These quantized wave-packets of radiation are measured in the photo-electric effect, as a photon impacts an electron, and transfers its momentum and energy to the electron. An atomic harmonic oscillator that vibrates at frequency ν can only emit photons with a quantized energy of $E = h\nu$, or in integral multiples of this energy $E = nh\nu$. If this basic unit of energy is much greater than the average amount of thermal energy $E = kT$ due to the disordered thermal motion of the atomic harmonic oscillator, then it becomes very unlikely that energy can be transferred, or that a photon can be emitted, at this frequency. An atomic harmonic oscillator that vibrates at a high frequency does not have enough thermal energy to emit a photon at that frequency unless the temperature becomes very hot, in the range that $E = kT$ is greater than or equal to $E = h\nu$. This is the basic reason there is an exponential cutoff in the intensity of radiation at higher frequencies.

We can apply this result for blackbody radiation to the universe. The universe is like a box that contains blackbody radiation left over from the big bang event. That radiation is in thermal equilibrium with the universe. The formula for intensity of that radiation $I(\nu) = 4h\nu^3/c^2 \{ \exp(h\nu/kT) - 1 \}$, determines the temperature of the universe in terms of the measured frequency spectrum of background microwave radiation left over from the big bang event, and gives a temperature of about 2.7 degrees Kelvin. The universe has cooled since the big bang event because the universe has expanded, just like an expanding gas that cools as it expands.

Thermodynamic equilibrium is an idealization that really does not apply to the universe, because there is no such thing as a truly isolated system within the universe. Every distinct system in the universe interacts with every other system. The universe is most definitely not at thermal equilibrium. This is obvious, since we are aware of the fact of a bright sun that shines during the day, and a dark night sky during the night. If the universe was at thermal equilibrium, everything would be the same temperature, and there would be no difference between the daytime sky and the nighttime

sky. At thermal equilibrium, the sky would always be the same temperature, and we would not have a hot sun in the daytime sky that is distinctly different than the cool dark nighttime sky. The universe is way out of thermal equilibrium. The entire universe, and everything in the universe, is characterized by non-equilibrium systems. The reason for this universal state of non-equilibrium is because of the second law of thermodynamics. All the energy in the universe flows from more ordered states of organization to less ordered states, which is to say that heat flows from hotter objects to cooler objects. The second law is all about the flow of energy, or the flow of heat, through the universe. As heat flows, information becomes more disorganized. The nature of that flow of energy is gravitational collapse, as energy flows from the big bang event to the black hole, the same way a river flows from the top of the mountain to the bottom of the ocean. The big bang event is the most ordered state of the universe, a state with a uniform distribution of matter and energy, and the black hole is the most disordered bound state of the universe, a state of maximal gravitational collapse, with maximal disordered information, or entropy. All the bound states that form within the universe form somewhere between the big bang event and the black hole. The entropy of the universe increases as those bound states form.

Bound states form in the universe as the entropy of the universe increases. The second law of thermodynamics says that the flow of energy through the universe is from more ordered to less ordered states, which is why all bound states form. The second law specifies how all the bound states of the universe form as all the energy in the universe flows from the big bang event to the black hole. The big bang event is the most ordered state of information in the universe because it is a uniform distribution of matter and energy, with most of that matter and energy in the form of hydrogen atoms and photons. As matter and energy form bound states under the influence of gravitational attraction, the amount of entropy in the universe increases. The black hole is the most disordered state of information in the universe because it represents maximal gravitational collapse of matter and energy. The flow of energy from the big bang event to the black hole is what the second law is all about. The second law describes how energy flows from more ordered to less ordered states, or how entropy increases over the flow of time.

The nature of entropy is confusing, especially its nature for bound states. Entropy always increases as any bound state forms. The formation of

bound states is inherently related to the increase in entropy. The second law is also confusing because for the entire universe the dominant effect is gravity, while for smaller systems in the universe the dominant effect is electromagnetism. For the entire universe, the flow of energy is determined by gravitational collapse, as energy flows from the big bang event, a state with a uniform distribution of matter and energy, to the black hole, a state of maximal gravitational collapse. The complex behavior of smaller systems in the universe is mostly directed by electromagnetic interactions, but the overall flow of energy, and time, is still determined by gravity.

The second law seems confusing, but it's really not that difficult to understand. The nature of entropy is disordered information, or disordered states of energy. Energy always has a potential and kinetic aspect, and information becomes disordered because kinetic energy becomes disordered as the things that move around tend to move around in random directions. The reason energy flows is because of kinetic energy, but as energy flows, the flow of energy tends to become more disordered as the things that move around tend to move in random directions. Energy is always conserved as energy flows, but information tends to become more disordered as energy flows, which is to say energy flows from more ordered to less ordered states. The second law says that energy flows from the hotter to the colder object, which is only a statistical description of how kinetic energy becomes more disordered as things tend to move around in random directions over the course of time.

A hot object radiates away heat because of electromagnetic radiation radiated away from that object. That radiation carries kinetic energy away from the object, and the nature of heat is disordered kinetic energy. Entropy increases as that radiation is radiated away because the radiation is radiated into random directions, and so that kinetic energy becomes more disordered. A hotter object radiates away more heat than a cooler object because the total amount of radiation radiated away increases as the temperature increases, and so heat tends to flow from the hotter to the colder object. The hotter object cools as heat is radiated away, so things tend to come into thermodynamic equilibrium with the environment as heat is radiated away. This is not only for ordinary objects, but for the entire universe. But the ultimate environment is the entire universe, and so thermal equilibrium would mean everything in the universe is at the same temperature, which is definitely not the case for the state of the universe at the present time. The universe is way out of thermal equilibrium.

The universe was hottest at the time of the big bang event, and the coldest object in the universe is a black hole. If the universe continues to expand indefinitely, the temperature of the universe will eventually approach absolute zero as its size approaches infinity, which will be the ultimate state of equilibrium of the universe. But at the present time, the universe is expanding, and energy flows. That universal flow of energy is from the big bang event to the black hole.

The second law of thermodynamics describes how energy flows in an energy gradient, from more ordered states to less ordered states. The nature of that energy gradient is gravity. The flow of energy through the universe is like the flow of a river from the top of the mountain to the bottom of the ocean. In conventional physics, ordered states of matter and energy are conceptualized as bound states of point particles. The nature of an energy gradient in space is called a force. Classical equations of motion relate the trajectories of point particles through space and over time, $x = x(t)$, to those forces. In quantum field theory the nature of a force is conceptualized as the exchange of point particles between other point particles, like the exchange of photons between charged particles. The second law describes the nature of an energy gradient in time as energy flows from more ordered to less ordered states. Where does this energy gradient originate? The big bang event is the origin of the energy gradient. Early in the history of the universe there was a very uniform distribution of matter and energy. Most of the matter was hydrogen gas evenly distributed throughout the universe. Hydrogen gas coalesced into stars. Why did this happen?

Matter and energy clump together from the big bang event to form stars because of gravity. The protons in hydrogen atoms fall together under the influence of gravity to form the star. As the hydrogen atoms fall together under the influence of gravity they move faster, which is only possible because each hydrogen atom is electrically neutral, with a negatively charged electron bound to a positively charged proton. As hydrogen atoms fall together to form the star, gravitational potential energy is converted into kinetic energy, and the atoms move faster. But a star only radiates away electromagnetic radiation because of nuclear fusion. Near the end of the fall, a proton must have enough directed kinetic energy to overcome the electrical repulsion of another proton. The two protons must get close enough together that their nuclear attraction, due to the short range strong nuclear force, overcomes their electrical repulsion, and the protons fuse together. As protons fuse, or bind together, they radiate away some of their

kinetic energy as electromagnetic radiation. That is the only way their velocity can fall to less than escape velocity. Light from the sun that strikes the earth is electromagnetic radiation that arises as protons fuse together into atomic nuclei inside the sun and some of their kinetic energy is converted into electromagnetic radiation.

That kinetic energy arose because protons fell together from the big bang event under the influence of gravity. The yellow light that reaches the earth from the sun carries some of that directed kinetic energy. As electromagnetic radiation strikes the ocean on the surface of the earth, the water molecules in the ocean absorb some of that kinetic energy. The ocean tends to warm up because water molecules absorb some of that electromagnetic radiation, or directed kinetic energy, and water molecules in the ocean move faster. Yellow light from the sun carries directed kinetic energy to the earth, which water molecules in the ocean absorb, and so they move faster. The ocean does not move faster, but only heats up as that kinetic energy is absorbed. The temperature of the ocean is directly related to the average kinetic energy of each water molecule in the ocean.

Why does the ocean only heat up rather than move faster as a water molecule absorbs electromagnetic radiation and moves faster? The water molecules move around like little billiard balls, and tend to scatter off of each other as they bump into each other. Since water molecules tend to scatter off of each other randomly, the directions of their velocities also change randomly, which is to say the kinetic energy of all the water molecules in the ocean is randomly directed. Even though at a microscopic level all the water molecules in the ocean are moving around with an average velocity related to the temperature of the ocean, their velocities are randomly directed, and so at the macroscopic level of the ocean it appears the ocean is at rest. The ocean is not really at rest, but at a macroscopic level we cannot see the individual velocities of all those water molecules, we can only perceive that disordered kinetic energy as heat. The water molecules in the ocean do not really move around randomly. Their movements obey the same laws of motion that the movement of everything else in the universe obey, but we are ignorant of the microscopic details of that movement. We can only perceive that microscopic movement as heat. If the ocean is hot enough, occasionally a water molecule near the surface of the ocean will receive such a powerful shot from another water molecule that it gains enough velocity that it is shot right out of the ocean into the atmosphere as a molecule of water vapor, and we say that water evaporates from the ocean. That hot water vapor rises in the atmosphere.

The water molecules move more slowly as they rise in the atmosphere because of the earth's gravitational attraction, and the water vapor cools as it rises. The molecules in the atmosphere are gravitationally bound to the earth because they do not have escape velocity, which is about 12,000 meters/sec while the average velocity of a water molecule at room temperature is about 300 meters/sec. As those molecules rise in the atmosphere, kinetic energy is converted into gravitational potential energy. As water molecules rise, they move more slowly, which is why the water vapor cools as it rises, and condenses into clouds. The clouds are carried by the wind and strike the mountainside, where the cooler water vapor condenses into rain drops that fall on the top of the mountain. Why does the wind blow in the atmosphere? The same electromagnetic radiation that carries directed kinetic energy from the sun to the earth also warms the atmosphere, but there is a gradient in that warming that follows the day/night cycle, with warming during the day and cooling at night. The only reason why we have a day/night cycle is because there is a hot yellow sun in the sky by day and a cool dark sky by night.

That differential temperature warming by day and night creates a temperature gradient in the atmosphere. That temperature gradient creates a pressure gradient, and that pressure gradient makes the wind blow. All of that directed kinetic energy arises from the electromagnetic radiation that reaches the earth from the sun, and that energy ultimately arises from the big bang event because hydrogen atoms fell together under the influence of gravity to form the sun. That gravitational collapse of matter and energy is also the only reason why there is a planet earth, and why there is a hot sun in the sky by day and a cool dark sky by night. The rain that falls on the top of the mountain also falls in a gravitational gradient. As that rain falls it collects into a river, and the water in the river flows back to the ocean as the water molecules fall down the mountainside. The water molecules fall down the mountainside under the influence of gravity, and as they fall they move faster as gravitational potential energy is converted into kinetic energy. As the water molecules fall, the river flows faster, and the directed kinetic energy of the flow of water through the river can perform useful work, like turning a water wheel. As the water molecules flow faster through the river, they tend to bump into each other more often, and randomly scatter off of each other in random directions of motion, like little billiard balls. As the water molecules move faster in random directions, the water in the river heats up, and the temperature of the river increases. The water molecules that move faster in random directions do not contribute

to the directed flow of the river down the mountainside, they only contribute to the temperature of the river, which is the nature of heat. Heat energy is simply kinetic energy that is randomly directed at the microscopic level of water molecules, and so at the macroscopic level of the river can no longer perform useful work. That is the nature of entropy.

Entropy is simply kinetic energy that has become disordered at the microscopic level, like the random motion of water molecules, which is the nature of the temperature, or heat content, of the water. Kinetic energy that is directed at the macroscopic level, like the velocity of the water in the river that turns a water wheel, can perform useful work at the macroscopic level of the river. Kinetic energy directed at the microscopic level, like a photon directed from the sun that causes a water molecule to evaporate into the atmosphere, can only perform useful work at the microscopic level. The essential nature of the flow of energy is that potential energy is converted into directed kinetic energy, but all kinetic energy that is directed at a macroscopic level, like the flow of water through the river, will eventually become disordered as the water molecules randomly bump into each other, scatter off each other, and tend to move in random directions at a microscopic level. The directed kinetic energy of the river eventually turns into heat, a more disordered kind of kinetic energy. The tendency of directed kinetic energy at a macroscopic level to become disordered over time at a microscopic level is the essence of the second law, which simply says that energy tends to flow from more ordered to less ordered states, and the example of the water molecules that randomly bump into each other is how it operates through electromagnetic interactions, which is the dominant force here on planet earth.

But the story is very different for gravitational interactions, which is the dominant force for the entire universe. To consider the universal level, we only have to consider what happens to all the directed electromagnetic radiation that reaches the earth from the sun. That energy arrives as yellow photons, and each photon is a quantum of electromagnetic radiation that carries a quantized amount of energy related to the frequency of vibration, as $E=h\nu$. All the energy that reaches the earth from the sun is eventually radiated back into outer space. Hot yellow photons arrive to the earth by day, and cooler infrared radiation is radiated back into the dark night sky by night. Energy is conserved, which means the same total amount of energy that arrives from the sun by day is radiated back into outer space by night, which is the case as long as the average temperature of the earth's

atmosphere remains constant. But the yellow photons that arrive by day have a higher frequency of vibration than the infrared photons that are radiated away by night. Since energy is quantized as $E = h\nu$, this means more infrared photons are radiated away by night than yellow photons received by day.

The infrared photons that are radiated away at night are radiated into outer space in random directions. Energy is conserved in this process, but entropy increases as energy flows, because there are more infrared photons radiated away at night than yellow photons received by day, and those infrared photons are directed in random directions. The tendency as energy flows is for entropy to increase, and that is exactly what happens as the directed yellow photons that arrive from the sun are eventually converted into the more disordered infrared photons that are radiated into outer space in random directions. But what eventually happens to the energy of all those infrared photons? They eventually fall, under the influence of gravitational attraction, into the most disordered object in the universe, an object with maximal gravitational collapse, a black hole. A black hole is the most disordered object in the universe, an object with maximal entropy. The flow of all energy through the universe flows through its universal gradient, and completes the entire nature of its flow as it flows from the big bang event, the most ordered state in the universe, to the black hole, the most disordered state in the universe.

We discussed why entropy tends to increase on the surface of the earth as water molecules bump into each other and scatter into random directions of movement, but why is a black hole the most disordered object in the universe? To really understand the nature of entropy, we have to understand the nature of bound states. The river or the ocean is a bound state of water molecules, just like ice is a bound state of water molecules. Ice can be melted into water, and water can be evaporated into water vapor. We call these transitions phase transitions. Liquid water is a bound state of water molecules that can transition to either ice or water vapor, which are different kinds of bound states of water molecules, in the sense of coherent organization, which is the nature by which things hold together, or cohere. All bound states arise because of the coherent organization of the things that are bound together within the bound state. A phase transition is simply a change in coherent organization that results in a different kind of bound state.

Phase transitions form bound states at the macroscopic level. Liquid water is only a different kind of coherently organized bound state of water molecules than is ice. Ice and liquid water are both bound states of water molecules defined at a macroscopic level. In both cases, the water molecules continue to move around at a microscopic level because of their average kinetic energy, which is related to temperature as $KE = \frac{1}{2}mv^2 = 3kT/2$. In ice the water molecules seem to be frozen in place, but they still move around at a microscopic level, just not as freely as they do in liquid water. The random motion of water molecules defines temperature, and is related to entropy. Ice and liquid water are both coherently organized bound states of water molecules, but in ice the water molecules have a greater tendency to be frozen in place, and in liquid water they move around more freely.

The basic nature of the flow of energy through the universe is that things tend to move faster, and have more directed kinetic energy, as they fall under the influence of gravity, which also tends to make matter and energy clump together. A star forms because hydrogen atoms fall together under the influence of gravity. As hydrogen atoms fall together, they move faster, and that is why the star is hot. The star is only a bound state of hydrogen atoms that fall together under the influence of gravity. But the star also radiates away photons because the protons inside the hydrogen atoms tend to fuse together under the influence of the strong nuclear force. As the protons fall together they overcome their electrical repulsion and fall into a very deep well of nuclear attraction. But for the bound state of an atomic nucleus to form some of that kinetic energy must be radiated away as photons, or the protons will continue to fall right past each other, like a comet that falls right past the sun if the comet has escape velocity and can escape from the gravitational attraction of the sun. The protons only bind together into a bound state of an atomic nucleus because they radiate away some of their kinetic energy as photons, which is why they move with less than escape velocity. When an electron binds to a proton to form the bound state of a hydrogen atom it also radiates away some of its kinetic energy in the form of a photon, and so it also has less than escape velocity. When water molecules bind together into the bound states of liquid water or ice, they also radiate away some of their kinetic energy in the form of photons, and so they also have less than escape velocity.

Radiation of disordered kinetic energy is the essential nature of how all bound states form. Some of the kinetic energy of the things that are bind-

ing together must be radiated away so that those things have less than escape velocity and can form bound states. That is the only way coherently organized bound states can form. As those things radiate away some of their kinetic energy, entropy tends to increase, because the energy that is radiated away is always quantized as $E = h\nu$. Since only part of the directed kinetic energy of those things is radiated away, by the very process of radiating away some of that kinetic energy there are now more things, the original thing that now moves more slowly with less than escape velocity, and the extra thing that carries away some of the kinetic energy.

Since that extra thing tends to move in random directions as that kinetic energy is radiated away, the net effect is that there is more disordered kinetic energy, and overall entropy is increased, by the very process of forming the bound state and radiating away some of the kinetic energy. That increase in entropy is the reason why bound states tend to form over the flow of time. Energy flows from more ordered to less ordered states, and entropy increases as bound states form. All bound states of the universe form because the entropy of the universe increases as those bound states form, which is how energy flows through the universe.

The direction of the flow of energy and the flow of time is a statistical phenomena related to the organization of information. Information becomes more disordered as bound states form. The second law of thermodynamics specifies how all the bound states of the universe form as energy flows from the big bang event to the black hole. There are no bound states in the initial maximally ordered state of the universe, except for the universe itself, which is a uniform distribution of matter and energy. The ultimate final bound state of the universe is the black hole. The black hole is defined by the event horizon, a surface where the escape velocity is equal to the speed of light. The event horizon of a black hole is easily determined by the formula for escape velocity from the surface of a gravitating body, which is given by $v^2 = 2GM/R$, where M is the mass and R is the radius of that gravitating body. Relativity theory says that nothing can travel faster than the speed of light. To determine the radius of the event horizon, simply equate escape velocity with the speed of light, $v = c$, which gives $R = 2GM/c^2$. A black hole must form whenever a sufficient amount of mass gravitationally collapses into a small enough region that the escape velocity from that region is equal to the speed of light. The event horizon of the black hole is a surface of radius R where the escape velocity of that region, due to gravitational attraction, is the speed of light. Since nothing can travel faster

than the speed of light, nothing can escape from the black hole. No signal that originates from inside a black hole can ever cross the event horizon.

This is a puzzle, and seems to indicate that the black hole is a different kind of bound state than the bound states of everything else in the universe. The bound states of all other things only form as those things radiate away some of their kinetic energy as photons, move more slowly, have less than escape velocity, and form bound states. This is the case for the bound states of all atomic nuclei, atoms, molecules, and all macroscopic objects like liquid water or ice. But those bound states are all due to nuclear or electromagnetic interactions. An atomic nucleus forms because of the strong nuclear force, and the bound states of atoms, molecules, and macroscopic objects like liquid water or ice only form because of the electromagnetic interaction, as electrons are attracted to protons. Gravity is different. The entropy of a black hole is not related to radiating away something that carries kinetic energy so that the things that bind together have less than escape velocity. Once something crosses the event horizon of a black hole it cannot escape because the escape velocity is equal to the speed of light, and nothing can travel faster than the speed of light. How does the entropy of the black hole arise and why is it the maximal entropy?

The entropy of the black hole is related to Hawking radiation, a purely virtual quantum process. Near the event horizon of the black hole, virtual particle-antiparticle pair creation occurs, such as electron-positron pairs, and is referred to as a vacuum fluctuation. Virtual pair production arises from the vacuum state, or void, as a spontaneous quantum fluctuation in the energy level of the void, which is zero. The virtual particle carries positive energy and the virtual antiparticle carries an equal amount of negative energy, so that the total energy of this virtual process adds up to zero. But the virtual antiparticle can cross the event horizon and fall into the black hole while the virtual particle moves away from the event horizon and carries positive energy away from the black hole, so that it appears the black hole radiates away positive energy radiation, called Hawking radiation. This is not necessarily a minor effect, as the enormous energy of Quasars is suspected to be a variant of Hawking radiation that arises from rapidly rotating very massive black holes. The energy released from Quasars is rotational energy that is related to the angular momentum of those rotating black holes. The formation of black holes is also not a rare event. Observational evidence indicates that there is a very massive black hole at the center of every galaxy. The black hole at the center of our

galaxy, the Milky Way, has a mass about a million times the mass of the sun, which gives it a large event horizon.

The total amount of Hawking radiation radiated away from the black hole only depends upon the surface area of the event horizon of the black hole, $A = 4\pi R^2$, which only depends on the radius of the black hole, $R = 2GM/c^2$, determined by the mass of the black hole. The bigger the event horizon, the more Hawking radiation is radiated away from the black hole, since the virtual pair production process of Hawking radiation only occurs in the vicinity of the event horizon. The entropy and the temperature of the black hole are related to the total amount of Hawking radiation, which is related to the surface area of the event horizon. This is how the holographic principle was discovered. The total amount of disordered information in the black hole, which is the total entropy of the black hole, is directly proportional to the surface area of the event horizon of the black hole. All of that information is encoded on the event horizon of the black hole, with one bit of information per Planck area. The total amount of disordered information in the black hole is the surface area of the event horizon, $A = 4\pi R^2$, in units of the Planck area. The usual formula for the Planck area, $Gh/2\pi c^3$, only depends on the gravitational constant G , Planck's constant h , and the speed of light c , which are fundamental constants of nature. Since all energy and information in the universe eventually ends up in the black hole, whatever is true for the black hole must also be true for the universe. Hence the holographic principle that the universe is defined on surfaces of quantized space-time, with one quantized bit of information defined per unit of Planck area. The way information is defined for any bound state in the universe is no different than the way it is defined on the event horizon of a black hole, except a black hole is a bound state with maximal gravitational collapse, and that means maximal entropy since entropy can only increase as bound states form.

The universe is only composed of surfaces of quantized space-time that define bound states of information and act as holographic viewing screens. A surface of quantized space-time is a bounding surface that defines a bound state of information, and defines everything that appears to happen in the apparent three dimensional world bounded by that surface. The event horizon of a black hole is just a special kind of viewing screen where you almost see nothing, except even for a black hole you see Hawking radiation. Only the void is truly 'nothing'.

Everything in the universe is in a constant process of returning to its true state, which of course, is nothing. That nothingness, which is the nothingness of empty space, is holographically woven into the somethingness that we call perceivable physical reality. The information for everything in the physical universe is defined on surfaces of quantized space-time that are quantized out of the void of empty space. Even the perceivable fabric of the space-time geometry of a physical universe is holographically woven out of that nothingness of empty space. Everything in a physical universe is information defined on a bounding surface of quantized space-time that holographically defines everything that appears to happen in that apparent three dimensional world.

The entropy of a black hole represents the amount of disordered information that defines the black hole. The explanation for black hole entropy is Hawking radiation. In the vicinity of the black hole event horizon, virtual particle-antiparticle pairs are continuously created out of the vacuum state. Normally, the virtual particle-antiparticle pairs annihilate each other in a short period of time, but the event horizon of the black hole alters this normal process. The antiparticle can fall into the black hole and carry negative energy with it, while the particle moves away from the event horizon and carries positive energy away from the black hole. Conservation of energy requires that the virtual antiparticle carries an equal and opposite amount of energy as the virtual particle. An observer outside the event horizon only sees the positive energy particle, which appears to be a 'real' particle, as that particle travels toward the observer. From the perspective of that observer, the virtual particle appears to become a 'real' particle, as the event horizon separates the virtual particle from the virtual antiparticle. The virtual antiparticle that falls into the black hole is hidden information, which is the information hidden behind the event horizon from the observer. The nature of the entropy of the black hole is the information that is hidden behind the event horizon from the observer. The event horizon forms a boundary that separates the observer from the information hidden behind that boundary. The entropy of the black hole measures the amount of information hidden from the observer behind that boundary, and is directly proportional to the surface area of that boundary. The holographic principle tells us that the event horizon is a surface of quantized space-time, which is like a holographic viewing screen that encodes one bit of disordered information per Planck area defined on that surface. Everything the observer perceives in the apparent three dimensional world bounded by that surface is like a holographic projection from that bound-

ing surface. The 'real' particle that appears to travel toward the observer is only a holographic description of events, and is just like a 'virtual reality' that the observer perceives as displayed upon the viewing screen. But the principle of equivalence tells us that there is no effect of gravity for an observer in free fall through empty space. If that observer is in free fall, then the event horizon, or the viewing screen, must disappear. In some sense, the apparent three dimensional world holographically defined on that viewing screen disappears for an observer in free fall through empty space. What is left if that world disappears? Only empty space is left.

What eventually happens to all the disordered information inside a black hole? The strange answer is black hole evaporation. A black hole has a temperature and radiates thermal blackbody radiation. The temperature of a black hole is inversely proportional to its mass. The nature of black hole temperature is a consequence of the holographic principle, which describes how information becomes more disordered due to gravitational collapse. A black hole forms in a physical universe because of the nature of gravitational collapse, which disorders information. But because of Hawking radiation, a black hole radiates disordered thermal blackbody radiation back into its parent universe. The more massive the black hole, the lower its temperature, and the colder the nature of its thermal blackbody radiation. If the parent universe is cold enough, then the black hole will radiate away more thermal blackbody radiation back into its parent universe than the amount of energy that falls into the black hole. The black hole will eventually evaporate away into nothing as it radiates blackbody radiation back into its parent universe. The more blackbody radiation it radiates away, the smaller it becomes, and that means it becomes hotter and radiates more rapidly. Eventually all the disordered information in the black hole is radiated away into the parent universe in the form of disordered blackbody radiation, and the black hole disappears in a thermal explosion. The black hole eventually evaporates away into nothing.

How can information leave the black hole and return to its parent universe if no signal that originates inside the black hole can ever cross the event horizon? The answer is Hawking radiation, which is a purely virtual quantum phenomenon. Outside the event horizon, virtual particle-antiparticle pair production takes place. The nature of the black hole is that either the particle or antiparticle can cross the event horizon and fall into the black hole, while the paired particle escapes from the black hole and carries energy away from the event horizon. The black hole appears to radiate

energy away from the event horizon. The amount of energy radiated away is a result of thermodynamic equilibrium, like blackbody radiation, and only depends upon the temperature of the black hole, which is inversely related to the mass of the black hole. The holographic principle is inherent in the nature of Hawking radiation. The total amount of radiation radiated away from the black hole, and the total amount of disordered information that defines the black hole, is proportional to the surface area of the event horizon. The event horizon of a black hole is a bounding surface that defines a bound state of information. All of that information is encoded on the bounding surface.

There is an easy way to see the nature of the holographic principle that does not require the complicated mathematics of quantum field theory in a curved space-time used by Hawking. Imagine we have a black hole with radius $R = 2GM/c^2$, and with an area of the event horizon $A = 4\pi R^2$. We're interested in how the area of the event horizon changes as we add a bit of information to the black hole. The change in area is related to the change in radius as $\Delta A = 8\pi R\Delta R$. The smallest bit of information that we can add to the black hole is a single photon with a wavelength about equal to the size of the radius of the black hole. This is the smallest bit of information that can fall across the event horizon and become gravitationally trapped within the black hole. The energy of that photon is given in terms of its frequency as $E = h\nu$. But for a photon we know that the frequency and wavelength are related as $c = \lambda\nu$. If we assume that the smallest bit of information that can fall into the black hole is a photon with wavelength $\lambda = 2\pi R$, then the energy of that photon is $E = hc/2\pi R$. But the addition of that energy to the black hole will increase the mass of the black hole by an amount $\Delta E = \Delta Mc^2$. The radius of the event horizon gives us another relationship $\Delta R = 2G\Delta M/c^2$. If we equate the energy of the photon that falls into the black hole with the increase in mass energy, then $hc/2\pi R = \Delta Mc^2 = \Delta Rc^4/2G$, or $R\Delta R = 2Gh/2\pi c^3$. But this expression gives us an estimate of how much the area of the event horizon increases as the smallest possible bit of information is added to the black hole. The usual definition of the Planck area is $Gh/2\pi c^3$, so this argument shows that as a single bit of information is added to the black hole, the size of the event horizon increases by about one Planck area. This is the holographic principle, which simply says that all the information for the black hole is encoded on the event horizon, with one bit of information per Planck area.

This estimate for the smallest size bit of information we can add to a black hole also gives an estimate of the temperature of the black hole. If we

equate the energy of the smallest bit of information photon $E = h\nu$ with the energy of disordered thermal motion per unit of information $E = kT$, we find that $kT = hc/2\pi R = hc^3/4\pi GM$. The correct answer from Hawking is $kT = hc^3/16\pi^2 GM$. If the black hole is colder than the surrounding space, then the black hole is a net absorber of energy, since energy tends to flow from the hotter to the colder object, which is the second law. But if the black hole is hotter than the surrounding space, then the black hole radiates away Hawking radiation into that space, which is disordered thermal blackbody radiation, and the black hole eventually evaporates away into nothing.

Why does the mass of the black hole decrease as Hawking radiation is radiated away? The simple answer is energy is conserved. Virtual particle-antiparticle pair production requires no energy. Virtual particles are created out of nothing and annihilate back into nothing. The particle radiated away from the black hole carries positive energy while the particle that falls into the black hole carries negative energy. The total energy of this virtual process adds up to zero, as if nothing actually happens. Something is created from nothing. In some sense, the entire physical universe is created from these kinds of quantum fluctuations, as virtual particle-antiparticle pair production spontaneously arises from the vacuum state, or void. The mass of the black hole decreases through Hawking radiation because of the negative energy particles that fall into it. Since mass and energy are related as $E = mc^2$, negative energy is like negative mass. This description of how a black hole radiates Hawking radiation only seems strange because it is the holographic description of events. In terms of the viewing screen description of quantum gravity, conservation of energy and information make perfectly good sense. Nothing strange ever happens to all the fundamental spin variables defined on surfaces of quantized space-time that encode all the quantized bits of information. Conservation of energy is the same as conservation of information.

What happens before the big bang event? What happens after the black hole? The simple answer is nothing. We could say the void happens, but nothing ever happens in the void because there is nothing in the void of empty space. The physical universe is only dynamically defined as an ordered sequence of events from the big bang event to the black hole. The big bang event is a point of space-time singularity that is similar to the point of space-time singularity at the center of the black hole. Inflationary cosmology tells us that the entire universe arises in a big bang event as a

spontaneous eruption of energy from the void, or vacuum state. That spontaneous eruption of energy from the void is understood as a quantum fluctuation in the energy level of the vacuum state, which is zero.

The phenomenon called exponential expansion of space-time geometry is an essential aspect of inflationary cosmology. Inflation of space-time geometry is due to a kind of symmetry breaking that gives rise to an unstable cosmological constant that is responsible for the exponential expansion of space-time early in the history of the universe, and that results in a uniform distribution of matter and energy throughout the universe. Any large scale irregularities in an initially disordered state of the universe are 'ironed out' by inflation as long as there is uniformity at the smallest scale of the universe. The unstable cosmological constant is a kind of 'anti-gravity' that sets the scale for inflation of space-time.

It's instructive to examine how an unstable cosmological constant is constructed early in the history of the universe, since it demonstrates the nature of symmetry breaking. With quantum field theory, the cosmological constant is understood to be nothing more than vacuum energy, which is also called dark energy.

With any quantum field theory, there is constant virtual particle-antiparticle pair production throughout all of space-time from the vacuum state, or void. Any quantum field, $\Phi(x, t)$, will generate a vacuum energy at every point in space-time because of virtual particle-antiparticle pair production. That vacuum energy can be written as a function of the field, or as $V(\Phi)$. The basic idea of symmetry breaking in quantum field theory is analogous to the spontaneous magnetization of magnets, and nicely demonstrates the connection to the holographic principle.

The nature of a magnet is a bound state of atoms, like iron atoms, where each atom has an intrinsic magnetic moment that is due to the combination of electric charge carried by electrons and atomic nuclei, and the orbital and spin angular momentum of those particles. A magnetic moment is like an electrically charged 'spinning top' that generates an intrinsic magnetic field just because it is charged and spinning. This is as much the case for the magnetic moment of an electron, with its intrinsic quantum numbers of spin and electric charge, as it is for an iron atom, with its electron and nuclear spin, and the orbital angular momentum and elec-

tric charges of those particles, or for the spinning earth, with its rotational angular momentum and electrical currents deep within its molten core. But all of this information ultimately reduces down to fundamental spin variables defined on a surface of quantized space-time because the spins act like little magnets.

Spontaneous magnetization of magnets only occurs because the spins have a potential tendency to align with each other. There is always an energetic competition between the potential tendency of spins to align together and the kinetic tendency of those spins to flip into random directions of non-alignment. If the temperature of the system is too hot, there is too much disordered kinetic energy in the system, and there is no global alignment. If the temperature of the system is low enough, then the potential tendency to align energetically wins out over the kinetic tendency to flip into random directions, and global alignment occurs, but spins continue to flip directions even after global alignment occurs.

There is an interesting phenomena called 'scaling' about the approach to the phase transition where global alignment occurs. As spins begin to locally align with each other they form local groups, and those groups then have a tendency to align with other groups to form larger groups, which then tend to align into even larger groups, until the size of the largest group is the same order of magnitude as the entire system. But even in a globally aligned system, spins continue to flip directions and dynamically rearrange themselves.

There is a subtlety about the magnetization of actual magnets that arises from the nature of spin. It naively seems that spins align because their magnetic moments attract each other if they point in the same direction, but that is not the actual case. The strength of those magnetic interactions is about a thousand times too small. Spontaneous magnetization occurs because there is a tendency for electron spin alignment. A global magnetic field then results only because each electron has a magnetic moment that is due to its spin and electric charge.

If magnetic interactions are not responsible for global spin alignment, then what is? The answer is the exclusion principle, which says no two electrons can share all the same quantum numbers or occupy the same space-time point because they are spin $\frac{1}{2}$ particles. Two identical electrons cannot occupy the same state. The tendency is for electron spin to point in oppo-

site directions, which is the case as electrons fill the same quantized energy level, or atomic orbital. An atomic orbital can only be occupied by two electrons that have opposite directions of spin. All the properties of matter composed of electrons and atomic nuclei are due to the exclusion principle. The stability of matter is due to the exclusion principle. The only reason matter occupies space, and does not collapse, is because of quantum uncertainty and the exclusion principle. The exclusion principle is inherent in the nature of spin $\frac{1}{2}$ particles and quantum field theory.

Spin 1 particles, like photons, are totally different in that they prefer to share all the same quantum numbers and have their spins point in the same direction, or align, which is the reason why a laser emits coherent electromagnetic radiation. The tendency of spin 1 particles to align and of spin $\frac{1}{2}$ particles to anti-align is purely a quantum phenomena related to the nature of spin carried by all point particles. Spin 1 particles tend to align because their wave functions behave like commuting numbers $\varphi_1\varphi_2 - \varphi_2\varphi_1 = 0$. Spin $\frac{1}{2}$ particles tend to anti-align because their wave functions behave like anti-commuting numbers $\varphi_1\varphi_2 + \varphi_2\varphi_1 = 0$. That is their only difference. The nature of quantum field theory is that every electron in the universe is identical to every other electron, and every photon is identical to every other photon, because any particle that is described by the same state of quantum numbers is an identical excitation from the vacuum state, or void. The nature of spin $\frac{1}{2}$ particles is that no two identical particles can occupy the same state, while for spin 1 particles the tendency is to occupy the same state.

Spontaneous magnetization is only possible in some exceptional circumstances, like for iron, because the tendency for electron spin anti-alignment somehow results in global spin alignment. The explanation is complicated because as one spin anti-aligns with another spin, and then that spin anti-aligns with still another spin, there is somehow a tendency for global spin alignment. But the ultimate explanation for spin alignment is the viewing screen description of quantum gravity. The nature of spin carried by point particles, and the nature of quantum field theory, is only a holographic description of events. The fundamental spin variables defined on viewing screens of quantized space-time have a tendency for spin alignment that is due to the computational rules of quantum gravity. Those viewing screens are bounding surfaces that define a three dimensional world. Global spin alignment on surfaces of quantized space-time is the reason spontaneous symmetry breaking is possible in any physical system.

Global spin alignment is called a phase transition, and is the nature of symmetry breaking, as the spins globally align with each other throughout the system.

The result of global electron spin alignment is the entire system develops a global magnetic field, which is analogous to a quantum field, $\Phi(x, t)$. Symmetry breaking means the system develops a global magnetic field because the spins, and their intrinsic magnetic moments, globally align with each other in a particular direction throughout the system. The phase transition occurs because disordered kinetic energy is transferred away from the system as the temperature of the system is lowered. A neat way to see how this is possible is to write the vacuum energy, $V(\Phi)$, which describes the ground state energy of the system, in terms of an expansion: $V(\Phi) = a + b\Phi^2 + c\Phi^4 + \dots$. Only even powers of Φ occur because the vacuum energy must have a minimum. The parameters a , b , and c depend upon the temperature of the system, and can also be written in terms of an expansion: $b(T) = \alpha + \beta T + \dots$. If these parameters are all positive, then the minimum value of $V(\Phi)$, or the ground state energy, occurs at $\Phi = 0$, and there is no global magnetic field. But if some of the parameters become negative, then the ground state may occur at a non-zero value $\Phi = \Phi_0$ and the system spontaneously develops a global magnetic field. To see how this is possible, write $b = \beta(T - T_c)$, where T_c is the critical temperature at which the phase transition occurs. To find the ground state, we look for the minimum value of $V(\Phi)$. As disordered kinetic energy is transferred away from the system, the temperature is lowered, and eventually the parameter b becomes negative. In that case, the ground state energy of the system occurs for the non-zero field strength $\Phi_0 = \{\beta(T_c - T)/2c\}^{1/2}$. This kind of 'power law' relationship is experimentally confirmed in spontaneous magnetization below the critical temperature.

In the case of the unstable cosmological constant early in the history of the universe, spontaneous symmetry breaking occurs through a similar mechanism, but the vacuum energy is a little more complicated. At high temperatures, the ground state energy of the system is still at $\Phi = 0$, but as the system cools, the system undergoes symmetry breaking because the ground state energy is at some non-zero value $\Phi = \Phi_0$ determined by the vacuum energy function $V(\Phi)$. But that function may look a bit like a rollercoaster, with more than a single locally minimum value. The absolute minimum value determines the true ground state, but there can be a false vac-

uum, which is a local minimum of the vacuum energy that is not the absolute minimum. As the system makes the transition from $\Phi = 0$ to $\Phi = \Phi_0$ it may stop for a while in the false vacuum. While the system is in the false vacuum, it is in an unstable state that will eventually decay into the true vacuum, but while it is in that unstable state an unstable cosmological constant is generated that is responsible for the exponential expansion of space-time.

A false vacuum is an unstable state, like super-cooled liquid water that eventually must transition into the form of ice, which is a more stable state. Liquid water can be cooled below the freezing point of water, but this is an unstable state that at some point must rapidly transition into the form of ice. As ice forms from super-cooled water, heat is released, just like in any phase transition. In a similar way, as the universe transitions from a false vacuum state to a true vacuum state early in the history of the universe, heat is released. That 'heat' then takes the form of the material physical universe that we are all familiar with. But while the universe is in the unstable state of a false vacuum, the universe rapidly inflates in size because of the 'anti-gravity' of an unstable cosmological constant.

The underlying reason for the inflation of space-time is an unstable process of virtual particle-antiparticle pair production that results in an unstable vacuum energy. The inflation of space-time 'orders' information at a point of space-time singularity, which 'starts' the second law of thermodynamics in the universe that is created with that big bang event. Any initial irregularities in the organization of information that arise as a quantum fluctuation in the energy level of the vacuum state are 'ironed out' by inflation of space-time. All of that energy spontaneously erupts into a physical universe, which then undergoes gravitational collapse.

The total energy of the universe is zero because the universe arises as a quantum fluctuation in the energy level of the void. The reason the total energy of the universe is zero is because the negative potential energy of gravitational attraction cancels out all other forms of positive energy, like kinetic energy and mass energy. Zero total energy means the universe is just on the cusp of being unbound, like a particle with escape velocity. This is described as the universe being on the cusp between an 'open' and 'closed' universe, which does not collapse back upon itself since its expansion has just enough kinetic energy to keep expanding indefinitely, but with an ultimate expansion rate of zero. As the universe expands indefi-

nitely, the curvature of the universe approaches zero as the size of the universe approaches infinity, which is called a 'flat' universe, described by the Euclidean geometry of empty space. As the universe continues to expand, it continues to cool, just like an expanding gas that cools as it expands. The current temperature of the universe, measured from the background microwave radiation left over from the big bang event, which behaves like blackbody radiation, indicates a temperature of about 2.70 Kelvin. This is obtained from the formula for the intensity of blackbody radiation as a function of the frequency of that radiation, $I(\nu) = 4h\nu^3/c^2 \{ \exp(h\nu/kT) - 1 \}^{-1}$, which of course demonstrates the quantum nature of blackbody radiation. As the universe expands indefinitely, its temperature will approach absolute zero as its size approaches infinity. This is called the 'heat death' of the universe. What happens to all the black holes in the universe? A black hole has a temperature inversely related to the mass of that black hole. A black hole the mass of the sun has a temperature about 10^{-7} degrees Kelvin. As the universe continues to expand indefinitely and cools below this temperature, the black hole eventually evaporates away into nothing, as it radiates away all of its energy back into that very cold universe in the form of disordered thermal blackbody radiation.

There is another complicating factor with the expansion of the universe, which is the cosmological constant that appears to take on a non-zero value for the present state of the universe. The cosmological constant is like a kind of long range 'anti-gravity', which means that the expansion rate of the universe appears to increase over time, as everything in the universe repels everything else. This repulsive force counteracts the effect of gravity at cosmological distances, and causes the universe to exponentially expand faster and faster over the course of time. The value of the cosmological constant means the universe appears to double in size about every fifteen billion years. The nature of an expanding universe is that every point moves away from every other point, and the velocity of that movement is proportional to the distance of separation. From every point of view in the universe, the universe appears to expand, and the rate at which things move away from each other is directly related to the distance between those things. If an observer looks out into an expanding universe, at some point the things that are moving away appear to move at the speed of light. In an exponentially expanding universe that distance never changes, and is about fifteen billion light years for our universe. Everywhere we look in the universe, there is a point about fifteen billion light years away, where the universe appears to expand at the speed of

light. Since no signal can travel faster than the speed of light, no signal can ever reach us from that point of no return. This is just like the point of no return that defines the event horizon of a black hole, except it defines a cosmic event horizon. Every observer is surrounded by a cosmic event horizon, defined by a sphere where the universe at that point appears to expand at the speed of light, and no signal can ever reach that observer from beyond that horizon. That observer can only see things as far out as that cosmic horizon.

How can the universe appear to expand from the big bang event? Doesn't the universe have to expand into 'something' larger than itself? Imagine that space is only two dimensional with one spatial dimension called x and another called y . If space was flat, then the world would be defined in the x - y plane. But space-time is curved so we can take that flat plane and roll it up any way we please. Imagine that space is deformed into the shape of a balloon. The world is defined on the surface of that balloon. The big bang event is like all the air is taken out of the balloon and so it collapses down to a very tiny region that looks like a point from far away. Now begin to blow up the balloon, which is like the flow of time. Space appears to expand as the balloon is blown up. Imagine that on the surface of the balloon we paint little objects like galaxies, stars, and planets. These objects appear to move away from each other as the balloon expands. That expansion is known as Hubble's law. As the balloon expands, the velocity with which two points on the balloon separate away from each other is proportional to the distance of separation. But those objects also appear to gravitationally attract each other, and if they are close enough together and move with less than escape velocity, they tend to clump together into even larger objects. If enough mass is concentrated into a small enough region of space, then a black hole forms. What does the universe expand into if there is 'nothing' larger than the universe? The universe is holographic, and expands into the void, which is the empty 'background space' the universe is created within as a big bang event.

How can the balloon be blown up if space-time geometry is defined upon the surface of the balloon? In some sense, that blowing up of the balloon is the energetic flow of information from the big bang event to the black hole, which is the same as the flow of time defined over an ordered sequence of events. That flow is defined as energy flows from more ordered to less ordered states, and every state of the universe is an event. As information flows in the energetic gradient of gravitational collapse from big bang to

black hole, space-time appears to expand, and matter and energy appear to clump together under the influence of gravitational attraction. The perceived flow of time is only an ordered sequence of events defined by the nature with which those states of information become increasingly disordered as energy flows from the big bang event to the black hole. Each perceived event is a state of the universe. The holographic principle tells us that each state of the universe is holographically defined on a surface of quantized space-time that acts as a viewing screen and projects its perceivable images to a point of view. The universe only holographically appears to expand from the big bang event as those viewing screens are perceived over a sequence of events, just like the animated frames of a movie. All the information for the physical universe is defined on surfaces of quantized space-time. The logical consistency of science requires that space-time geometry can only be quantized on those surfaces. The void is the empty 'background space' within which all the perceivable actions of the universe are animated upon those viewing screens of quantized space-time, and it is the source of all the information defined on those viewing screens.

How can the universe have a beginning as a big bang event? What does it mean to say that the universe has an ending? The universe arises as a spontaneous eruption of energy from the vacuum state, which is the void of empty space. That spontaneous eruption of energy is understood as a quantum fluctuation in the energy level of the void. The nature of the inflation of space-time early in the history of the universe is to 'order' the information that spontaneously arises with that eruption of energy. The nature of gravitational collapse is to 'disorder' that information, which becomes maximally disordered with the formation of a black hole. The formation of every bound state disorders information. The sequence of events that we call the flow of time is only the formation of those bound states.

The important point about the inflation of space-time is that it 'orders' information at a point of space-time singularity, which is the big bang event. That information is encoded by some kind of fundamental spin variables, defined on surfaces of quantized space-time, with one bit of quantized information per Planck area. The nature of inflation of space-time is not to create that information. That information all arises from the void, as empty space is quantized into surfaces of quantized space-time. That information arises as a quantum fluctuation in the energy level of the void, which is zero. That information is initially disordered because of the

nature of that quantum fluctuation. Inflation of space-time is how the information is 'ordered', in the sense that gravitational potential energy is ordered, while kinetic energy is disordered. Inflation of space-time only results in a uniform distribution of matter and energy throughout the early universe, which then undergoes gravitational collapse. The nature of gravitational collapse is to disorder information, until the ultimate disordered bound state of the universe, the black hole, is formed. The second law is all about how information is disordered through gravitational collapse, and inflationary cosmology is only about how information is ordered through the 'anti-gravity' of an unstable cosmological constant that arises early in the history of the universe.

The inflation of space-time does not create the information in the universe. That information is created as the void of empty space quantizes itself into surfaces of quantized space-time. The void is the source of all quantized bits of information in the universe. Information is encoded in the form of spin variables that reflect rotational symmetry of empty space. Those quantized bits of information obey the laws of the universe. The laws of the universe also reflect the nature of the void, since all those laws reflect the symmetry of empty space. The symmetry of empty space is broken as those spin variables point in particular directions and align together. All the actions of the universe, which arise as broken symmetries, are holographically animated on viewing screens of quantized space-time that are animated just like the frames of a movie. Each viewing screen holographically projects its perceivable images to a point of view, where the image is perceived. All the perceivable 'objects' defined in the universe are holographically defined on those viewing screens. All the behaviors of those 'objects' are holographically animated on those viewing screens over a sequence of events ordered in the universal flow of energy, just like the animated frames of a movie. The ordered sequence of events animated on those viewing screens arises with that universal flow of energy. All the quantized bits of energy in the universe obey the laws of the universe as energy flows through the universe, which reflects the symmetry of empty space. All of those actions holographically reflect the perfectly symmetric nature of the void as broken symmetries. All the perceived actions animated on those viewing screens holographically mirror the nature of the void, but who is watching the animation? Who is the perceiving 'subject'?

Notes

An introduction to the holographic principle is found in the article "Information in the Holographic Universe" by Jacob Bekenstein in *Scientific American* August 2003. A more thorough discussion of the physics involved in the holographic principle is found in the article "The Holographic Principle" by Raphael Bousso, and in the article "The World as a Hologram" and the book *The Black Hole War* by Leonard Susskind. The second law of thermodynamics, as it relates to the big bang event, the black hole, inflationary cosmology and the problem of unification, is discussed in *The Road to Reality* by Roger Penrose. In the original derivation by Hawking, the entropy of a black hole was found to equal one-quarter the area of the event horizon, expressed in natural units of Planck area. Here we follow the suggestion of Susskind that the Planck area be redefined as $4Gh/2\pi c^3$, so that black hole entropy is exactly equal to the area of the event horizon.

There is no conflict between mysticism and science. There is a conflict between the science of 2000 BC and the science of 2000 AD. To hold onto an outdated science is childish.

Joseph Campbell

Ignorance is strength.

George Orwell

This is not the way of Tao
Whatever is contrary to Tao will not last long

Tao-Te-Ching

Thus shall ye think of all this fleeting world
A star at dawn, a bubble in a stream
A flash of lightning in a summer cloud
A flickering lamp, a phantom, and a dream

The Diamond Sutra

I was dreaming that I was a butterfly fluttering happily. Suddenly, I awoke. Now I wonder who I am. A man who dreamed he was a butterfly, or a butterfly dreaming it is a man.

Chuang Tzu

These things too shall pass away

Source unknown

Is not philosophy the study of death?

Plato

All philosophy is a footnote to Plato.

Alfred North Whitehead

Faith is the substance of things hoped for, the evidence of things not seen

Hebrews

I believe in Spinoza's God who reveals himself in the orderly harmony of what exists.

Albert Einstein

The spirit of the Lord, indeed, fills the whole world, and that which holds all things together knows every word that is said.

Book of Wisdom

There is that in me-I do not know what it is
But I know it is in me

Walt Whitman

To meet my thousand, thousand faces, I roam the world

Rumi

And we, with our unveiled faces reflecting like mirrors the glory of the Lord,
all grow brighter and brighter as we are turned into the image that we reflect.

Corinthians

What did your face look like before you were born?

Zen koan

Out of the cradle endlessly rocking

Walt Whitman

O body swayed to music, O brightening glance
How can we know the dancer from the dance?

William Butler Yeats

Relation is the essence of everything that is

Meister Eckhart

All creatures are interdependent

Meister Eckhart

Little lamb, who made thee?
Dost thou know who made thee?

William Blake

Tiger, tiger burning bright
In the forests of the night
What immortal hand or eye
Dare frame thy fearful symmetry?

William Blake

God loves all creatures as God

Meister Eckhart

God is creating this entire world full and entire in this present now. There where time never penetrates, where no image shines in, in the innermost and highest aspect of the soul, God creates the entire Cosmos.

Meister Eckhart

What really interests me is whether God had any choice in the creation of the world.

Albert Einstein

To know that what is impenetrable to us really exists, manifesting itself as the highest wisdom and the most radiant beauty, this knowledge, this feeling is at the center of true religiousness.

Albert Einstein

Science without religion is lame, religion without science is blind.

Albert Einstein

You will hardly find one among the profounder sort of scientific minds without a peculiar religious feeling of his own. But it is different from the religion of the naive man. For the latter God is a being from whose care one hopes to benefit and whose punishment one fears; a sublimation of a feeling similar to that of a child for its father, a being to whom one stands to some extent in a personal relation, however deeply it may be tinged with awe. But the scientist is possessed by the sense of universal causation. The future, to him, is every whit as necessary and determined as the past. There is nothing divine about morality, it is a purely human affair. His religious feeling takes the form of a rapturous amazement at the harmony of natural law, which reveals an intelligence of such superiority that, compared with it, all the systematic thinking and acting of human beings is an utterly insignificant reflection.

Albert Einstein

All the gods, all the heavens, all the hells, are within you. The gods are within you-this is what the myths are all about. With our mythology the symbols became interpreted as facts. God became a fact not a symbol. In our mythology nature is fallen and corrupt-the idea of a conflict between good and evil, and we are invited to stand for the good against the evil-rather than putting ourselves in accord with nature. What else is there to worship but nature-some figment of your imagination that you put up in the clouds?

Joseph Campbell

All things are without a self. We are all illusions of a consciousness that is the ground of being.

The future comes from nowhere else than the energy of the psyche. The energy is within you. Life is a manifestation of the consciousness.

Joseph Campbell

'I am the source'. This is the truth of truths. All is within-time, space, causality. The energy of consciousness-the energy of life-engaged in the field of time-is the power of life to throw off death and come into new birth. Where there is time there is inevitably birth and death. Where there is time there is inevitably sorrow-the loss of what is valued. Everything is experienced in terms of pairs of opposites-in the field of time. Beyond is the transcendent-that which transcends duality-the timeless-not engaged in the field of time. The source-from which all comes and to which all returns-is undifferentiated consciousness-the void.

Joseph Campbell

The universe is the unity of all things. If one recognizes his identity with this unity then the parts of his body mean no more to him than so much dirt, and death and life, end and beginning, disturb his tranquility no more than the succession of day and night.

Chuang Tzu

Misfortune comes from having a body
Without a body how could there be misfortune?
Surrender yourself humbly; then you can be trusted to care for all things
Love the world as your own self; then you can truly care for all things

Tao-Te-Ching

I discovered the secret of the sea in meditation upon a dewdrop.

Kahlil Gibran

Tao in the world is like a river flowing home to the sea

Tao-Te-Ching

Row, row, row your boat
Gently down the stream
Merrily, merrily, merrily, merrily
Life is but a dream

Nursery Rhyme

The Nature of Spontaneous Emergence

The Principle of Least Action

Everything in the universe, which includes the behavior of all the things in the universe, spontaneously emerges in the universal flow of energy. The nature of the universal flow of energy is the second law of thermodynamics. The nature of spontaneous emergence is best understood with the concept of the formation of bound states, or symmetry breaking. As energy flows in its universal gradient, like a river that flows down a mountainside and returns to the ocean, everything in the universe spontaneously emerges in that flow of energy because of the way energy is bound together into those coherently organized bound states. All of that coherent organization is due to symmetry breaking, like liquid water that freezes into ice. Even the body is only a bound state of energy that arises from the nature of symmetry breaking, like any other bound state of energy in the universe. The body is composed of body organ systems, and each body organ system, like the mind, is also a bound state of energy and information. Each body organ system is a bound state of cells, each cell is a bound state of atoms and molecules, and those atoms and molecules are bound states of electrons and atomic nuclei.

Even the electrons and quarks inside the atomic nuclei are bound states, but this is where the holographic principle comes in. There is an ultimate level at which all the information in the universe is defined. That fundamental level is the Planck area. The reason information is bound together on a surface of quantized space-time is because that information is encoded as fundamental spin variables, and there is an inherent tendency for spin alignment. That is the only reason why the surface of quantized space-time acts like a holographic viewing screen.

The reverse scenario is also the case. A society is a bound state of bodies, a solar system is a bound state of planets and a star, and a galaxy is a bound state of solar systems. The entire universe is a bound state of everything in the universe. All that information and energy is defined at the fundamental level of the Planck area. But scientific reductionism can only go so far. There must be a source of all that energy and information. The source is the void. The entire universe arises in the big bang event as a spontaneous eruption of energy from the void, which in inflationary cosmology is understood as a quantum fluctuation in the energy level of the void. The void is the source of all the energy and information in the universe. All the

quantized bits of information and energy in the universe arise from the void, with one bit of information per quantized unit of space-time geometry, which is the Planck area. All those quantized bits of energy and information are defined upon surfaces of quantized space-time. Those quantized bits of energy and information all obey the laws of the universe, and those laws all reflect the symmetry of empty space. The void is the source of all the quantized bits of energy and information in the universe, and it is the source of the laws of the universe that all those bits of information and energy obey as energy flows through the universe. All the actions of the universe are enacted as energy flows through the universe and the symmetries of empty space are broken.

Spinoza, the favorite philosopher of Einstein, says it the best: "That eternal and infinite being we call God, or Nature, acts from the same necessity from which it exists". The void acts from the same necessity from which it exists, which is the symmetry of empty space. The flow of energy through the universe, from which all actions of the universe arise, is determined by the symmetry of empty space.

The second law specifies that entropy, which measures disordered information, increases as energy flows through the universe, but the flow of energy through the universe is not random. Once the universe arises as a spontaneous eruption of energy from the void, the flow of energy through the universe obeys the laws of the universe, which all reflect the nature of the symmetry of empty space. This principle is manifest in string theory, and is why empty space is ten dimensional, which is the only way all the laws of the universe can arise from symmetry.

The nature of symmetry breaking is to break the symmetry of empty space. The symmetry of empty space is broken when a surface of quantized space-time is quantized from empty space. Each fundamental element of quantized space-time, or Planck area, encodes a quantized bit of information, which is analogous to a spin variable. The nature of spin is to encode quantized information, like a spin $\frac{1}{2}$ variable that either points 'up' or 'down', and so encodes information in a binary code. The nature of spin reflects the rotational symmetry of empty space, and the law of conservation of angular momentum. The rotational symmetry of empty space is broken whenever a spin variable points in some particular direction. The symmetry of empty space is further broken when those spin variables coherently align with each other and form a bound state. A coherently organized

bound state of spin variables tends to point in a particular direction as they align together, and that breaks the symmetry of empty space. Those directions define the nature of all the actions enacted in the universe.

The entire universe and every form of energy within the universe are defined on surfaces of quantized space-time that arise within the void. Each fundamental element of quantized space-time, or Planck area, encodes a bit of information, which is also a quantized bit of energy. The holographic principle gives a natural explanation for how information and energy are quantized, in the form of spin variables, which naturally arise from the symmetry of empty space as empty space is quantized and that symmetry is broken. In relativistic quantum field theory, spin is understood to arise as a quantized consequence of the rotational symmetry of empty space. The process of quantizing empty space into surfaces of quantized space-time naturally results in the encoding of information on those surfaces in the form of spin variables. The energy inherent in each spin variable has a kinetic aspect, which is the tendency of each spin to flip directions, and a potential aspect, which is the tendency of different spins to align together, like little magnets. The tendency of spins to spontaneously align together is the prototypical example of spontaneous symmetry breaking, and explains how bound states form in the universe, and why everything is a form of energy.

The spontaneous formation of bound states, which are all forms of energy, is a natural consequence of the holographic principle. The entire universe arises as a spontaneous eruption of energy from the void, and is understood in inflationary cosmology as a quantum fluctuation in the energy level of the void, which is zero. The universe is a bound state of everything within it, but the universe is on the cusp of being unbound, since the total energy of the universe is zero, like a particle with escape velocity. The total energy of the universe is zero because the negative potential energy of gravitational attraction cancels out all forms of positive energy, like kinetic energy and mass energy. With the holographic principle, it's understood that all of that energy is defined upon surfaces of quantized space-time with one quantized bit of energy per Planck area, and those surfaces all act as holographic viewing screens that project perceivable holographic images from the viewing screen.

Each surface of quantized space-time is a bounding surface that holographically defines everything that appears to happen in the apparent

three dimensional world that is bounded by that surface, but those viewing screens also define bound states of information. The perceivable holographic images projected from the surface correspond to the bound states, or forms of energy, defined on the surface. The world is animated, just like the frames of a movie over a sequence of events, as a sequence of viewing screens is observed in order. The order of the viewing screens is determined by the universal flow of energy, as energy flows from the big bang event, the most ordered state of information in the universe, to the black hole, the most disordered bound state of information in the universe. The universal flow of energy is determined by gravitational collapse, just like the flow of a river that flows from the top of the mountain to the bottom of the ocean. As energy flows in its universal gradient, bound states of energy spontaneously form. That energy becomes more disordered as bound states form, which eventually results in the most disordered bound state of energy possible, which is the black hole.

This is really where the holographic principle is most helpful to understand the relationship of the void to the universe. The void is the nature of infinite empty space, which is absolute space. Empty space is absolute because there is nothing in it, and so it never changes. The nature of the void is not dynamical, since there is nothing in the void, and it cannot change. It is the timeless nature of reality. The void is the primordial nature of existence that exists 'before' the universe is created in a big bang event. The universe is defined upon surfaces of quantized space-time, and those surfaces act like holographic viewing screens that are animated over a sequence of events in the universal flow of energy, just like the animated frames of a movie. The nature of the perceived flow of time is a part of the perceivable world, and only arises because of the way a sequence of viewing screens is animated over an ordered sequence of events in the universal flow of energy, just like the frames of a movie. The nature of the void, the primordial nature of existence, does not exist within the world or within the perceived flow of time, but is outside the world. The world is holographic, animated upon viewing screens, and the void is outside. Those viewing screens are all quantized out of the void of empty space, and are embedded within empty space. The void is the changeless, empty 'background space' within which all the perceivable actions of the universe are animated upon those viewing screens of quantized space-time, and the void is the source of all the information defined on those viewing screens. The void is outside of everything that can be perceived in the perceivable world.

The formation of a body in the world is just the spontaneous formation of a bound state of energy, a bound state that forms somewhere between the big bang event and the black hole. A bound state forms because of the development of coherent organization, but eventually that coherent organization is lost, and the bound state becomes disorganized and falls apart. Disorganization of information for all bound states is inevitable, because all energy flows in its universal gradient from big bang event to black hole. Every bound state that forms is inherently unstable, and eventually must fall apart as energy flows in its universal gradient, just like a snow pack that forms on the side of the mountain, but must eventually collapse down the mountainside in an avalanche, or melt away, and rejoin the flow of water in its return to the ocean.

All bound states form because of the coherent organization of the flow of energy that holds the bound state together over a sequence of events, but eventually the flow of energy becomes disorganized and the bound state falls apart. Every body that is born and holds together for a while must eventually die. The life of a body in the world is animated on a sequence of viewing screens just like anything else in the world. All information is defined on surfaces of quantized space-time. The body is a bound state of energy and information, and the complex behaviors of that body all arise because of the way emotional energy coherently flows through that body, which is determined by the laws of the universe.

The simplest body to consider is a single cell. Even single celled organisms have recognizable emotional responses, as they move toward whatever promotes body survival and express desire, or move away from whatever threatens body survival and express fear, or move against whatever threatens body survival and express anger. How can we understand emotional responses for single celled organisms? A single cell is a coherently organized bound state of atoms and molecules. Those molecules can become quite complex in nature, such as DNA and RNA molecules, complex protein molecules, carbohydrates, and lipids. All of these molecules interact with each other. For example, certain protein molecules regulate which genes are expressed on DNA molecules, and that genetic expression results in the synthesis of protein molecules. But at a more fundamental level, we can understand these interactions as the nature of coherently organized bound states, which we can characterize as dynamical orbits. The nature of the complicated orbits for the molecules that comprise a cell is vastly more complex than the simple orbits we've discussed so far, like the orbit of the

earth around the sun or the orbit of an electron around an atomic nucleus, but the basic principle is the same. The cell is a coherently organized bound state, and that means some kind of complex orbits for everything inside the cell. The molecules inside the cell all orbit around each other in some complicated way, which is why the cell holds together as a bound state while the behaviors of the cell are enacted. Those behaviors are inherently emotional in nature.

The nature of emotion is best understood with the concept of attractors and basins of attraction. The complex way energy flows through the cell, as the behaviors of the cell are enacted, is coherently organized, and this is what we recognize as emotional responses. The dynamical organization of a cell is characterized by complex bound state orbits, as everything inside the cell orbits everything else in some complicated way. The DNA molecules are as much bound to the proteins as the protein molecules are bound to the DNA molecules. If everything inside the cell was not bound together in some complex way, the cell would fly apart because of the kinetic energy of all the molecules, the same way the gas molecules inside a container fly apart if the container is opened, and the gas escapes from the container. Everything inside the cell has less than escape velocity, and so is bound to the cell, just like the atmosphere that is bound to the earth. That escape velocity is determined by electromagnetic interactions between all the molecules. Part of those interactions arise from the cell membrane, which acts like the walls of a container, and keeps everything trapped inside. But the membrane is permeable, and molecules can pass through the membrane. The cell membrane has channels that open and close in response to electrical and chemical signals, which facilitates that trans-membrane movement. Other signals influence which chemical reactions occur within the cell, and enable the cell to respond to its environment. The entire system of the cell is a coherently organized bound state, but that bound state is a non-equilibrium system that interacts with its environment as matter and energy flow through the cell. The resultant behavior of the cell is characterized by some kind of complex bound state orbits.

Those orbits are best described as attractors that drain a basin of attraction. The basin of attraction is like the drainage basin of a mountain range, and the attractor is like the river that the mountain range drains into. The mountain range is divided into different basins of drainage, which drain into different rivers. The flow of water from the mountaintop to the river

is like the flow of energy through the cell. The behavior of the cell is determined by how energy flows through the cell. If energy flows toward a particular attractor, then that results in a particular kind of behavior. The initial conditions of the cell determine which attractor energy flows towards, and so determine the nature of the behavior. The initial conditions determine which basin of attraction energy flows within, like a basin of drainage that flows toward a particular river. The initial conditions are the nature of the stimulus, and the particular attractor that energy flows towards is the nature of the response, which is the behavior that arises from that particular kind of attractor. The net effect is that emotional behavior occurs in a pattern of stimulus and response. That behavior can change over time because the coherent organization of the attractors and basins of attraction can become dynamically reorganized as energy flows through the cell over an ordered sequence of events, which means the cell can learn from experience. The coherent organization of information inside the cell is a kind of memory of prior events that influences future behavior.

The complex behaviors of a cell arise because of the way emotional energy coherently flows through that cell, which is determined by the laws of the universe. A body is a bound state of cells, and the complex behaviors of a body arise because of the way emotional energy coherently flows through that body, which is also determined by the laws of the universe. All quantized bits of energy in the universe flow in the universal gradient from big bang event to black hole, just like any river that flows from the top of the mountain to the bottom of the ocean. That flow of energy is described by the second law of thermodynamics, which is as valid for biological bodies as for any other thermodynamic system.

The story about the nature of entropy is not quite complete because biology was left out, which is how the coherently organized bound states called bodies form, which is a little bit different than how physical bound states form. The difference is in the nature of physical and biological symmetry breaking. The bound state of liquid water forms because the water molecules attract each other, and if their average velocity is less than escape velocity, those molecules will bind together into liquid water. Water vapor at 100° C, the boiling point of water, still has too much kinetic energy for the water molecules to bind together into liquid water. The water molecules must radiate away some of their kinetic energy as photons, an amount of kinetic energy known as the heat of condensation, in order that the average velocity of each water molecule falls to less than escape veloc-

ity, and then the water molecules can bind together into the bound state of liquid water.

The nature of the phase transition is that there is always a balance between the amount of potential energy in the system and the amount of disordered kinetic energy, or heat, in the system. The water molecules attract each other because of electromagnetic interactions, as electrons are attracted to protons and repelled by other electrons. The water molecule is overall electrically neutral, but there is an uneven distribution of electric charge in space. The electrons are arranged in some uneven way around the atomic nuclei, and so the water molecules can electrically attract each other, which is the nature of their potential energy. The strength of those electrical attractions between molecules determines an escape velocity, just like the strength of gravitational attraction on the surface of the earth determines an escape velocity for a rocket ship that is fired into outer space.

If the amount of disordered kinetic energy in the system of water molecules is too high, which means the average velocity of each water molecule is greater than that escape velocity, then the water molecules remain unbound as water vapor. But if the average velocity falls below that escape velocity, which happens if some of the water molecules radiate away some of their kinetic energy as photons, then the water molecules can bind together into the bound state of liquid water. This all happens at constant temperature, the boiling point of water. The energy that is radiated away for the phase transition to occur is the heat of condensation, and is the same as the heat of evaporation, the amount of energy required to turn liquid water into water vapor at the boiling point of water. The amount of energy that is radiated away only depends on the escape velocity for water molecules to form liquid water, which is determined by the spatial arrangement of those molecules. There is also a lower escape velocity for the formation of ice that is determined by the spatial arrangement of those molecules when they freeze into place. As water freezes, the water molecules are rearranged in relatively fixed positions, which minimizes the amount of energy of that spatial arrangement. But water only freezes if heat, which is disordered kinetic energy, is radiated away from liquid water.

There is always a balance between the amount of potential energy and kinetic energy in the system of water molecules, and that balance determines if the phase transition will occur. That balance can be altered if

kinetic energy is added or removed from the system, which happens if water molecules absorb or radiate away photons. The phase transition that forms ice from liquid water is similar to condensation, and only occurs as disordered kinetic energy is radiated away from the system of liquid water. The water molecules tend to freeze into place as kinetic energy is removed from the system. The velocity of the water molecules falls below the escape velocity for the formation of ice, which arises from the way electric charge is rearranged in space as water freezes, and is lower than the escape velocity for the formation of liquid water. Even in solid ice the water molecules continue to move around, just not as freely as they move around in liquid water.

Symmetry breaking with biological systems also forms bound states, but is a bit different since a biological system is not restricted to the addition or removal of kinetic energy. Biological systems can also undergo the addition or removal of potential energy. Addition of potential energy to a biological system is something we are all familiar with, and is called eating. When we eat food, we add high potential energy molecules, like proteins and carbohydrates, to our bodies, and that is the addition of potential energy to the bound state we call a body. This is really no different than the absorption of photons by water molecules, except that addition only increases the amount of kinetic energy in the system, and not the amount of potential energy. A much better example is the absorption of photons by a plant, which uses the directed kinetic energy of the photon in the process of photosynthesis. The plant increases the amount of potential energy in the system with the process of photosynthesis. The reason that process is able to increase potential energy is because the directed kinetic energy of the photon is used to break a chemical bound. A carbon atom is bound to oxygen atoms in the carbon dioxide molecule, CO_2 , utilized by the plant in the process. When those bonds are broken, free carbon and oxygen atoms are liberated. The directed kinetic energy of the photon is used to break that chemical bond and liberate free carbon and oxygen atoms. The oxygen atoms are released into the atmosphere, which is why plants release molecular O_2 with the process of photosynthesis. The free carbon atoms are then allowed to bind together, but that binding is constrained to occur in the construction of larger carbon molecules, like carbohydrates and proteins. Some of the directed kinetic energy of the photon is incorporated into those larger carbon molecules, and is turned into electromagnetic potential energy.

The process is really no different than the way a water wheel utilizes the directed kinetic energy of a river to convert that kinetic energy into potential energy. The directed kinetic energy of the flow of the river turns the water wheel, which lifts some of that water out of the river and up above the surface of the earth. As the water is lifted above the surface of the earth, and some of that water is stored at that higher level, useful work is performed. Some of the directed kinetic energy of the river is converted into gravitational potential energy. Gravitational potential energy can then be converted back into kinetic energy if the water stored above the surface of the earth is allowed to fall back to the surface of the earth. The water wheel 'turns' directed kinetic energy into gravitational potential energy, which is converted back into kinetic energy.

In the process of photosynthesis, the directed kinetic energy of a photon is used to break a chemical bond in a CO_2 molecule, which liberates a free carbon atom. Those carbon atoms are allowed to bind together into larger carbon molecules like carbohydrates. In that process, kinetic energy is converted into electromagnetic potential energy. The carbohydrate molecule stores potential energy the same way the water wheel stores potential energy as it lifts water above the surface of the earth. The only real differences between the way a water wheel works and the process of photosynthesis are that the water wheel stores gravitational potential energy while the carbohydrate molecule stores electromagnetic potential energy, and the water wheel operates at the macroscopic level of the river while the process of photosynthesis operates at the microscopic level of molecules. Both processes 'turn' directed kinetic energy into potential energy.

The process of photosynthesis requires carbon dioxide molecules are split apart, which liberates free carbon atoms and oxygen molecules. The carbon atoms are rearranged to form long carbon chains, as $\text{NCO}_2 \rightarrow \text{CN} + \text{NO}_2$. But this process requires energy because each carbon dioxide molecule is bound together in a very deep potential energy valley of electromagnetic attraction. The chemical bond of each carbon dioxide molecule must be broken, which requires energy. This is really no different than lifting a heavy rock out of a deep hole. Where does the energy come from? The directed kinetic energy of photons of electromagnetic radiation supply the energy in the process of photosynthesis. The chemical equation is $\text{CO}_2 + \gamma_1 \rightarrow \text{C} + \text{O}_2 + \gamma_2$. A photon γ_1 of higher energy $E_1 = h\nu_1$ is absorbed, and another photon γ_2 of lower energy $E_2 = h\nu_2$ is emitted, for the process of photosynthesis to occur. The higher energy photon is visible

light and the lower energy photon is infrared radiation. Only because the photon supplies energy is the carbon atom lifted out of the very deep potential energy valley of the CO_2 molecule. The carbon atom is lifted to a higher level of electromagnetic potential energy as it is lifted out of the deep potential energy valley. This is just like the heavy rock that is lifted to a higher level of gravitational potential energy if it is lifted out of the hole. The carbon chain C_N has a higher level of electromagnetic potential energy than the carbon atoms in the CO_2 molecules. The high potential energy barrier of the CO_2 molecule must be climbed before the carbon atoms can settle into the less deep potential energy valley of the carbon chain C_N . This process requires energy, and is just like rolling a heavy rock uphill.

Photosynthesis inside a plant allows for the formation of long carbon chains with higher potential energy. That electromagnetic potential energy is obtained from the directed kinetic energy of photons. The directed kinetic energy of photons is turned into electromagnetic potential energy, just like a water wheel that turns the directed kinetic energy of a river into gravitational potential energy as water is lifted out of the river. Higher potential energy means a more ordered system. A more ordered system means less entropy in the system. The organization of carbon atoms inside the plant has less entropy because of photosynthesis. Entropy can appear to decrease locally inside the body of the plant, but only because there is an overall increase in entropy for the entire universe. As energy flows in its universal gradient, like a river that flows from the mountaintop to the ocean, entropy can appear to locally decrease inside the body of the plant only because universal entropy increases. Energy is always conserved as energy flows, but entropy tends to increase as energy flows, since energy tends to flow from more ordered to less ordered states. In some sense, the plant is 'swimming' upstream as entropy is locally decreased. How is it possible that the entropy of carbons atoms inside the body of the plant decreases as the plant undergoes photosynthesis?

The answer is that the entropy in the environment increases more than the entropy inside the plant decreases. The total entropy of plant plus environment increases over time because the environment becomes more disordered as the plant becomes more ordered. How does the environment become more disordered as photosynthesis takes place inside the plant? The photons radiated away from the plant disorder the environment. The plant absorbs higher energy photons than the photons emitted. The absorbed photons are visible light and the emitted photons are infrared

radiation. The infrared photons are more disordered because there are more of them, because of the conservation of energy, and they are radiated away into random directions into the environment. The visible light photons arrive from the hot sun during the daytime, and the infrared photons are radiated into the cool dark night sky during the nighttime. The flow of energy is always directed from the hotter object to the colder object. In effect the plant eats high energy photons during the daytime, and excretes lower energy photons at night. The photons radiated away increase the entropy of the environment. That environment is the universe, which includes a hot sun and a cool dark night sky. This process, as energy flows down its universal gradient like a river that flows from the mountaintop to the ocean, is the only way large chain carbon molecules, like carbohydrates, can become formed within the body of a plant.

When animals eat plants, they incorporate some of the potential energy stored in those carbohydrate molecules into their bodies. That potential energy can be converted back into kinetic energy. The muscles of the animal utilize the potential energy stored in carbohydrates when the muscle cells burn those carbohydrate molecules and convert that potential energy back into kinetic energy. Directed kinetic energy can be used to lift up the arm of the animal, as muscles in the arm of the animal are contracted. The kinetic energy expressed by the muscle can be directed to lift up a glass of water that is held in the arm of the animal, and in the process that directed kinetic energy is converted in gravitational potential energy, which is converted back into kinetic energy if the glass is dropped to the ground.

The complex behaviors of the plant or the animal only arise from the complex ways in which directed kinetic energy is converted into potential energy, and that potential energy is converted back into directed kinetic energy. Energy is stored as directed kinetic energy is 'turned' into potential energy. Complex behaviors are enacted as potential energy is 'burned' inside the body of the organism, which releases directed kinetic energy, and allows for enactment of the behavior. All energy flows in its universal gradient, and all the quantized bits of energy in the universe obey the laws of the universe. All the directed kinetic energy within the universe arises from the big bang event and ultimately reflects the nature of gravitational collapse as gravitational potential energy is converted into directed kinetic energy, which can be converted into electromagnetic potential energy within biological bodies. That allows those bodies to enact complex behaviors as that potential energy is converted back into directed kinetic energy.

The form of the biological body only arises because of the way the flow of energy is coherently organized as that flow of energy holds the body together as a bound state and also allows the complex behaviors of the body to be enacted. The form of the body is only a coherently organized bound state of energy that arises in the universal flow of energy. The form of the body and the complex behaviors of the body arise because of the way the flow of energy through the body is coherently organized, which is what allows the body to hold together as a bound state as the behaviors of the body are enacted. All of that coherent organization arises from the nature of symmetry breaking. The only real difference between physical symmetry breaking, like the formation of a block of ice, and biological symmetry breaking, like the formation of a body, is that physical systems are limited to the absorption and radiation of kinetic energy, while biological systems can also absorb and excrete potential energy, which is what gives biological systems greater flexibility of behavior.

The determinate factor in any phase transition, or example of symmetry breaking, is the balance between potential energy and kinetic energy. In physical systems, like a system of water molecules, kinetic energy can be added or removed. In a biological system that is able to eat other biological systems, potential energy can also be added to the system. The balance between potential energy and kinetic energy can be altered either because potential energy is added or kinetic energy is removed. In either case, the system can undergo a phase transition. The interesting question is whether or not entropy increases as the bound states of biological systems are formed through biological phase transitions, the same way entropy increases for physical phase transitions as bound states form.

As a system of water molecules, in the form of water vapor, radiates away some of its kinetic energy as photons and forms the bound state of liquid water, there is an overall increase in entropy because of the photons radiated away. What about for a plant that absorbs photons and undergoes the process of photosynthesis? The plant absorbs yellow photons by day, but by night the plant radiates away heat in the form of infrared radiation. The entropy of the plant decreases through the process of photosynthesis as some of the directed kinetic energy of yellow photons is converted into high potential energy molecules like carbohydrates, but overall entropy increases because of the infrared photons that are radiated away at night. More infrared photons are radiated away by night than yellow photons absorbed by day because energy is quantized as $E = h\nu$, and the infrared

photons are radiated away in random directions, so overall there is an increase in entropy just as there is when liquid water forms. When an animal eats the plant and uses the high potential energy of carbohydrates to perform some useful work, like the search for more food, those carbohydrates are able to energize the performance of that work because they are burned inside the body of the animal. The carbon atoms in the carbohydrates are burned with oxygen to form CO_2 and H_2O . As the carbohydrates are burned, they generate heat. That heat is disordered kinetic energy that must be excreted away into the environment. The animal eats high potential energy molecules like carbohydrates, and excretes disordered kinetic energy into the environment, and in the process there is also an overall increase in entropy, because of the disordered kinetic energy that is excreted away.

Biological symmetry breaking is really not any different than a physical phase transition, except that the balance between potential energy and disordered kinetic energy in the system can be altered because the biological system can eat high potential energy molecules and excrete away disordered kinetic energy. Only that extra flexibility makes biological systems appear different. A good example of biological symmetry breaking is the formation of a blood clot, which is really no different than freezing of water into ice. Ice freezes because the water molecules freeze into fixed positions relative to each other as their average velocity falls below an escape velocity determined by the arrangement of electric charges in space, but those molecules can still move around because of their kinetic energy.

The water molecules freeze into fixed positions because their average velocity falls below escape velocity, which happens because kinetic energy is removed from the system, and the balance between potential energy and kinetic energy is altered in favor of potential energy. When the clotting proteins in the blood form a blood clot, essentially the same thing happens. The clotting proteins freeze into fixed positions relative to each other because their average velocity falls below an escape velocity. This process is initiated not because kinetic energy is removed from the system, but because potential energy is added to the system. That addition of potential energy to the vascular system occurs with the release of tissue factors that occur with tissue injury, and that process alters the balance in favor of potential energy. As clotting proteins bind together to form the blood clot, heat is released, just as a photon is released when an electron binds to a proton. Heat is disordered kinetic energy that is radiated away from the

system, so that overall there is an increase in entropy, just as there is when liquid water freezes.

The blood is full of clotting proteins that have a potential tendency to bind together and a kinetic tendency to move in random directions. As a blood clot forms, the potential tendency of the clotting proteins to form chemical bonds and bind together energetically wins out over their kinetic tendency to move in random directions, exactly like a physical system of water that freezes into ice. Chemical bonds are due to electromagnetic interactions, as electrons and atomic nuclei exchange photons, which occurs because of the uneven distribution of electric charges inside molecules. Ice freezes because heat is radiated away from liquid water. But blood clots form at a stable body temperature. How is that possible? The answer is there is always a balance between the potential tendency of molecules to bind together and their kinetic tendency to move around. That balance can be altered if disordered kinetic energy is radiated away from the system, but the balance can also be altered if potential energy is added to the system. Symmetry breaking can occur in either case. The system holds together as a bound state because the potential tendency of the things inside the system to bind together energetically wins out over the kinetic tendency of those things to move around in random directions. A blood clot forms because potential energy is added to the system, which occurs with tissue injury as tissue factors are added to the vascular system. Those tissue factors are molecules that add potential energy and alter the balance in favor of the formation of blood clots. But there is another complicating factor with the clotting system that makes it more complex than a straightforward phase transition. The clotting system is in an unstable state that is analogous to a false vacuum or super-cooled water. That unstable state rapidly transitions to a more stable state as potential energy is added to the system. The development of a blood clot is more like an avalanche that develops as another snowflake is added to a snow pack that rapidly collapses down a mountainside.

The nature of a false vacuum is a false energy minimum, like the false bottom of a roller coaster ride. The roller coaster can only climb the next hill and reach the true bottom of the ride if it has enough kinetic energy to get over the hump of the next hill. If the roller coaster does not have enough kinetic energy, it gets stuck in the false bottom of the ride, which is an unstable state, like a false vacuum. The clotting system is in an unstable state, like super-cooled liquid water that will eventually transition into the

form of frozen ice and release heat. That transition occurs as the system moves from a false energy minimum to a more stable state.

The addition of tissue factors is potential energy that lowers the size of the hump of the next hill, so that there is now enough kinetic energy to climb that hill and reach the true bottom of the ride. This is just like a snow pack that is stuck on the mountainside in a false energy minimum until the addition of another snowflake triggers an avalanche that collapses down the mountainside, or a roller coaster that races to the true bottom of the ride if it gets over the hump. The transition does not occur because kinetic energy is added and the roller coaster moves faster, but because potential energy is added, which lowers the size of the hump. That hump is a potential barrier.

The reason the false energy minimum is called an unstable state is because there is always some quantum probability that the system will 'tunnel' through the barrier due to quantum uncertainty in the amount of kinetic energy in the system, which is related to uncertainty in position. A tunneling event from a false energy minimum to a true energy minimum is a quantum transition from an unstable state to a more stable state. The smaller the barrier, the more likely a tunneling event will occur, which means it occurs faster. But if the hump becomes small enough, then the system can climb the barrier, and make a classical transition.

When a carbohydrate molecule is burned, energy is released as the system moves from a false to a true energy minimum, and makes a transition from an unstable to a more stable state. That transition occurs faster if kinetic energy is added as the system is heated, or if the potential barrier between the false and true minimum is lowered as potential energy is added, which is called a catalyst. The only reason we heat an object before it will burn is because that heat makes the transition occur faster, but a catalyst has the same effect. All burning occurs as an unstable state makes a transition to a more stable state and releases energy in the form of heat. The addition of heat to the system only makes the transition occur faster, as does the addition of a catalyst. Even without the addition of heat or a catalyst, the system will eventually transition to a more stable state and release energy in the form of heat.

Tissue factors released with tissue injury are molecules that add potential energy to the system. The system of clotting factors is in an unstable state, or false energy minimum, because it does not have enough kinetic energy

to get over the hump, which is the potential barrier between the false and the true minimum, which is a more stable state. The system could make a quantum transition, or tunneling event, to the true minimum, but if the potential barrier is large, the decay time for that transition to occur is very long. The tissue factors lower the size of the potential barrier, and that either shortens the decay time, or lowers the barrier sufficiently that the system has enough kinetic energy to make a classical transition to the true energy minimum. In either case, as the clotting factors bind together they radiate away heat, which is disordered kinetic energy, and there is an overall increase in entropy, just as occurs when liquid water freezes.

The important point is that entropy increases whenever a bound state forms, whether that bound state is physical or biological in nature. The flow of energy through the universe, from the big bang event to the black hole, simply expresses that entropy increases as bound states form, which is another way to say energy flows from more ordered to less ordered states. Those bound states are always more disordered in nature if the disordered kinetic energy that must be radiated away from the bound state for the bound state to form is included. There is an increase in entropy with the formation of any bound state. The ultimate bound state in the universe is the black hole, a state of maximal gravitational collapse, and therefore maximal entropy. All the bound states that form between the big bang event and the black hole, which includes the formation of all biological bodies, form because of the increase in entropy that occurs as those bound states form.

The second law is all about the direction of the flow of energy, and the flow of time, through the universe, which is always directed toward the formation of bound states and an increase in entropy, or disordered information. The second law is about how information becomes more disordered through gravitational collapse as bound states form, while inflationary cosmology is about how that information became ordered early in the history of the universe through the 'anti-gravity' of an unstable cosmological constant. With the holographic principle, each bound state that forms in the universe is understood to be defined on a viewing screen, which is a bounding surface of quantized space-time with one bit of information per Planck area. The perceived flow of time is understood as an ordered sequence of events, or an ordered sequence of viewing screens, just like the animated frames of a movie. The second law explains why perceivable bound states form in the perceived flow of time, but it does not explain

which bound states will form. To understand which bound states will form its necessary to use the action principle. The probability for the formation of any bound state is determined by the action principle.

All the laws of physics, like gravity and electromagnetism, can be expressed as an action principle. The classical laws of physics arise from the principle of least action, and the fundamental nature of quantum physics is always expressed with an action principle. The quantum state is a state of potentiality, and includes all possible ways any action can be performed. The probability that any action will be performed in any particular way is proportional to the probability amplitude, $z = \exp(2\pi i \mathcal{S}/h)$, where \mathcal{S} is a quantity called *Action*. The nature of \mathcal{S} , which is a dynamical concept in the mathematical formulation of theoretical physics, can be conceptualized as the amount of energy utilized to perform any action, or behavior, that can be enacted in the universe. Every possible way any action can be performed is a 'path', and the quantum state of potentiality is a sum over all possible paths. For example, as a point particle moves from one spatial point to another, that motion can be conceptualized to follow a particular path, or trajectory, through space and over time. That path can be parameterized as a trajectory $x = x(t)$. Inherent in the concept of a trajectory is that the particle moves from a given spatial point at some moment in time to another spatial point at another moment in time. The trajectory simply connects those two space-time points. The sum over all possible paths is a sum over all possible ways to connect those two space-time points. The behavior of a bound state of N particles can also be conceptualized as the coherently organized motions of N point particle trajectories, $x_j = x_j(t)$, with $j = 1, 2, \dots, N$. The behavior of that bound state is thereby reduced to the behavior of those N point particles.

Each possible path that each point particle can take is weighted with a probability amplitude that depends upon \mathcal{S} for that path. The fundamental nature of quantum theory is to take a sum over all possible paths, but to weight each path with the probability amplitude z . The most likely way any action can be performed is when \mathcal{S} is minimized, which is the principle of least action. The basic reason why that is the most probable path is because the complex number z tends to cancel out for those paths that are non-stationary values of \mathcal{S} , and tends to add together for those paths that minimize \mathcal{S} . The reason for that cancellation and summation is because the complex number $z = \exp(i\theta)$, where $\theta = 2\pi\mathcal{S}/h$, can be written as $z = \cos(\theta) + i\sin(\theta)$, and acts like a vector in the complex plane. That vec-

tor tends to cancel out for non-stationary values of θ , and to sum up for stationary values of θ , which are those values that minimize \mathcal{S} . Those stationary paths are the most probable paths. In this sense, least action is like minimized energy expenditure in the performance of an action.

Where does the principle of least action come from, and why is the quantum state of potentiality always a sum over paths, with each path weighted by the probability amplitude $z = \exp(2\pi i \mathcal{S}/h)$? All the laws of the universe can be expressed as a principle of least action, but all of those laws also reflect the symmetry of empty space. The principle of least action is already inherent in relativity theory, and all quantum field theories are unified with relativity theory through the compactification of extra dimensions. Take for example a point particle that appears to move through 3+1 dimensional space-time and follows a trajectory parameterized as $x = x(t)$. The total energy of that particle as it moves around is characterized by a kinetic aspect and a potential aspect. The kinetic energy typically has terms like $\text{KE} = \frac{1}{2}mv^2$, and the potential energy depends on how that particle interacts with other particles. If the particle is an electron that is attracted to a proton, the potential energy of attraction is given by $\text{PE} = e^2/r$, or if the particle moves in the gravitational field of a mass M , the potential energy of attraction is given by $\text{PE} = GmM/R$. With relativity theory, we understand that the gravitational field gives a measure of the curvature of space-time geometry, and the principle of least action simply says that the particle will follow the path that minimizes the 'distance' between two space-time points in that curved space-time geometry. To understand the nature of motion in a curved space-time geometry consider the nature of motion on a surface of a sphere, like the surface of the earth. That motion is constrained to occur on the surface of that sphere. The shortest distance between two points on the sphere is a curved line called a geodesic. If we parameterize position on the surface of the sphere in terms of coordinates like latitude and longitude, then we can always express the shortest distance between two points on that surface in terms of those coordinates and the curvature of that sphere. In the same way, the 'shortest distance' between two space-time points in a curved space-time geometry is expressed in terms of some coordinates, (x, t) , and the curvature of that space-time geometry, which is measured by the metric $g_{\mu\nu}(x, t)$.

The reason that geometry is curved is because matter and energy curve space-time geometry. With compactification of the fifth dimension, we understand that electric charge is only quantized momentum directed in

the fifth dimension. The quantized momentum directed in the fifth dimension also curves space-time geometry, but the field that measures that curvature is the electromagnetic field, not the gravitational field. The point particle still follows the path that minimizes the 'distance' between two space-time points in a curved geometry, but that curvature is measured both by the gravitational field and the electromagnetic field. Electric charge is the source of the electromagnetic field the same way matter and energy are the source of the gravitational field. Electric charge is a kind of energy that is due to quantized momentum directed in the compactified fifth dimension, and all energy curves space-time geometry. The compactified extra components of the metric that correspond to the fifth dimension, which we call the electromagnetic field, measure the curvature of space-time geometry that arises from momentum directed in the compactified fifth dimension.

The principle of least action simply says that the point particle will follow the path that minimizes the 'distance' between two space-time points, no matter how the curvature of that curved space-time geometry arises. Quantum theory simply says that all possible paths are possible. The quantum states of potentiality is a sum over all possible paths, weighted with the probability amplitude $z = \exp(2\pi i \mathbf{S}/h)$. The fundamental reason for the nature of the probability amplitude arises from the nature of quantum uncertainty. The uncertainty principle is inherent in the probability amplitude. The reason is because the change in the amount of \mathbf{S} for the path of a point particle that has a change in position Δx over a time interval Δt , and that moves with momentum $p = mv$ and with a total energy $E = KE + PE$, behaves like $\Delta \mathbf{S} = (p\Delta x - E\Delta t)$. This is an exact relationship in the limit of the differential $\Delta t \rightarrow 0$, and where $v = \Delta x/\Delta t$. This change in the amount \mathbf{S} directly corresponds to the 'distance' between two nearby space-time points in a curved space-time geometry, and so if \mathbf{S} is minimized that 'distance' is also minimized. In the language of relativity theory that 'distance' is written as $ds^2 = g_{\mu\nu} dx_\mu dx_\nu$, and \mathbf{S} can always be written in terms of that 'distance'. That 'distance' inherently involves terms in the metric that represent the nature of fields, and those fields represent potential energy. The principle of least action only implies the 'shortest distance' between two space-time points. For the motion of a free point particle with position x at time t , and with constant momentum and energy, we can simplify this relationship and write $\mathbf{S} = (px - Et)$. The probability amplitude for that path then behaves like $z = \exp\{2\pi i(px - Et)/h\}$, which describes the nature of wave motion for point particles. The uncertainty principle specifies that

both the momentum and position of the point particle, or its energy and time, cannot be simultaneously measured with complete accuracy. There is always uncertainty in these dynamical variables, and that uncertainty is inherent in wave motion.

The probability amplitude $z = \exp\{2\pi i(px - Et)/h\}$ describes the nature of wave motion for point particles. That wave motion inherently has quantum uncertainty in the dynamical variables for position and momentum of the particle, and for the energy and time coordinate of the particle. But the probability amplitude also demonstrates the nature of the quantum interference pattern that underlies the physical phenomena of holography. Information can be encoded on the two dimensional surface of a hologram only because of that interference pattern.

The experiment that best demonstrates the nature of quantum uncertainty, and the nature of the quantum interference pattern, is the double slit experiment. The experiment is first performed with waves of electromagnetic radiation. The source of waves is directed toward a screen where there are two slits. The basic form of a wave function for electromagnetic waves is $f(x, t) = A \exp(2\pi i[x/\lambda - \nu t])$, where A is the amplitude of the waves, and λ and ν are the wavelength and frequency of the waves. We can immediately see the quantum correspondence $p = h/\lambda$ and $E = h\nu$. This wave function obeys the wave equation for electromagnetic waves since $E^2 = p^2c^2 + m^2c^4$, which for the massless photon means $c = \lambda\nu$, and the wave equation takes the simple form $\partial^2\varphi/\partial t^2 = c^2\partial^2\varphi/\partial x^2$. The reason this describes wave motion is because $\exp(i\theta) = \cos\theta + i\sin\theta$.

If one slit in the screen is covered, then the wave only travels through the other open slit, and that slit acts as a point source of waves. With only one slit open, a certain intensity of radiation is measured by a detector behind the screen. That intensity depends upon the electromagnetic wave function as it travels from the slit to the detector. Intensity of radiation is equal to electromagnetic field strength squared, which is the absolute value squared of the wave function. The absolute value squared of a complex number, \mathbf{z} , is obtained by multiplying that complex number by its complex conjugate, $|\mathbf{z}|^2 = \mathbf{z}^*\mathbf{z}$. With only slit 1 open there is an intensity $I_1 = |\varphi_1|^2 = A^2$, while for only slit 2 open there is an intensity $I_2 = |\varphi_2|^2 = A^2$. An interesting thing happens when both slits are open. Then there are two point sources of waves and the waves interfere with each other. This is just like the interference pattern of water waves seen on the surface of a pond

when two rocks are thrown into the pond at the same time. In some places the waves add together and reinforce, and in other places they subtract and cancel out.

The intensity of radiation measured behind the screen with both slits open is given by $I_{12} = |\varphi_1 + \varphi_2|^2$. This describes an interference pattern. The nature of the interference pattern is most easily seen if we express the waves in terms of complex numbers as $\varphi_1 = A \exp(i\theta_1)$ and $\varphi_2 = A \exp(i\theta_2)$. To obtain I_{12} use the definition of the complex conjugate and the absolute value squared to find

$$I_{12} = (\varphi_1^* + \varphi_2^*)(\varphi_1 + \varphi_2) = A^2 \{ \exp(-i\theta_1) + \exp(-i\theta_2) \} \{ \exp(i\theta_1) + \exp(i\theta_2) \}.$$

To work out the value for this expression use the two identities $\exp(i\theta_1) \exp(i\theta_2) = \exp\{i(\theta_1 + \theta_2)\}$ and $\exp(i\theta) = \cos \theta + i \sin \theta$. This gives the intensity to be $I_{12} = 2A^2 \{1 + \cos(\theta_1 - \theta_2)\}$. This equation describes an interference pattern that oscillates from zero to $4A^2$.

This interference pattern is very different than the individual intensities $I_1 = I_2 = A^2$ found with only one slit open. With the interference pattern, there are places with no intensity $I_{12} = 0$, and places with more than the expected intensity $I_{12} = 4A^2$, rather than the constant value $I_1 + I_2 = 2A^2$ that would be expected if there was no interference. This is exactly what is expected for wave motion. The intensity with both slits open is not just the sum of intensities with each slit open individually $I_{12} \neq I_1 + I_2$. The interference pattern is due to wave motion that adds together in some locations and cancels out in other locations. Part of the wave travels through open slit 1, and part through open slit 2. When the waves recombine at the detector they are either in phase or out of phase with each other. Wave motions that are in phase or out of phase with each other can superimpose to create an interference pattern, as the amplitudes either reinforce each other or cancel each other out. When we describe waves that are in or out of phase with each other, we implicitly refer to the phase angle θ of a complex number. That complex number acts like a vector in the complex plane, and is directed with angle θ in some direction. The directions of those vectors in the complex plane determine if waves will superimpose with each other, or cancel each other out.

The measurement of electromagnetic radiation intensity follows an interference pattern as expected, since this radiation is described by a wave. But something else even more interesting is apparent from the experiment. If

the source of radiation is low enough in intensity, but high enough in frequency, the detector measures the arrival of radiation in discrete units just like the clicks of a Geiger counter. Each click of the detector measures the arrival of exactly one photon.

Electromagnetic radiation behaves like a wave as it passes through the double slits to give the interference pattern for intensity. Part of the wave travels through one slit, and part of the wave travels through the other slit. As waves recombine at the detector, they create the interference pattern. But the radiation behaves like a particle as it is measured by the detector. The electromagnetic radiation is measured to arrive at a particular location of the detector one photon at a time. It seems that the radiation behaves both like a wave and a particle. The reason waves can behave like particles is because each photon is a quantized excitation of electromagnetic field strength, and is localized in the form of a 'wave-packet'.

The experiment is now repeated with an electron source. An electron gun is used to emit electrons one at a time directed at a screen with two slits. A detector behind the screen measures the arrival of an electron. Either the electron detector clicks like a Geiger counter, or it does not click. A click indicates that an electron has been measured to arrive at the detector. The electron behaves like a particle. It is either measured to arrive or not to arrive. With only slit 1 open the probability of measurement of an electron is P_1 , and with only slit 2 open the probability of measurement is P_2 . What is the probability with both slits open? The probability with both slits open is not the sum of probabilities: $P_{12} \neq P_1 + P_2$. An interference pattern is found exactly as is the case for electromagnetic radiation. That interference pattern has exactly the same appearance as found for photons.

The electron behaves like a wave as it passes through the double slits. The wave function due to slit 1 is $\Psi_1 = A \exp(i\theta_1)$, and due to slit 2 is $\Psi_2 = A \exp(i\theta_2)$. Just like for the intensity of electromagnetic radiation, the probability for measurement of arrival of an electron is related to the absolute value squared of the wavefunction. We find $P_1 = |\Psi_1|^2 = A^2$, $P_2 = |\Psi_2|^2 = A^2$, and $P_{12} = |\Psi_1 + \Psi_2|^2 = 2A^2 \{1 + \cos(\theta_1 - \theta_2)\}$. The interference pattern is created by wave reinforcement when waves are in phase, and wave cancellation when waves are out of phase. The interference pattern only depends on the phase relationship between the two wave functions. The electron behaves like a wave as it passes through the double slits. We designed the experiment so that only one electron is emitted at a time. Each electron individually behaves as a wave. The only way to have an

interference pattern is if part of the electron wavefunction travels through one slit, and part through the other slit. The two parts of the wavefunction are either in phase and reinforce each other, or out of phase and cancel out, when they arrive at the detector. But when the electron arrives at the detector it behaves like a particle and is counted one at a time. The electron wavefunction $\Psi(x, t)$ is interpreted as a probability amplitude. The probability for measurement of the electron at any location and time depends on the amplitude squared $P(x, t) = |\Psi(x, t)|^2$. But what happens to the electron wavefunction after the electron is measured?

To answer this let's try to actually measure which slit the electron travels through. Let's shine a light at one of the slits. Light will scatter off of the charged electron as the electron passes through the illuminated slit. If we detect the scattered light then we know the electron passed through that slit. Every time the detector behind the screen clicks to measure the arrival of an electron we look for the scattered light to tell us which slit the electron passed through. What do we find? If the scattered light tells us the electron passed through slit 1, then the detector will measure probability P'_1 . If the scattered light indicates slit 2, then P'_2 is measured. P'_1 and P'_2 look exactly like P_1 and P_2 found when either one or the other slit was covered up. The interference pattern has disappeared. The very act of measuring which slit the electron passes through destroys the interference pattern. The total probability the electron travels through either slit is simply the sum $P'_{12} = P'_1 + P'_2$. There is no interference pattern. How is that possible?

If we turn the light off, the interference pattern $P_{12} = |\Psi_1 + \Psi_2|^2$ is restored. Only if we measure which slit the electron travels through is the interference pattern destroyed. The act of measurement of the electron's location destroys the wave-like behavior. Why does this happen? When light scatters off an electron as it passes through the slit, the light also has a particle-like behavior. The scattering of light is due to an impact of a photon with the electron. As the photon impacts the electron there is a transfer of momentum, just like two billiard balls scattering off each other. The act of measuring the electron's position changes its momentum. Transfer of momentum between particles is quantized because momentum is quantized, and that is the explanation for the uncertainty principle. The position and momentum of a particle cannot be simultaneously measured with complete accuracy, because any measurement of the position of that particle requires a quantized exchange of momentum between that particle and

another particle. Since momentum and wavelength are related as $p = h/\lambda$, the amount of momentum Δp that must be transferred to measure the position within an accuracy of $\Delta x \leq \lambda/2\pi$ requires that $\Delta p \Delta x \geq h/2\pi$, which is the uncertainty principle.

The double slit experiment also allows us to recover the fundamental rule of quantum theory that the quantum state is the sum over all possible paths, with each path weighted with a probability amplitude $z = \exp(2\pi i \mathbf{S}/h)$ that only depends on \mathbf{S} for that path. The quantum state of the particle, as it travels from the source of the particles to the detector, is the sum of probability amplitudes that it will travel through each opening in the screen. Instead of a single screen with two holes in it, let's put up an infinite number of screens, and drill an infinite number of holes in each of those screens, until all the screens disappear. The screens all disappear if they are only composed of holes. Instead of the constrained motion of a particle that can only travel through either of the two holes in a single screen, the particle can then travel any path through space. Even if there is only empty space between the source of the particles and the detector, the quantum state is still the sum of all the probability amplitudes for the particle to travel through each of the holes in all of the (nonexistent) screens.

The probability amplitude $z = \exp(2\pi i \mathbf{S}/h)$ also allows for a geometrical explanation for the nature of spin angular momentum. If a particle with position x moves in a circular orbit of radius r with momentum $p = mv$, then \mathbf{S} takes the form $\mathbf{S} = px = pr\theta$, where the position of the particle in its circular orbit is given in terms of an angle θ as $x = r\theta$. If we use the quantum relationship $p = h/\lambda$, and fit a integral number of wavelengths into the circumference of the circular orbit, $2\pi r = n\lambda$, where $n = 0, 1, 2, \dots$, then $2\pi px/h = n\theta$, and $z(\theta) = \exp(in\theta)$. For the case $n=1$, we find that $z(\theta+2\pi) = z(\theta)$, since $\cos(2\pi) = 1$. This is found to be the case because $z(\theta+2\pi) = z(2\pi)z(\theta)$, and $z(\theta) = \cos(n\theta) + i\sin(n\theta)$. Under a rotation by an angle of 2π the probability amplitude turns into itself for integer values of n . But what if we fit a half-integral number of wavelengths into the circumference of the circular orbit? In the case $n=1/2$ something very interesting happens. If we let $n=1/2$, then we find that $z(\theta+2\pi) = -z(\theta)$ because $\cos(\pi) = -1$. Under a rotation by an angle of 2π the probability amplitude turns into the negative value of itself for half-integer values of n . The negative sign arises only because we fit a half-integral number of wavelengths in the circumference of the orbit. The usual objects we are familiar with in the world turn into themselves with a rotation by 2π . Rotate an ordinary

object around an axis of rotation by 2π and you have the same object. But for a spin $\frac{1}{2}$ object, which is called a spinor, the object turns into the negative of itself when it undergoes a rotation around some axis of rotation by 2π . The reason this is a quantum possibility is because we can fit a half-integral number of wavelengths into the circumference of a circle. If that is the case, then for the wave to complete its entire wavelength requires two rotations around the circle, or a rotation by an angle of 4π . The difference in sign between an ordinary object $z(\theta+2\pi) = +z(\theta)$, and a spinorial object $z(\theta+2\pi) = -z(\theta)$, is a reflection of the symmetry of empty space, and is reflected in the behavior of the wave function for a point particle with spin angular momentum. A spin 1 particle behaves like a commuting number, $\varphi_1\varphi_2 - \varphi_2\varphi_1 = 0$, and a spin $\frac{1}{2}$ particle behaves like an anti-commuting number, $\Psi_1\Psi_2 + \Psi_2\Psi_1 = 0$. The difference in sign arises from symmetry or anti-symmetry under rotation by 2π of ordinary and spinorial objects. This explanation also demonstrates why compactification of any dimension turns a translational symmetry into a rotational symmetry. Movement in that compactified dimension is just like the rotation around a circle in the complex plane. This is most evident for a spin $\frac{1}{2}$ object. The probability amplitude always behaves like $z(\theta_1+\theta_2) = z(\theta_1)z(\theta_2)$. For a spin $\frac{1}{2}$ object, $z(2\pi) = z^2(\pi) = (j)^2 = -1$, which is a reason the complex plane is so important for the explanation of physical phenomena.

Let's go back to the principle of least action. Relativity theory tells us that least action corresponds to the motion of a point particle that is determined by the 'shortest distance' between two space-time points in a curved space-time geometry. That motion follows a particle trajectory, $x = x(t)$. Can we demonstrate this principle from relativity theory? The whole secret is in the nature of the metric. To simplify things, let's look at how distance is measured in a hypothetical two dimensional world. In that two dimensional world, a particle can only move in one of two independent directions. If that two dimensional world is perfectly flat, then that motion occurs in the x - y plane. We know how to measure distance in the x - y plane from the Pythagorean theorem. If we specify two points in the x - y plane, as (x, y) and (x', y') , then the distance ΔD between those two points is determined by $(\Delta D)^2 = (x - x')^2 + (y - y')^2 = \Delta x^2 + \Delta y^2$. But space-time is curved, so we can deform the x - y plane into any shape we want. Let's imagine that motion is constrained to occur on the surface of a sphere, like the surface of the earth.

If the radius of the sphere is very large compared to the distance between two nearby points, then the surface of the sphere will locally appear to be flat, like the plains of Kansas. We can set up an x - y coordinate system on this apparently flat surface. This x - y coordinate system defines a grid much like a highway system that crisscrosses Kansas with roads running north-south and east-west. But if we measure distance with this coordinate system we discover that the Pythagorean theorem is not valid because of the curvature of the sphere. The curvature of the two dimensional surface is discovered if we measure the distance between two nearby points with our coordinate system and apply the Pythagorean theorem to check for flatness. We discover that the earth is not flat. We're not in Kansas anymore Dorothy.

The concept of a metric is easier to understand for a two dimensional curved surface. For a given curved surface and a given coordinate system that locates points on that surface, the metric describes how distances are measured in terms of these coordinates. If we call that coordinate system (x_1, x_2) , the distance between two nearby points on that surface can be written as $\Delta D_2 = g_{11}\Delta x_1^2 + (g_{12} + g_{21})\Delta x_1\Delta x_2 + g_{22}\Delta x_2^2$. The parameters g_{ab} for $a, b = 1, 2$, are called the metric, and depend on how the coordinate system is defined, which is to say that $g = g(x)$. The metric locally measures the amount of curvature of the surface, but these parameters are always expressed in terms of some coordinate system defined on the surface. The physical distance measured between two nearby points only depends on the curvature of that surface, and not on the choice of a coordinate system. Pick a new coordinate system and the metric changes to a different form, but it still has to describe how physical distances are measured on the curved surface. If the surface is flat, like the flat x - y plane, then $g_{11} = g_{22} = 1$, and $g_{12} = 0 = g_{21}$, which defines a flat Euclidean geometry.

The metric is easy enough to conceptualize for two dimensional surfaces. Now make the leap to 3+1 dimensional space-time. A space-time point is located by four coordinates. This is written as $x_\mu = (x_0, x_1, x_2, x_3)$, where x_0 is related to the time coordinate t as $x_0 = ct$, and x_1, x_2 , and x_3 are the three spatial coordinates. Each point in space-time is located with three spatial coordinates and a time coordinate. Just as a two dimensional surface can become curved, a 3+1 dimensional space-time geometry can also become curved. The definition of a curved or non-Euclidean geometry is that distances between two nearby points do not obey the Pythagorean theorem. These distances can be described in terms of a metric that measures the

curvature of that space-time geometry. In relativity theory, this ‘distance’ is written as $\Delta s^2 = \sum g_{\mu\nu}(x)\Delta x_\mu\Delta x_\nu$, or more simply as $\Delta s^2 = g_{\mu\nu}(x)\Delta x_\mu\Delta x_\nu$, where the sum over the indices $\mu, \nu = 0, 1, 2, 3$, is implied. The quantity Δs is called the proper time interval.

The proper time interval Δs is independent of the coordinate system we use to define locations in space-time, just like the distance between two nearby points on a curved two dimensional surface is independent of the choice of a coordinate system. The proper time interval is a relativistic invariant, and is how ‘distance’ is measured in a curved space-time. The proper time interval between two space-time points only depends on the curvature of that space-time geometry, which is measured by the metric, and is independent of the coordinate system we use to locate points in that space-time geometry. The only invariant measure of ‘distance’ in space-time is the proper time interval.

The principle of least action simply says that the motion of a point particle will follow a path, or particle trajectory $x = x(t)$, that minimizes the ‘distance’ between two points in a curved space-time geometry. That ‘distance’ is always written in terms of the proper time interval Δs , which is defined in terms of the metric as $\Delta s^2 = g_{\mu\nu}(x)\Delta x_\mu\Delta x_\nu$. The metric measures the curvature of space-time geometry, and is determined by Einstein’s field equations for the metric. The metric is the gravitational field. Space-time geometry is curved because matter and energy curve space-time geometry. Matter and energy are the source of the gravitational field, which are ‘lines of force’ that exert forces on all matter and energy, and so determine the motion of all matter and energy in space-time.

To see how this works in practice, we have to know the form of the metric for some given distribution of matter and energy. The simplest case to consider is empty space. Empty space means that there is no matter or energy. There is nothing in empty space. This gives the metric for flat space-time, which is also called the Minkowski metric, and is characterized as $g_{00} = 1, g_{11} = g_{22} = g_{33} = -1$, and all other values of $g_{\mu\nu} = 0$. The minus sign indicates that we’re in space-time. The time coordinate is treated differently than the spatial coordinates because of motion, and motion is inherent in space-time geometry. With the Minkowski metric, the proper time interval is given by $(\Delta s)^2 = (c\Delta t)^2 - (\Delta x_1)^2 - (\Delta x_2)^2 - (\Delta x_3)^2$. This equation describes the light-cone. Any massive particle that moves between two points in a Minkowski space-time has a positive value for its proper time

interval, because its velocity v , which is defined by $v^2 = \{(\Delta x_1)^2 + (\Delta x_2)^2 + (\Delta x_3)^2\} / (\Delta t)^2$, is less than the speed of light. In Minkowski space-time we can write $(\Delta s)^2 = (c^2 - v^2)(\Delta t)^2$. Since light only moves at the speed of light, the proper time interval for a light wave is $\Delta s = 0$.

For a flat space-time geometry, the expression $\Delta s = 0$ defines the light-cone. Two space-time points on the light-cone are related as $v = c$. The light-cone is defined by signals that connect two space-time points. Those signals travel at the speed of light, $c^2 = \{(\Delta x_1)^2 + (\Delta x_2)^2 + (\Delta x_3)^2\} / (\Delta t)^2$. Light is such a signal. The light-cone defines the limit with which any signal can be sent between two space-time points. For a physical signal to be sent between two space-time points, those two points must fall within or on the light cone, as $(\Delta s)^2 = 0$.

The equation $\Delta s = 0$ defines space-time points connected by the propagation of a light signal. These points fall on the light cone. What about points with $\Delta s > 0$? These points fall within the light cone. Let's say we have a massive particle that moves through space-time with constant velocity v . The coordinate system that is defined with the particle always at the origin of that coordinate system is called the particle's rest frame. In the particle's rest frame, the particle doesn't move. That's the definition of the rest frame. The particle is at rest in its rest frame. In this coordinate system $v = 0$, which means $\Delta x_1 = \Delta x_2 = \Delta x_3 = 0$. This means that in the rest frame $\Delta s = c\Delta t$, and the proper time interval simply gives a measure of the amount of time that elapses in the rest frame. The proper time interval is just a measure of the passage of ordinary time in the particle's rest frame. If the particle carries a clock, then the proper time interval is related to the amount of time that passes on that clock. What does this mean for a light wave? Is there a rest frame for the light wave? The proper time interval for the light wave is $\Delta s = 0$. If light waves could carry clocks, then all time intervals between events would be zero, or $\Delta t = 0$. All events occur at the same time. Time stands still for light waves.

The proper time interval is a physically measurable 'distance' in space-time. If $(\Delta s)^2 < 0$, then the proper time interval Δs becomes an imaginary number. This would happen if one space-time point was inside the light cone and the other space-time point was outside the light cone. For a signal to connect these two space-time points, the signal would have to travel faster than the speed of light. Such signals are called tachyons. They are

not possible within relativity theory, since this would imply that the proper time interval is an imaginary value, and is no longer a physically measurable 'distance'. No physical signal that connects two space-time points can ever travel faster than the speed of light.

Relativity theory predicts the phenomena of time dilatation, which means that time appears to run more slowly for a moving object from the perspective of a stationary object. Imagine an astronaut in a spaceship that travels away from earth at constant velocity v in the x_1 direction. Let's call the coordinate system attached to earth the x -coordinate system, and the coordinate system attached to the spaceship the z -coordinate system. Time as measured on earth is described by a time coordinate called t . We'll let $t = 0$ define when the spaceship is launched from earth. An observer on earth measures the distance to the spaceship at two different times separated by a time interval Δt , and finds the spaceship travels away from the earth by a distance Δx_1 in this time interval. From the perspective of the earth, the spaceship appears to travel away from earth at an observed velocity $v = \Delta x_1 / \Delta t$. But from the perspective of the astronaut in the spaceship, these two events are related as $\Delta z_1 = 0$, since the spaceship does not move relative to the astronaut. The observer on earth watches the spaceship through a telescope. The spaceship has a window, and inside the ship a clock is seen. The observer on earth watches this clock tick through the telescope. The observer on earth also has a clock on earth that is identical to the clock inside the spaceship. What is the relationship between the ticking of the clock in the spaceship as observed from earth through the telescope, and the ticking of an identical clock on earth?

Each tick of the clock is an event. Let's call the time interval between two ticks of the clock on earth ΔT , which is a constant inherent to the clock. The two events we focus on are two ticks of the clock in the spaceship. The coordinate system x is attached to the astronomer on earth who watches the spaceship through the telescope, and is the rest frame of the astronomer. The coordinate system z is attached to the astronaut in the spaceship, and is the rest frame of the astronaut. From the point of view of the astronaut in the spaceship, time flows just as fast as time flows on earth. From the astronaut's perspective of the flow of time, the time interval between two ticks of an identical clock in the spaceship is also ΔT . Let's call the time interval between two ticks of the clock in the spaceship as observed through the telescope by the astronomer on earth Δt . How is Δt related to ΔT ?

The proper time interval Δs between any two events is always the same interval, since Δs is a relativistic invariant 'distance' that is measured in space-time. This means $(\Delta s)^2 = (c\Delta t)^2 - (\Delta x_1)^2 - (\Delta x_2)^2 - (\Delta x_3)^2$. This 'distance' is a relativistic invariant, and does not depend upon the choice of a coordinate system. For a spaceship that only moves in the x_1 direction, the relationships between the x and z coordinate systems are $\Delta z_2 = 0 = \Delta x_2$, $\Delta z_3 = 0 = \Delta x_3$, and $\Delta z_1 = 0$, since z is the rest frame of the spaceship. Only the coordinate difference Δx_1 has a non-zero value, since this is the distance the spaceship appears to travel in the time interval Δt as observed from earth, which localizes the clock within the spaceship between the two events of the two ticks of the clock. From the perspective of the astronaut in the spaceship the clock does not move, which means $\Delta z_1 = 0$. The clock in the spaceship moves away from earth with constant velocity $v = \Delta x_1 / \Delta t$. This allows us to rewrite the above equation as

$$(c\Delta T)^2 = (c\Delta t)^2 - (\Delta x_1)^2 = (c^2 - v^2)(\Delta t)^2.$$

We find that

$$(\Delta t)^2 = (\Delta T)^2 / \{1 - (v/c)^2\}.$$

Remember ΔT is the time interval between two ticks of the clock in the spaceship as observed by the astronaut. As observed by the astronomer on earth who watches this clock through a telescope, the time interval between two ticks of the clock in the spaceship is

$$\Delta t = \Delta T / \{1 - (v/c)^2\}^{1/2}.$$

The time interval $\Delta t > \Delta T$ since $1 / \{1 - (v/c)^2\} > 1$. The time interval between two ticks of the spaceship clock as observed from earth is greater than the time interval between two ticks of the clock as observed by the astronaut in the spaceship. From the perspective of the earth, the time interval between two ticks of the clock in the spaceship is longer than on earth, or time appears to run more slowly, which is called time dilatation.

A flat space-time is a space-time without gravity. In general relativity, Einstein's field equations for the metric determine how matter and energy curve space-time geometry, which is a space-time with gravity. The gravitational field, or metric, measures the curvature of space-time geometry. Space-time with gravity is not a flat geometry. The metric $g_{\mu\nu}(x)$ measures the curvature of space-time geometry, and is expressed in terms of a par-

ticular coordinate system $x_\mu = (ct, x_1, x_2, x_3)$. In relativity theory, the principle of least action only implies the ‘shortest distance’ between two space-time points in a curved space-time geometry. Point particles move along particle trajectories that minimize the ‘distance’ between two space-time points. That ‘distance’ is always written in terms of the proper time interval Δs defined by $\Delta s^2 = g_{\mu\nu}(x) \Delta x_\mu \Delta x_\nu$. Newton’s equations of motion for the path of the particle trajectory, $x = x(t)$, are found by minimizing that ‘distance’.

How does this work in practice? Let’s locate the position of a point particle with a spatial coordinate $\mathbf{r} = (x_1, x_2, x_3)$. There is an assumption with Newton that $\mathbf{r} = \mathbf{r}(t)$ is a function of time. The velocity and acceleration of the point particle are written as time derivatives $\mathbf{v} = d\mathbf{r}/dt$ and $\mathbf{a} = d\mathbf{v}/dt$, and are related to the forces $\mathbf{F}(t)$ that act on the particle through Newton’s law of motion, as $\mathbf{F} = m\mathbf{a}$. But with Einstein there are no forces. There is only curved space-time geometry. The time coordinate of a space-time point is only another coordinate, just like the spatial coordinates.

How is the concept of motion represented by relativity theory? The strange answer is that it is not. Relativity theory describes a static space-time geometry within which a particle trajectory is only a geometric path in space-time, like a curved geodesic line between two points on the surface of a sphere. Nothing moves in relativity theory. We simply solve Einstein’s field equations to determine how space-time geometry is curved and find the ‘shortest distance’ between two space-time points in that curved geometry to determine a particle trajectory. The geometry we discover is static, and has no inherent concept of motion. But this is not how we observe the world. Things do appear to move around in a manner as described by Newton. How is this Newtonian world-view regained from Einstein?

The only possible answer is that there must be a ‘mechanism’ that allows for the sequential measurement of events in space-time. In relativity theory, an event in space-time is only a particular space-time point $x_\mu = (x_0, x_1, x_2, x_3)$. To have the perception of motion, different events must be measured in sequence and related to each other. This measurement process somehow allows for the perception of motion and the flow of time. Relativity theory has nothing to say about how this measurement process occurs, but quantum theory has a great deal to say about this measurement process. But before we discuss quantum theory, let’s discuss how the principle of least action arises from relativity theory.

The motion of matter and energy within a curved space-time is determined from the space-time metric $g_{\mu\nu}(x)$ by a geometrical principle, which is the principle of least action. Let's go back to the example of how distance is measured on a curved two dimensional surface. The geodesic is a curved line that measures the shortest distance between two points on the curved surface. We can imagine this process of measurement as connecting a tape measure between two points on the surface and pulling the tape measure tight to give the shortest distance. The tape measure follows a curved path along the surface. If the tape measure is stretched tight, then this is the minimum distance between the two points. But we'd like to translate this process into mathematics. The first part of the process is to mathematically express the distance between those two points for any possible path that can be taken between the points in terms of the metric and the coordinate system, and then to give a rule for how to minimize that distance.

All the particle trajectories followed by matter and energy in space-time are determined by a similar kind of geometrical principle that involves the proper time interval Δs . The proper time is the only invariant measure of 'distance' in space-time. A particle trajectory is determined from the proper time interval by the action principle. The action principle requires that the proper time be stationary for any path or trajectory a point particle can follow. The meaning of a stationary path is related to how the proper time interval changes as the path of the trajectory changes. A stationary path is one that maximizes the proper time interval of the path.

The action principle is analogous to a physical measurement of the shortest distance between two points on a two dimensional surface as the tape measure is pulled tight. In relativity theory, the path of a particle trajectory is the path that maximizes the proper time, which is the same as least action. But a proper time interval is the same as an ordinary time interval measured in the rest frame of a massive particle. The action principle in effect says that the path followed by a particle between two points in space-time is the path for which a clock that is carried by that particle will give the longest possible time interval compared to any nearby possible paths. This is what it means to say that the proper time interval for the trajectory is maximized compared to all nearby paths. How does the particle 'know' how to follow a path that maximizes the amount of time that elapses on a clock that the particle carries? Do particles 'know' anything?

The principle of least action is equivalent to Newton's law of motion $\mathbf{F} = m\mathbf{a}$. But what does motion mean in relativity theory? The trajectory of the particle is determined by a geometrical principle that involves the proper time. A trajectory is a path through space-time. Each point in space-time is an event labeled as $x_\mu = (ct, x_1, x_2, x_3)$. This describes a four dimensional geometry with the $x_0 = ct$ coordinate as static as any of the spatial coordinates. Two nearby events x and x' are separated by $\Delta x = x - x'$. These two events have a spatial separation $\Delta \mathbf{r} = \mathbf{r} - \mathbf{r}'$ and a temporal separation $\Delta t = t - t'$ in that particular coordinate system.

For there to be the perception of motion, there must be a measurement. One event must be measured followed by measurement of another event. Relativity theory describes geometry that is static without measurement. The trajectory a particle follows is a geometrical path through static space-time. Only with measurement can there be the perception of motion. If an event at x is measured followed by the measurement of an event at x' there can be the perception that the particle moved over the spatial segment $\Delta \mathbf{r}$ in a time interval Δt . This is measurement of sequential events in space-time. What does it mean that one event is measured followed by the measurement of another event? Each event that is measured is an event in space-time. The only invariant 'distance' that can relate individual measurements of events is the proper time interval between two events.

Einstein's theory of general relativity expresses the gravitational field in terms of the space-time metric $g_{\mu\nu}(x)$. The underlying assumption of relativity theory is that space-time has a geometrical structure. Space-time geometry has curvature, and the metric measures that curvature. The choice of a coordinate system that localizes events in space-time cannot change this geometrical structure. Only the metric determines how physical distances are measured between nearby points in space-time. Since space-time is geometrical, the only measurable physical 'distance' that is independent of the choice of a coordinate system is the proper time interval.

The theory of relativity is based upon the principle of equivalence, which basically says that there is no way to distinguish between the force of gravity and an accelerating frame of reference. The acceleration of an object that appears to occur in a gravitational field, such as an apple that accelerates as it falls in the earth's gravitational field, is equivalent to the motion that occurs in an accelerating frame of reference, such as the motion of an

apple that is dropped inside a spaceship that accelerates through empty space. There is no way to distinguish the motion of an object in a gravitational field from the motion that appears to occur in an accelerating frame of reference without gravity. The effects of all possible accelerating frames of reference are equivalent to the effects of gravity. The principle of equivalence arises from the fact that there is only one kind of mass, or that inertial mass is the same as gravitational mass. In Newton's equations of motion for gravity $F=ma$, the same mass enters into the gravitational force $F=GmM/R^2$, and so $a=g=GM/R^2$. This principle is only an extension of the equivalence of all frames of reference in constant velocity motion relative to each other, within which the laws of physics are identical, to include all accelerating frames of reference, which are always equivalent to the effects of gravity. The implication of the principle of equivalence is that in free fall all the effects of gravity disappear from any point of view, since in free fall the effects of gravity and acceleration exactly cancel out from every point of view. At its most fundamental level, the principle of equivalence simply expresses the symmetry of observation from all possible points of view in empty space. All observers, no matter what their apparent state of motion relative to each other, have equal claim to the validity of their observations.

To quote from Brian Greene, "All observers, regardless of their state of motion, may proclaim that they are stationary and 'the rest of the world is moving by them', so long as they include a suitable gravitational field in the description of their own surroundings". The essential nature of relativity theory is symmetry among all possible observational points of view, which is a consequence of the symmetry of empty space. There is a deep connection between this symmetry and the symmetry of all other fundamental forces unified with gravity through compactification of extra dimensions. Since all the fundamental forces are unified with gravity through compactified extra dimensions, in free fall, all the effects of all forces disappear from any point of view that is freely falling through empty space. The equivalence of all possible points of view in empty space is reflected in the nature of the gravitational field, which can always be represented as the curvature of space-time geometry.

How can we use the principle of equivalence to demonstrate the gravitational curvature of space-time? Imagine a spaceship that accelerates through empty space with a constant acceleration $a=g$. Let's place a clock in the front of the spaceship and an identical clock in the back of the spaceship, separated by a distance x . Imagine that the clock in the front of the

spaceship emits a flash of light every ΔT seconds, and that an observer at the back of the spaceship measures the arrival of each flash of light. That observer compares the time interval $\Delta T'$ between the arrival of each flash of light with the inherent time interval recorded on the clock in the back of the spaceship, which is ΔT , since the clocks are identical. The flash of light appears to arrive early, since the spaceship accelerates while the flash of light travels at the speed of light from the front clock to the back clock, and so the observer at the back of the spaceship observes that the front clock runs fast. If the spaceship moves at a velocity v , the time it takes a light wave to travel from the front clock to the back clock is given by $\Delta t = (x - \Delta x)/c$, where the back clock has moved forward by a distance $\Delta x = v\Delta t$ in the time it takes the light wave to reach the back of the spaceship. This gives $\Delta t = x/c(1 + v/c)$, which is approximated as $\Delta t = x(1 - v/c)/c$ in the non-relativistic limit. But the spaceship accelerates at a rate $a = g$, so by the time the next flash of light is emitted, the velocity of the spaceship has accelerated to $v + g\Delta T$. This means the next flash of light only requires a time $\Delta t' = x(1 - v/c - g\Delta T/c)/c$ to travel to the back of the spaceship. But the difference in these two time intervals is also the observed difference in the time intervals between two consecutive flashes of light as observed in the front and the back of the spaceship $\Delta T' - \Delta T = \Delta t' - \Delta t$. This gives $\Delta T' = \Delta T(1 - gx/c^2)$. The clock in the front of the accelerating spaceship appears to run faster from the perspective of an observer in the back of the spaceship.

The principle of equivalence tells us there is no way to distinguish the effects of a gravitational field from an accelerating frame of reference. The acceleration due to gravity on the surface of the earth is $g = GM/R^2$, where M is the mass and R is the radius of the earth. If we have a clock on the surface of the earth and an identical clock at a height x above the surface of the earth, the principle of equivalence tells us that the clock at the higher elevation will appear to run faster by an amount $\Delta T' = \Delta T(1 - gx/c^2)$, compared to an identical clock on the surface of the earth. The clock at the higher elevation in a gravitational field runs faster because of its equivalence to a clock in an accelerating frame of reference. This prediction of the principle of equivalence has been experimentally confirmed. Another way to see the nature of the principle of equivalence is to consider a photon that falls in a gravitational field. The gravitational potential energy of an object of mass m at a height x above the surface of the earth is given by $V(x) = mgx$. If a photon with energy $E = h\nu$ falls from a height x down to the surface of the earth, then that photon gains an amount of potential energy

$\Delta E = mgx$. That photon has an amount of 'gravitational mass' specified by $E = mc^2 = h\nu$, which means $\Delta E = h\nu gx/c^2$. As the photon falls in the gravitational field its frequency increases by an amount $\Delta E = h\Delta\nu$, which gives $\Delta\nu = \nu gx/c^2$. The energy of the photon at the surface of the earth relative to its energy at a height x above the earth is $E' = h\nu' = h(\nu + \Delta\nu) = h\nu(1 + gx/c^2)$, which is the same as $\Delta T' = \Delta T(1 - gx/c^2)$ if we identify the frequency of vibration with an inherent rate of oscillation as $\nu = 1/\Delta T$.

The principle of equivalence explains the curvature of space-time geometry. How do we recover Newton's laws from this result? Einstein tells us to look at the proper time interval, which is related to the amount of ordinary time measured on a clock carried by a particle in that particle's rest frame. In the rest frame $\Delta s = c\Delta t$. Einstein tells us the particle will follow a geometrical path through space-time that maximizes the proper time relative to all nearby paths. If that particle moves in the earth's gravitational field at a height x above the surface of the earth, then the time interval measured on the particle's clock as observed from the surface of the earth is $\Delta t' = \Delta t(1 - gx/c^2)$. But if that particle moves with velocity v , we also have to include the effects of time dilatation, which gives

$$\Delta t' = \Delta t(1 - gx/c^2)/(1 - v^2/c^2)^{1/2}, \text{ or}$$

$$\Delta t = \Delta t'(1 - v^2/c^2)^{1/2}/(1 - gx/c^2).$$

In the non-relativistic limit we can approximate

$$\Delta t = \Delta t'(1 - v^2/2c^2 + gx/c^2).$$

As observed from the surface of the earth,

$$\Delta s = c\Delta t = c\Delta t'(1 - v^2/2c^2 + gx/c^2).$$

If we define the action in terms of the particle's mass m as $\Delta \mathbf{S} = -mc\Delta s$, then $\Delta \mathbf{S} = \Delta t'(\frac{1}{2}mv^2 - mc^2 - mgx) = (\text{KE} - \text{PE})\Delta t'$. The potential energy includes the mass energy and the gravitational potential energy : $\text{PE} = mc^2 + mgx$. To recover Newton's law of motion we're instructed to maximize the proper time, or minimize the action, which gives $F = ma$, or $mdv/dt = -mg$. This describes the motion of a particle of mass m within a gravitational field, where the acceleration due to gravity is $a = -g$, and the particle is located at position x and moves with velocity $v = dx/dt$. If we drop the particle from an initial height $x = x_0$ then the motion of that particle is described by the particle trajectory $x(t) = x_0 - \frac{1}{2}gt^2$. The meaning of the path of least action is that the kinetic energy $\text{KE} = \frac{1}{2}mv^2$ takes on its

lowest possible value for that path while the potential energy $PE = mgx$ takes on its largest possible value for that path, as the particle moves on this trajectory and these two kinds of energy tend to balance each other out. The particle trajectory as determined by Newton's law of motion is the path that gives the least amount of kinetic energy for the most amount of potential energy for the entire path. If we vary that path to try to lower the kinetic energy further, we'll find that we lose more potential energy, or if we try to vary the path to increase the amount of potential energy, we'll find that this requires even more kinetic energy. The path of least action is the path that minimizes the quantity $\mathcal{S} = \Sigma (KE - PE) \Delta t$ over the entire path as the particle moves between two space-time points.

The instruction from Einstein to maximize the proper time interval is the same as minimization of the action, which is the principle of least action, and describes the motion of point particles in a curved space-time. The principle of equivalence explains why space-time geometry is curved, and along with time dilatation, explains why maximized proper time is the same as least action. The principle of equivalence simply expresses that there is no way to distinguish between the effects of the force of gravity and an accelerating frame of reference, and from the point of view of 'free fall', acceleration exactly cancels out the effects of gravity. Time dilatation is simply a consequence of the constancy of the speed of light and the principle of relativity, which states that the laws of the universe are identical as observed by an observer in constant velocity motion. Einstein's field equations for the metric are only a mathematical generalization of these simple physical principles.

The simplest curved space-time geometry to consider is the gravitational field that arises from a spherical mass. Einstein's field equations for the metric can be solved for a spherically symmetric object of mass M . This is known as the Schwarzschild solution. This solution is expressed in terms of a radial vector $\mathbf{r} = (x_1, x_2, x_3)$, where the spherical mass is located at the origin of this coordinate system. The distance r to any point in space is given by $r^2 = x_1^2 + x_2^2 + x_3^2$. In the non-relativistic limit, where we ignore terms of order $1/c^2$, we can approximate the Schwarzschild metric in this coordinate system as $g_{00} = (1 - 2GM/rc^2)$, $g_{11} = g_{22} = g_{33} = -1$, and all other values of $g_{\mu\nu} = 0$. This metric describes a curved space-time, but the geometry is almost flat if $2GM/r$ is much less than c^2 . The Schwarzschild metric is also the metric that predicts black holes. If all the mass is concentrated within the event horizon of the black hole, the event horizon is determined

by $g_{00} = 0$, which gives the radius of the event horizon as $R = 2GM/c^2$. This is the radius where the escape velocity is equal to the speed of light.

How do we recover Newton's law of gravitation from Einstein? Let's look at the proper time interval between two nearby points x and x' in this space-time, labeled as $x = (x_0, \mathbf{r})$ and $x' = (x'_0, \mathbf{r}')$, with $x_0 = ct$, $\Delta x = x - x'$, and $v^2 = \Delta r^2/\Delta t^2$. We find that in the non-relativistic limit

$$\begin{aligned} (\Delta s)^2 &= g_{00} \Delta x_0^2 - (\Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2) \\ &= (1 - 2GM/rc^2) c^2 (\Delta t)^2 - (\Delta r)^2 \\ &= (c^2 - 2GM/r - v^2) (\Delta t)^2 \end{aligned}$$

How do we regain Newton's laws of motion? We imagine that $x = (ct, \mathbf{r})$ localizes the space-time coordinates of a point particle of mass m that is in orbit around the larger spherical mass M . The two events we consider are a measurement of the particle's coordinates at x and another measurement at a nearby coordinate x' . In the time interval $\Delta t = t - t'$ the particle moves on the short segment $\Delta \mathbf{r} = \mathbf{r} - \mathbf{r}'$. If we imagine the measurement of many such nearby events, the particle appears to move on a path $\mathbf{r} = \mathbf{r}(t)$ defined by this sequence of short segments $\Delta \mathbf{r}$.

To determine the path, or particle trajectory, that the point particle follows through this curved space-time, Einstein tells us that the proper time interval must be maximized. To make this look more familiar, let the velocity $\mathbf{v} = \Delta \mathbf{r}/\Delta t$, and write the proper time interval between two nearby events as $\Delta s^2 = \Delta t^2 \{ (c^2 - 2GM/r) - v^2 \}$. We're interested in the non-relativistic limit. The square root is approximated as $(1 - v^2/c^2)^{1/2} = 1 - \frac{1}{2}(v^2/c^2) + \dots$ and higher order terms are ignored. This means that we can approximate the proper time interval between two nearby events in the non-relativistic limit as $\Delta s = c\Delta t(1 - v^2/2c^2 - GM/rc^2)$.

We've seen something like this before. If we define the action in terms of the proper time as $\Delta \mathcal{S} = -mc\Delta s$, we find $\Delta \mathcal{S} = [\text{KE} - \text{PE}]\Delta t$, where $\text{KE} = \frac{1}{2}mv^2$, and $\text{PE} = mv^2 - GMm/r$. This is the same kind of relation we stated before that $\Delta \mathcal{S} = (p\Delta x - E\Delta t)$, where $p = mv$, $v = \Delta x/\Delta t$, and $E = \text{KE} + \text{PE}$. Just as promised, the action principle arises from the shortest 'distance' between two space-time points in a curved space-time geometry. Maximal proper time corresponds to least action. The gravitational potential energy $V(r) = -GMm/r$ arises from the metric, which measures the curvature of space-time geometry.

What if we have an electromagnetic field instead of a gravitational field, with an electromagnetic potential $\varphi(r)$? We still get the same kind of result because of compactification of the fifth dimension. For an electromagnetic field, the metric behaves like $g_{00} = 1$ and $g_{05} = g_{50} = -aA_0(x)$, where a is the radius of the compactified fifth dimension, and $A_\mu(x)$ is the electromagnetic potential. We then find that the proper time interval behaves like $\Delta s^2 = c^2\Delta t^2 - \Delta r^2 - 2acA_0(x)\Delta t\Delta x_5$. The term $\Delta x_5/\Delta t$ represents the amount of momentum directed in the fifth dimension, which is what we call the electric charge of a point particle located at position x . If we call that electric charge q , then we find $\Delta S = -mc\Delta s = [\text{KE} - \text{PE}]\Delta t$, where the potential energy includes the electromagnetic potential $\text{PE} = mc^2 - q\varphi(r)$, and where $q = cam\Delta x_5/\Delta t$. Recall that momentum in the fifth dimension is quantized as $p_5 = h/\lambda$, and $n\lambda = 2\pi a$, so the charge located at position x is also quantized as $q = nhc/2\pi$. If we include the terms of the metric that correspond to spatial directions $g_{\mu 5} = -aA_\mu(x)$, we find the potential energy includes a term $q\mathbf{v}\cdot\mathbf{A}$, where $\mathbf{v} = d\mathbf{r}/dt$, and $A_\mu(x) = (\varphi, \mathbf{A})$. Since Maxwell's equations for $A_\mu(x)$ are inherent within Einstein's field equations for the metric with a compactified fifth dimension, we have in effect derived all of electromagnetism from relativity theory.

We still have to prove that Newton's laws of motion arise from the principle of least action, which is the same as maximizing proper time. How is proper time maximized? The answer is to consider the concept of a variation. Let's consider the motion of a point particle of mass m that orbits a larger mass M . The radial coordinate r localizes the point particle in its orbit around the mass M . The particle follows some path $r=r(t)$, which is determined by the requirement that the proper time is maximized as the particle moves on this path. The path $r=r(t)$ is defined as the particle travels from an initial position $r=r_0$ at an initial time $t=t_0$ to a final position $r=r_f$ at a final time $t=t_f$.

We'll use the expression for the proper time interval

$$\Delta s = c\Delta t(1 - v^2/2c^2 - GM/rc^2)$$

that we've already derived. Let's assume the particle moves on a very short segment of the path Δr over a time interval Δt , and label each segment of the path with a number $n = 0, 1, 2, \dots, N$, where $t_n = n\Delta t$, $t_0 = 0$ and $t_f = N\Delta t$. The particle follows a path $r_n = r(t_n)$ with the n th segment given by $\Delta r_n = r_n - r_{n-1}$ and $v_n = \Delta r_n/\Delta t$. The n th segment of the path has a corresponding proper time interval Δs_n . Einstein tells us that to determine the

path the particle follows through curved space-time, the total proper time summed up for all these short segments Δr_n is maximized, as the particle moves from an initial position $r(t_0)$ to a final position $r(t_f)$. This is analogous to the shortest geodesic path on a curved surface. The total proper time is the sum over all segments from $n = 0$ to $n = N$:

$$s = \sum \Delta S_n = \sum c \Delta t \left\{ 1 - \frac{1}{c^2} \left(\frac{GM}{r_n} + \frac{1}{2v_n^2} \right) \right\}.$$

We want to find the path through space $r = r(t)$ that maximizes the proper time. Let's imagine that the path $r = r(t)$ is varied as $r(t) \rightarrow r(t) + \delta r(t)$. The function $\delta r(t)$ is a small variation in the path $r = r(t)$, but with the endpoints $r(t_0)$ and $r(t_f)$ held fixed. As we make this variation in $r(t)$ there will also be a variation in the proper time, or $s \rightarrow s + \delta s$. With some algebraic manipulation it's possible to work out an expression for δs valid for small δr :

$$\delta s = \sum \frac{\Delta t}{c} \left\{ \left(\frac{GM}{r_n^2} \right) \delta r_n - \frac{v_n \Delta(\delta r_n)}{\Delta t} \right\}.$$

Remember that $v_n = \Delta r_n / \Delta t$, and that $\Delta r_n = r_n - r_{n-1}$ is a short segment along the path $r_n = r(t_n)$, while $\delta r_n = \delta r(t_n)$ is a variation in that path. We make the variation in that path $r(t) \rightarrow r(t) + \delta r(t)$ to determine how the proper time changes as we change the path, $s \rightarrow s + \delta s$, and look for the path that maximizes the proper time. We can use the identity

$$\frac{\Delta\{v(\delta r)\}}{\Delta t} = v \Delta \left(\frac{\delta r}{\Delta t} \right) + \left(\frac{\delta v}{\Delta t} \right) \delta r$$

to rewrite

$$\delta s = \sum \frac{\Delta t}{c} \left\{ \left(\frac{GM}{r_n^2} \right) \delta r_n + \left(\frac{\Delta v_n}{\Delta t} \right) \delta r_n - \frac{\Delta(v_n \delta r_n)}{\Delta t} \right\}.$$

We can easily evaluate the sum

$$\sum \Delta t \left\{ \frac{\Delta(v_n \delta r_n)}{\Delta t} \right\} = \sum \Delta(v_n \delta r_n) = v(t_f) \delta r(t_f) - v(t_0) \delta r(t_0) = 0.$$

This is the case since all the terms in the sum for an intermediate segment

of the sum $v(t_{n+1})\delta r(t_{n+1}) - v(t_n)\delta r(t_n)$ exactly cancel out with the term for the preceding segment $v(t_n)\delta r(t_n) - v(t_{n-1})\delta r(t_{n-1})$. Exactly the same term that is added to the sum with one segment is subtracted from the sum with the next segment. The only terms in the sum that do not cancel out are the endpoints. The endpoints of the path $r = r(t)$ have been held fixed, which means $\delta r(t_0) = \delta r(t_f) = 0$ and so this sum is exactly zero. This finally gives us

$$\delta s = \sum \frac{\Delta t \delta r_n}{c} \left\{ \left(\frac{GM}{r_n^2} \right) + \left(\frac{\Delta v_n}{\Delta t} \right) \right\}.$$

The meaning of a stationary path is that the proper time is maximized. This means that for any possible variation in the path $r(t) \rightarrow r(t) + \delta r(t)$, the proper time takes on a maximal value. This is just like the slope of a function $f(x)$ that is zero, $df(x)/dx = 0$, when the maximal value of the function is reached. For the proper time this means that $\delta s/\delta r = 0$ for every possible variation $r(t) \rightarrow r(t) + \delta r(t)$, or simply $\delta s = 0$ for any variation $\delta r(t)$. The only way that $c\delta s = \sum \Delta t \{ GM/r^2 + \Delta v/\Delta t \} \delta r = 0$ for any arbitrary variation $\delta r(t)$, is if $\{ GM/r^2 + \Delta v/\Delta t \} = 0$. This requires that $\Delta v/\Delta t = -GM/r^2$. In the limit of the differential $\Delta t \rightarrow 0$, this is rewritten as $mdv/dt = -GM/r^2$, which simply says $F = ma$ with $F = -GM/r^2 = -dV/dr$, and where $V(r) = -GmM/r$. Newton's laws of motion and gravitation are simply a consequence of a curved space-time geometry and a maximized proper time, which is the same as least action. The particle follows a path through a curved space-time that maximizes the only invariant measure of space-time 'distance', which is the proper time. The particle follows a path that is like the shortest 'distance' between two space-time points.

With quantum theory we take the sum over all possible paths, and weight each path with the probability factor $z = \exp(2\pi iS/\hbar)$. The principle of least action is inherent in the sum over all possible paths, since the most probable path is the path that minimizes the Action. The complex number $z(\theta) = \exp(i\theta) = \cos \theta + i\sin \theta$ acts like a vector in the complex plane, and tends to cancel out for non-stationary values of θ , and to add together for stationary values of θ , which are those values that minimize the action, or maximize the proper time. Since the probability factor z represents the nature of wave motion for point particles, this is just like the interference pattern we see when waves reinforce each other or cancel each other out. The principle of least action is inherent in wave motion and interference patterns. This is the fundamental relationship that relates relativity theory

to quantum theory. In some sense, least action, or maximized proper time, is like minimized energy expenditure in the performance of some action. The actions that are most likely to occur in the universe, are those actions that minimize the amount of energy required to perform the action, which for particle motion is like the shortest 'distance' between two space-time points. We can always conceptualize the nature of any bound state in the universe as a bound state of point particles, and those point particles tend to follow particle trajectories that are like the shortest 'distance' between two space-time points in a curved space-time geometry. The nature of any coherently organized bound state arises from the coherent nature of those particle trajectories as the bound state holds together. The behavior of that bound state arises from the way that organization is coherently replicated in the same phase of organization over a sequence of events. The principle of least action simply requires that those behaviors occur in the most energy efficient way possible, with least action.

Let's get back to our discussion of coherently organized bound states. Any coherently organized bound state in the universe is a system that performs actions as that system coherently replicates its form over a sequence of events. A body is a coherently organized bound state in the universe that appears to survive over a sequence of events because its form is coherently replicated in the same coherently organized phase of organization, which is the basic nature of symmetry breaking. The form of the body only survives over a sequence of events because of the way energy coherently flows through the body to hold the body together as the behaviors of the body are enacted. The dynamical nature of Action can be conceptualized as the amount of energy utilized, or the energy expenditure required, for the body to perform that behavior as energy coherently flows through the body and coherently holds the form of the body together as the behaviors of the body are enacted. The actions of that body over a sequence of events, which are called emotional expressions, arise from the way the form of a body is coherently replicated as the behaviors of the body are enacted. The most likely actions of that body, in the sense of quantum probability, are those actions that minimize the Action. But we cannot consider a body in isolation. The body is part of the universe, and it is the universal Action that determines the probability for everything that appears to happen in the universe. Only the universal flow of energy, as it flows through all things in the universe, determines the behaviors of all those things. The universe 'chooses' those actions that minimize the universal Action, because that is the natural, or most probable, way for the universe to act.

The universe is always unbiased in its actions, and tends to choose the paths of least action for all things, because that is the most likely way, or natural way, for the universe to act. All the distinct things in the universe, all the bound states of the universe, tend to follow the paths of least action, which is the natural path. The path of least action is the natural path because its the most likely path in the sense of quantum probability. The quantum state of potentiality can always be expressed as a sum over paths. The most likely path is the path of least action. The nature of Action can be conceptualized as the amount of energy utilized by any system in moving from one state of organization to another, as the system coherently replicates its form over a sequence of events. Least action means the least amount of energy expenditure, or the greatest energy efficiency. Since all energy flows in its universal gradient, those systems that tend to survive are the systems that most efficiently transfer energy down its universal gradient, hence the survival of the fittest system. As energy flows in its universal gradient, and is transferred down its universal gradient like a river that flows from the top of the mountain to the bottom of the ocean, that energy is spontaneously organized into bound states. But every bound state that forms must eventually fall apart, like the snow pack that must eventually fall down the mountainside in an avalanche or melt away. The coherently organized flow of energy through every bound state is eventually recycled in new bound states. The natural cycles of death and rebirth of all things in the universe tend to follow the path of least action, which is the natural path. That is the natural way for the universe to act as universal creativity is expressed, which inherently requires transformation of form into new form. That transformation is like the burning that occurs as an unstable state makes a transition to a more stable state.

The energy efficiency of biological systems is demonstrated by the process of photosynthesis in a plant. Photosynthesis is the most energy efficient way to transfer energy down its gradient, which is the reason why a vegetated region is cooler in summer than a barren region, as the plant more efficiently radiates infrared radiation back into outer space at night. The directed kinetic energy of a photon that arrives from the sun is generated as protons burn inside the sun, fuse together, and release energy in the form of hot photons. That directed kinetic energy is efficiently radiated back into outer space in the form of more disordered infrared radiation by the plant that utilizes it. Photosynthesis is a mechanism that efficiently transfers energy down its gradient, but it is also a mechanism that performs useful work. The directed kinetic energy of a yellow photon

absorbed by the plant during the day is used to synthesize high potential energy organic molecules, and in the process directed kinetic energy is converted into potential energy. That electromagnetic potential energy is stored in high potential energy molecules, like carbohydrates. This is really no different than the directed kinetic energy of a river that turns a water wheel, as that directed kinetic energy is used to perform useful work or is stored in some potential form, except photosynthesis occurs at the microscopic level of molecules. The performance of useful work inherently involves the conversion of directed kinetic energy into potential energy.

That stored potential energy can be converted back into directed kinetic energy to perform useful work. The conversion occurs as the potential energy stored in molecules like carbohydrates is converted into directed kinetic energy as those carbohydrate molecules are burned inside of muscle cells. When muscles in the body are used to lift up an object, the electromagnetic potential energy stored in those molecules is used to generate directed kinetic energy, which is converted into gravitational potential energy as the object is lifted up. That gravitational potential energy can then be converted back into directed kinetic energy if the object is dropped. Biological mechanisms all convert directed kinetic energy into electromagnetic potential energy, which is converted back into directed kinetic energy at a later time to perform useful work, but they only do so because they are the most energy efficient mechanisms that transfer energy down its gradient. As energy is transferred down its gradient over the flow of time, entropy always increases. That increase in entropy is due to the disordered kinetic energy radiated away from the biological system that burns the high potential energy molecules and performs the work. The work performed by a biological system occurs as that energy flows down its gradient in the most energy efficient way possible, and as entropy increases over the flow of time.

Its important to recognize that there are always two principles involved in the performance of any action. The second law of thermodynamics is a description of how the flow of energy is directed through the universe. Energy is directed to flow in its universal gradient as all the bound states of the universe form and entropy increases, and explains why bound states must form over the flow of time. Which bound states are most likely to form is determined by the principle of least action. Energy tends to flow in the most energy efficient way possible as energy is transferred down its universal gradient. The bound states that are most likely to form are those

mechanisms that minimize the action, or most efficiently transfer energy down its gradient, and is the basis for the survival of the fittest body. But all the coherently organized bound states that form in the universe are inherently unstable, eventually become disorganized, and fall apart, as energy flows down its gradient.

A body is a coherently organized bound state in the universe that appears to survive over a sequence of events because its form is coherently replicated in the same coherently organized phase of organization, which is the basic nature of self-organization. Self-organization of form can only arise from the nature of symmetry breaking, as that form is coherently replicated in the same phase of organization, which is as much the case for a block of ice as it is for a biological body. Any coherently organized bound state in the universe, which includes any biological body, is a system that performs actions as the form of that system is coherently replicated over a sequence of events. The form of the body survives over a sequence of events because of the way energy coherently flows through the body to hold the body together as the behaviors of the body are enacted. The nature of the principle of least action is the bodies that tend to survive are those that perform their actions in the most energy efficient way possible as energy is transferred down its universal gradient, which is the survival of the fittest body.

Every coherently organized bound state of energy in the universe, which includes every body, is inherently unstable, and must eventually become disorganized, or fall apart. No coherently organized bound state can hold together forever. That coherently organized flow of energy, which flows through a body as that body holds together over a sequence of events and enacts its behaviors, is eventually recycled in new bodies. That recycling of the flow of energy is the nature of the natural cycles of death and rebirth of all bodies, which is simply a consequence of how all energy flows through the universe in its universal gradient and spontaneously organizes itself into complex forms that eventually become disorganized. New forms of energy are spontaneously organized as that energy is recycled. The forms that tend to survive the longest are the forms that most efficiently transfer energy down its gradient, or enact their behaviors with the least action.

The nature of body survival is that bodies must eat each other, because that is how potential energy is transferred from one body to another body, and how the flow of energy is recycled. The nature of all body development, growth and survival requires the transfer of potential energy from one

body to another, which means bodies must eat each other in order to develop and survive. The development of a new body, which we call the birth process, and the growth and development of an infant into an adult, which we call the maturation process, requires the transfer of potential energy to the developing body. Even after that development is over, body survival still requires that the body must eat other bodies. Bodies only survive because they eat each other, which is how potential energy is transferred between bodies. The survival of the fittest body inherently requires that bodies must eat each other, since that is how potential energy is most efficiently transferred from one body to another. That energy efficient transfer process always reflects the principle of least action, which determines the most energy efficient mechanisms. Those energy efficient transfer mechanisms spontaneously arise because of symmetry breaking that occurs as potential energy is added to a body. The nature of symmetry breaking is the formation of the coherently organized bound states of energy that we call bodies.

The nature of eating and excreting also reflects the second law of thermodynamics, since entropy must always increase as bound states form. The coherently organized bound state of a body only forms as potential energy is added to the system, but that system must then radiate away disordered kinetic energy, which is why all bodies must eat and excrete. The bodies that perform their actions in the most energy efficient way, with least action, are most likely to survive as bodies eat each other. The survival of the fittest body, as bodies eat each other, is simply a reflection of the principle of least action, expressed as all energy flows in its universal gradient. Least action simply means that energy flows in the most efficient way possible, with the least amount of energy expenditure, as any coherently organized bound state of energy, like a body, is held together over a sequence of events, and its behaviors are enacted due to the way energy coherently flows through that body.

Energy is information. That information is spontaneously organized into complex forms as it flows in an energy gradient. Every complex form that forms in the universe is organized as energy flows in its universal gradient from big bang event to black hole. The nature of organization into complex form is what is meant by spontaneous emergence. The nature of spontaneous emergence is the nature of symmetry breaking. A simple example is the spontaneous formation of a vortex in the atmosphere. A hurricane forms in the atmosphere as the atmosphere flows in an energy gradient. The nature of an energy gradient for the atmosphere is the nature of a

pressure and temperature gradient. As the atmosphere flows in a pressure and temperature gradient, the hurricane spontaneously emerges under the right conditions. Why does the hurricane emerge? The hurricane emerges because of the laws of physics. The hurricane is the atmospheric mechanism that minimizes the action. The hurricane is a mechanism that efficiently transfers energy down its gradient. That efficiency is the only reason why the hurricane is randomly selected from the quantum state. Least action is directly related to the probability of occurrence. Under the right atmospheric conditions, the hurricane is the most energy efficient mechanism possible that transfers energy down its gradient, and therefore is the mechanism that is most likely to be randomly selected.

Why is there an energy gradient in the atmosphere? There is a pressure and temperature gradient in the atmosphere because there is a hot sun that shines by day and a cool dark sky by night. The only reason there is a hot sun in the sky by day and a cool dark sky by night is due to gravitational collapse of matter and energy that took place after the big bang event. The nature of what is meant by 'after the big bang event' is the universally ordered flow of information from the big bang to black hole. All complex forms of matter and energy organized in the universe spontaneously emerge as energy flows in its universal gradient from the big bang to black hole. Those complex forms include the forms of all biological bodies. The life of an embodied person in the world is only an ordered sequence of natural events animated in the universal flow of energy. Everything that is observable within the physical universe spontaneously emerges from the universal quantum state of potentiality.

That process of spontaneous emergence appears to occur through a process of random selection. The probability that anything can appear to happen in the universe is directly related to the action required for that occurrence, which is expressed in terms of quantum probability amplitudes. Bodies spontaneously appear in the world, but they are also selected. The nature of 'natural selection' is that random selection process, which is an inherent aspect of the quantum state. But is there really a 'natural selection' process, or only the appearance of natural selection? Is a natural selection process even necessary if everything that can possibly appear to happen in the world is actually observed?

Notes

A discussion of complexity theory, self-organization, and the nature of biological symmetry breaking is found in *At Home in the Universe* by Stuart Kauffman.

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science.

Albert Einstein

Reality is merely an illusion, albeit a very persistent one.

Albert Einstein

I don't demand that a theory correspond to reality because I don't know what it is. Reality is not a quality you can test with litmus paper. All I'm concerned with is that the theory should predict the results of measurements.

Stephen Hawking

Consciousness is not a quality that one can measure from the outside.

Stephen Hawking

The eternal mystery of the world is its comprehensibility.

Albert Einstein

We are all illusions of a consciousness that is the ground of being.

Joseph Campbell

Have you no thought, O dreamer, that it may be all Maya, illusion

Walt Whitman

Long enough have you dreamed contemptible dreams

Walt Whitman

Look, it cannot be seen-it is beyond form
Listen, it cannot be heard-it is beyond sound
Grasp, it cannot be held-it is intangible
These three are indefinable
Therefore they are joined in one

Tao-Te-Ching

All existing things are really one

Chuang Tzu

I am large, I contain multitudes

Walt Whitman

The eye with which I see God is the same eye with which God sees me

Meister Eckhart

I see and know all times and worlds, as one, one, always one

Rumi

The Nature of the Quantum State

The Nature of the Observables, Observing and the Observer

The laws of the universe do not actually determine the behavior of everything that appears to happen in the universe. Those laws determine all possible behaviors. The laws of the universe, which can all be expressed as a principle of least action, only determine a quantum state of potentiality. But before we can discuss the quantum state, we need to be clear what we mean by the behavior of some 'thing' in the universe. When we describe the behavior of some 'thing' in the universe, we really mean the behavior of some distinct system of the universe. With the holographic principle, we understand that every distinct 'thing' in the universe is a coherently organized bound state of information. This is as much the case for the bound states that we call biological bodies as it is for the elementary particles we call electrons, quarks and photons.

The information for everything in the universe is defined at the fundamental level of the Planck area, with one bit of quantized information per Planck area. That information is encoded by some kind of fundamental spin variables. Everything else we can discuss in the universe, which includes the entire universe by itself, is a coherently organized bound state of information defined on a surface of quantized space-time. The fundamental reason for that coherent organization is the tendency for spin alignment, which is why the surface of quantized space-time acts like a holographic viewing screen. Spin alignment is the only reason why the viewing screen is holographic. The only truly fundamental 'things' in the universe are the quantized bits of information defined on the viewing screen. Every 'thing' else in the universe is a coherently organized bound state of information. Those bound states define distinct systems in the universe, but those distinct systems are all dynamically 'redefined' every event as energy coherently flows through the system. A distinct system only appears to be the 'same' system over an ordered sequence of events because of the way the form of that system is dynamically replicated in the same coherent phase of organization, which is what is meant by self-organization. The system only replicates its form because of the way energy coherently flows through the system to allow for that self-replication of form. The system is not really self-organized. All quantized bits of energy in the universe flow

in their universal gradient from big bang event to black hole, and obey the laws of the universe as they flow. All organization of form is universal in nature.

We'd like to formulate the quantum state of any distinct system in the universe, but this is not possible because all systems are dynamically redefined for every event. There is no such thing as an isolated system in the universe. Every distinct system interacts with all other distinct systems. If we could define an isolated system in the universe, like an isolated point particle, we could express the quantum state of that system in terms of a sum over all possible paths of that particle, with each possible path weighted with a probability amplitude that depends on the action for that path. The classical path, which is the path of least action, is the most probable path in the sense of quantum probability.

But there are no isolated systems in the universe, since everything interacts with everything else, so it really does not make sense to discuss the isolated quantum state of a distinct system. Only the quantum state of the entire universe makes any real sense. The quantum state of the universe must describe all possible paths that can be taken by any distinct system in the universe. But there really is no such thing as a distinct system that is absolutely the same from moment to moment. Every distinct system is dynamical in nature, and is dynamically reorganized as energy flows through that system over a sequence of events. Only the void, the empty 'background space', is absolutely the same, since it is not dynamical, and can never change. Every distinct system in the universe is a coherently organized bound state of information, and those bound states are dynamically reorganized from event to event, as energy coherently flows through the bound state and holds it together while the behaviors of the bound state are enacted over a sequence of events. Every bound state of the universe is dynamically reorganized every event as energy flows in its universal gradient. We can only identify a bound state as a distinct system over a sequence of events because of the way the form of that system is coherently replicated in the same phase of organization. If the quantum state of the universe is to be expressed as a sum over paths, it must include all possible paths that can be taken by all distinct systems in the universe. Those paths must include all possible behaviors of all distinct 'things' in the universe, including the universe itself as a bound state of everything in the universe.

Before we even try to formulate the quantum state of the universe, let's discuss how the quantum state is interpreted, since our formulation and interpretation must somehow be related. To make this easier, let's assume that we do have an isolated system, like an isolated system of point particles. The quantum state of that system can be described by a sum over all possible paths, which we can understand as a sum over all possible particle trajectories. Each possible path is weighted with a probability amplitude that depends upon the action for that path, and the most likely path is the path of least action. The behavior of this system of particles can be quite complicated because the particles interact with each other, which is why they can form bound states.

There are two alternative interpretations of quantum theory that try to make sense out of the quantum state of potentiality, which is a sum over all possible paths. The first is the standard interpretation, which basically says that at every moment, or for every event, choices are made from the quantum state of potentiality. Each choice is called a quantum state reduction, and chooses an actual state from the quantum state, which is a sum over all possible states. The sequence of actual states that are chosen over a sequence of events then defines an actual path that is chosen from the sum over all possible paths. For our system of point particles, the choices made for every event could be to specify the position of each particle at that moment in time, which would then define a particle trajectory for each particle, $x = x(t)$, over a sequence of events. The quantum state reduction that specifies the position of the particle at each moment in time defines the actual state of the particle for each event. That actual state is chosen from the quantum state, which includes all possible positions of the particle. The 'state' of the particle is its position at some moment in time, and the path of the particle are those positions arranged over a sequence of events.

As far as the quantum state is concerned, the particle can be at any position at any moment in time. But each possible position is weighted with a probability amplitude, which specifies the likelihood that the particle can be located at that position. The remarkable thing is that the sum over states is the same as the sum over paths. We already have an intuitive understanding of what a sum over paths means, as it is simply a sum over all possible particle trajectories, $x = x(t)$. What is more difficult is to have an intuitive understanding of what a sum over all possible 'states' means, and this is where most people find their eyes begin to glaze over. The first thing to be clear about is what we mean by a 'state'. This concept is very

confusing because there are two kinds of states, which are quantum states and actual states. But the only real difference between a quantum state and an actual state is in how quantum theory is interpreted. In classical physics we only discuss actual states, because the actual path that the particle follows in classical physics is always the path of least action. But in quantum theory we have to take a sum over all possible paths and weight each path with a probability amplitude that depends upon the action for that path. The classical path is only the most probable path in the sense of quantum probability.

What is the difference between a quantum state and an actual state? A quantum state is a possible state of the system of interest. In the case of a point particle that moves through space over time, the quantum state of the point particle can be taken to be its position in space at some particular moment in time. To make this discussion as concrete as possible, let's give the quantum state of the point particle a name, and call it $\Psi=|x\rangle$. The bracket notation for a state in quantum theory is conventional, and whatever is inside the bracket is a quantum state. The equation $\Psi=|x\rangle$ simply says that the quantum state of the point particle is that of a point particle that is located at position x . This kind of a quantum state is called an eigenstate. The most general quantum state is always expressed as a sum over all possible eigenstates, where each eigenstate is weighted with a probability factor. The position, x , is called the eigenvalue of the eigenstate $\Psi=|x\rangle$. The meaning of the eigenstate is that if we were to make an observation, or measurement, of the position of a point particle with a state that is described by an eigenstate, we would only find it at position x . This is where the interpretation of quantum theory comes in.

Once we measure, or observe, the position of the point particle to be located at position x , the eigenstate becomes an actual state. The process of actually observing the location of the point particle is called a quantum state reduction, and reduces any arbitrary quantum state of the system, which is expressed as a sum over eigenstates, to an actual state. We can always write the quantum state of the system as a sum over eigenstates. In the case of a point particle, we can write the quantum state of that particle as a sum over all possible eigenstates $\Psi=|x\rangle$, where each term in the sum is weighted with a probability amplitude that depends upon the action, and the sum is over all possible values of the position x . The remarkable thing about quantum theory is that this sum over all possible eigenstates is exactly the same as the sum over all possible paths, where each path is a

particle trajectory $x = x(t)$. The path of least action, which is the classical path, is simply those particle eigenstates, or values of x , that trace out the classical trajectory over a sequence of events. But there are always possible deviations, or quantum fluctuations, from the classical path. The probability of those quantum fluctuations is inherent in the quantum state.

The standard interpretation of quantum theory starts with the proposition that we can calculate a quantum state of potentiality for some system of interest, like the motion of a point particle. That quantum state is calculated as either a sum over paths or a sum over eigenstates. It is a lot easier to write down the quantum state as a sum over all possible paths, since all we need to know is the nature of any possible path for the system of interest, and how to mathematically specify the Action for any possible path. For the motion of a point particle, a path is simply a particle trajectory, $x = x(t)$, and we know how to mathematically specify the Action for a particle path in terms of parameters like particle position x and momentum $p=mv$. But when it comes time to interpret our quantum theory, we'd really like to be able to express the quantum state as a sum over eigenstates, like $\Psi = |x\rangle$. If we can formulate the quantum state as a sum over eigenstates, then we know the probability that the particle will be found at position x at any moment in time.

The process of actually finding the point particle at some particular position x at some particular moment in time is called a quantum state reduction. With a quantum state reduction, the quantum state of potentiality, which is a sum over all possible eigenstates, is reduced to a particular eigenstate. The particle is actually found at some particular position x if the quantum state is reduced to the particular eigenstate $\Psi = |x\rangle$. That is what the standard interpretation means.

That process of actually finding the point particle at some particular location x at some particular moment in time is also called a measurement or an observation. When we actually locate, or observe, the position of the point particle to be located at x , we measure that position. The standard interpretation says that a quantum state reduction is a measurement, or an observation, of the system of interest that is described by the quantum state. The quantum state can always be expressed as a sum over eigenstates, with each possible eigenstate weighted with a probability factor. When we make a measurement of the system, we reduce the quantum state to a particular eigenstate. The actual value of the system that we measure

is specified by that eigenstate. The actual value that is measured is called an eigenvalue, or an observable value. The eigenstates of the system specify the observable values of the system. In the case of a point particle, the position eigenstates, $\Psi = |x\rangle$, specify all possible positions of the particle, and the quantum state is a sum over all possible position eigenstates weighted with probability factors. If the position of the point particle is actually measured to be located at x , the standard interpretation says that the quantum state is reduced to that particular position eigenstate.

A quantum state reduction is a measurement of the system of interest, and the eigenvalue is an observable value. Every time the quantum state is reduced to an eigenstate, an observable value of the system is measured. How is the quantum state reduced? Every observation, or measurement, of the system is a quantum state reduction. The standard interpretation says that those quantum state reductions all occur randomly, but with a probability of measurement that is specified by the probability factors that are inherent within the quantum state. In the case of a point particle, a sequence of events that measures the position, x , of the particle in space over time defines a particular particle trajectory, $x = x(t)$. That sequence of observational events defines the observed path of the particle through space. The classical trajectory of the particle is only the path of least action. Each observational event that defines a point on the observed path is a quantum state reduction.

But there is something very odd about the process of quantum state reduction. The quantum state of a point particle describes the possible behaviors of that particle as it moves from one space-time point to another space-time point over some possible path. The initial and final space-time points of the path are fixed, which are called the initial conditions of the system. The quantum state describes the nature of all possible paths of the particle as it moves from the initial to final space-time point. But when we make a measurement of the particles position at some moment in time, in effect we specify the final space-time point of the path that brought the particle to that space-time point, and we specify the initial space-time point of the path that will take the particle away from that space-time point. A measurement always changes the initial conditions, and the quantum state of the particle is changed because the initial conditions are changed. In classical physics this makes no difference, because the particle will always follow the path of least action. But in quantum physics this does make a difference. The behavior of the particle is disturbed by the process of meas-

uring the position of the particle. That change in behavior is what the uncertainty principle is all about. The behavior of the particle is not the same after a measurement of its position is made, because the act of measuring the position of the particle changes its momentum. The only way we can measure the position of the particle is to scatter another particle off of that particle, and momentum is conserved in any scattering event. As we measure the particles position, we change the particles momentum, and so we have changed the quantum state because we have changed the initial conditions of the particle. By its very nature, a quantum state reduction is a disturbance in the behavior of the particle. That disturbance is what we call a choice.

The standard interpretation says that every quantum state reduction is a choice, but the choices that reduce the quantum state are made randomly. The random choices that reduce the quantum state are weighted with probability factors that are inherent within the quantum state. Those probability amplitudes can all be calculated from the laws of physics that apply to the system of interest, which only depend upon the Action for the system. Each quantum state reduction is an observational event, and measures some observable property of the system.

With the standard interpretation, the quantum state of potentiality is just like a probability distribution, and the process of quantum state reduction is like the process that randomly measures that probability distribution. Imagine that the quantum state is like a menu, and that each eigenstate is like an item listed on that menu. The quantum state is a sum over all possible eigenstates, which is just like the menu that is a sum of all the possible items listed on the menu. The concept of a probability distribution comes into the menu if some of the items are listed more than once. Let's say one item is listed four times and another item is only listed once. The probability of randomly choosing the first item, listed four times, is four times as great as the probability of randomly choosing the second item, listed only once. The process of quantum state reduction, as a particular eigenstate is randomly chosen from the quantum state, is just like the process that randomly chooses some item from the menu. That process of random choice randomly measures the probability distribution. The actual item that is chosen from the menu and delivered to your table for dinner is the item that is randomly chosen.

But there is an alternative interpretation to the standard interpretation, called the many world interpretation of quantum theory. The quantum

state of the system of interest can always be expressed as a sum over all possible paths. The many world interpretation simply says that all possible paths are actually observed. In the case of the point particle, all possible particle trajectories, $x = x(t)$, are actually observed. How is this possible? For every possible path of the particle, there is a presence of consciousness that observes that path of the particle. That presence of consciousness is called the observer. The nature of an observer in quantum theory is the presence of consciousness that observes the observables. In the many world interpretation, an observer is present for every possible path of the particle, and observes that path. In the standard interpretation, an observer is only present for the actual path of the particle. The actual path of the particle is determined by a sequence of observational events, and each event is a quantum state reduction. In the many world interpretation, there is no distinction between a 'quantum state' and an 'actual state'. There is no such thing as a quantum state reduction. Every possible path of the particle is an actual path that is observed by an observer. Every possible state of the system is an observational event. In the many world interpretation, the quantum state is never disturbed, because no choices are ever made. Everything that can possibly happen is actually observed.

Let's go back to our menu analogy. With the standard interpretation, the quantum state, like the menu, is only a state of potentiality. The menu only describes those possible items that can be delivered to your table. There are many possible items that can be chosen from the menu, but the actual item that is delivered to your table is the item randomly chosen. But what exactly does 'your table' mean? Your table is the table that you are present for. In other words, you are the observer. You are the 'one' that is present at 'your table'. The observer that is present at that table is the presence of consciousness that perceives the experience of the item being delivered to that table. The item that is delivered is the observable of the quantum state. The delivery of that item, which occurs through the process of random choice, or quantum state reduction, is also the process of observing that item. The observer of that observable item is the presence of consciousness that is present to observe the delivery of that item. With the standard interpretation, only one particular item, or observable value, is delivered as the quantum state is reduced to a particular eigenstate, and that is the item observed by the observer.

But with the many world interpretation, all possible observable values of the quantum state are actually observed. An observer is present for every

possible observable value. There is no quantum state reduction. No choices are made. There is no delivery of the item. Every item on the menu is its own table, and an observer is present at every table to observe whatever is presented on that table. An observer is present for every possible observable value of the quantum state. Every possible quantum state is its own 'table', and an observer is always present at each table to observe whatever is presented on that table. Instead of table, use the analogy of a play, and substitute the world 'stage' for table. In this sense, an observer is always present in the 'audience' for whatever is presented on that stage. The nature of consciousness belongs to the 'one' that is present in the audience, and the nature of the 'play' that plays in the 'theater of consciousness' is whatever is presented on that stage. To better understand the nature of the many world interpretation, we only need understand how a quantum 'state' is like a 'stage'.

The essential difference in the two interpretations is only in how we interpret the meaning of a 'state'. A 'state' simply describes the observable properties of some aspect of the observable universe that can be observed at some moment in time, such as the observable properties of a point particle. The most basic observable property of a point particle is its position x . In classical physics, the state of the point particle is simply given by the classical trajectory, $x = x(t)$, which is the path of least action. In the standard interpretation, we define a 'quantum state' $\Psi = |x\rangle$, and specify that the 'quantum state' is reduced to an 'actual state' if the position of the particle is actually measured at point x . The quantum state is a sum over all possible paths, weighted with probability amplitudes that depend on the action for each path. In the standard interpretation, an observer is only present for a quantum state reduction. In the many world interpretation, each quantum state is an actual state, and an observer is present for every possible state, or path.

How can we make sense of the many world interpretation of quantum theory? How is it possible that an observer, which is a presence of consciousness, is present for every possible quantum state? It all depends upon how we make sense of the quantum state, and that depends on how we formulate the quantum state of the universe. But before we try to formulate the quantum state of the universe, it helps to give another example of the problem we are up against. If we give quantum theory an incorrect interpretation, we'll find that there are paradoxes in our interpretation. Those quantum paradoxes simply indicate that we have given quantum theory an

incorrect interpretation. Correct the interpretation and the paradoxes disappear.

These paradoxes of quantum theory show up in a phenomena called quantum entanglement. The quantum states of apparently different systems are entangled because those systems interact with each other. But we already knew that from the holographic principle, since all the apparently distinct systems in the universe are only coherently organized bound states of information that interact with each other. Those systems are all dynamically reorganized over a sequence of events as they interact with each other.

The nature of how distinct systems interact with each other is the nature of spin alignment. The holographic principle tells us that every apparently distinct system in the universe is only a coherently organized bound state of some kind of fundamental spin variables defined on a surface of quantized space-time. All spin variables have a tendency to align with each other because of the phenomena of spin alignment. The quantum states of different surfaces are entangled with each other because different spin variables have a tendency to align or anti-align with each other. Spin alignment is the reason the quantum state is all tangled up.

Quantum entanglement is all about how different surfaces of quantized space-time share information with each other because of the tendency for spin alignment. The quantum state of the universe is a state of potentiality, and somehow must be expressed in terms of those surfaces of quantized space-time, which ultimately reduces down to how information is encoded on those surfaces. Due to interactions between spins on different surfaces, the possible ways that information can be organized on one surface is correlated with how information can be organized on other surfaces. This basically says that everything that can possibly happen on one surface is connected to everything else that can possibly happen on any other surface because all spin variables interact with each other. The connectedness of all things is a consequence of quantum entanglement, which arises from the fundamental nature of spin alignment.

The phenomena of quantum entanglement is seen in a system as small as two spin $\frac{1}{2}$ variables. Let's make this as concrete as possible. In quantum theory a spin 'up' is designated by the quantum state $\Psi=|\uparrow\rangle$, and a spin 'down' by $\Psi=|\downarrow\rangle$. An arbitrary quantum state of spin is written as

$\Psi = a|\uparrow\rangle + b|\downarrow\rangle$. The parameters 'a' and 'b' are probability amplitudes that specify how likely it is that the spin $\frac{1}{2}$ can be measured to be 'up' or 'down' in any measurement. That measurement is a quantum state reduction that reduces the quantum state to either $|\uparrow\rangle$ or $|\downarrow\rangle$.

Spin $\frac{1}{2}$ can only be measured to be either 'up' or 'down'. That's what a quantum state reduction means. An arbitrary quantum state is like a menu of possibilities that says with a likelihood determined by the parameter 'a' that the spin can be measured to be 'up', and with a likelihood determined by 'b' that the spin can be measured to be 'down'. Those are the only two possibilities. A spin $\frac{1}{2}$ variable can only be measured to be either 'up' or 'down', which means the probability amplitudes satisfy $a^2 + b^2 = 1$. A spin measurement is a quantum state reduction that reduces the quantum state to either $|\uparrow\rangle$ or $|\downarrow\rangle$. That measurement requires a choice. Quantum theory says that nature makes her choices randomly.

Nature makes her choices randomly, but the quantum state can be organized into complex forms. The probability amplitudes inherent within the quantum state specify that organization. Think of the quantum state as a menu. Imagine that you randomly choose a meal off a menu but that the restaurant has listed one meal twenty times and another meal only once. You are twenty times as likely to randomly choose the meal listed twenty times as the meal listed only once. In terms of the spin quantum state this is the case if $a^2 = 20/21$ and $b^2 = 1/21$. The quantum state is a probability distribution that nature randomly measures. But you, the observer, are also present to observe the consequences of nature's choice. At least that is how the standard interpretation of quantum theory goes.

Quantum entanglement has to do with correlation of behavior between different spins. In the conventional description of elementary particles (like the electron and the photon) particles also have spin (the electron is a spin $\frac{1}{2}$ particle and the photon is a spin 1 particle). Even the graviton of relativity theory has spin (its a spin 2 particle). Particle spin is not the same as the fundamental spin variables that are defined on elementary Planck areas, which holographically encode information on surfaces of quantized space-time that act as holographic viewing screens. Particle spin is only an aspect of the holographic description of events described by a quantum field theory, but particle spin does help explain the nature of quantum entanglement. The classic "thought" experiment is to take an unstable spin zero particle, like a pi-meson, and let it decay into two spin $\frac{1}{2}$ particles.

The two spin $\frac{1}{2}$ particles move in opposite directions away from the site of the spin zero particle. Let's call those direction R and L. Diagrammatically:

$$\text{L-side } (\text{Spin } \frac{1}{2}) \leftarrow \leftarrow (\text{Spin } 0) \rightarrow \rightarrow (\text{Spin } \frac{1}{2}) \text{ R-side}$$

The most general quantum state of a single spin $\frac{1}{2}$ variable is $\Psi = a|\uparrow\rangle + b|\downarrow\rangle$. When two spin $\frac{1}{2}$ variables interact with each other, their quantum states become entangled, which is mathematically represented by the multiplication of those quantum states. But the two spins are constrained by the total amount of spin that arises from the pi-meson decay, which is zero. The entangled quantum state of that decay process, which describes a total spin of zero, is written as:

$$\Psi = a|\uparrow\text{R}\rangle|\downarrow\text{L}\rangle + b|\downarrow\text{R}\rangle|\uparrow\text{L}\rangle$$

The total spin has to add up to zero because spin is a conserved quantum number. For the total spin to be zero, if the R-particle is 'up' then the L-particle must be 'down', and if the R-particle is 'down' then the L-particle must be 'up'. Those are the only two possibilities that add up to a total spin of zero. The two spin $\frac{1}{2}$ particles move away from each other. Let's imagine that one travels to Mars and the other travels to Venus. A clever experimenter on Mars measures the direction of that spin as the particle passes by. There is another clever experimenter on Venus that measures the direction of that spin as it passes by. In the standard interpretation, a measurement is a quantum state reduction.

The quantum state can only be reduced to $|\uparrow\text{R}\rangle|\downarrow\text{L}\rangle$ or to $|\downarrow\text{R}\rangle|\uparrow\text{L}\rangle$. Those are the only two possibilities. A measurement is a quantum state reduction that chooses among these two possibilities. If the experimenter on Mars measures the particle spin that passes by to be 'up' then the experimenter on Venus must measure the particle spin that passes by to be 'down'. If the experimenter on Venus measures that particle spin to be 'up' then the experimenter on Mars must measure that particle spin to be 'down'. The results are always correlated with each other because the quantum states are entangled. Quantum entanglement means that different measurements, performed by different experimenters far away from each other, are always correlated with each other. The results of independent measurements separated far away from each other are correlated because of quantum entanglement. Entangled quantum states must always be reduced together no matter how far apart the things are that are measured.

Until the measurement is performed the quantum state is a state of potentiality. Once the measurement is performed the quantum state is reduced. What one experimenter measures is determined by what the other experimenter measures. It doesn't matter if the two experimenters are on opposite sides of the universe. The moment the experiment is performed on one side of the universe, the result of the experiment is also determined on the other side of the universe. But wait just one second! Doesn't that violate relativity theory that says no signal can travel faster than the speed of light? Relativity theory says that "nothing" can travel faster than the speed of light. How can the result of one measurement instantaneously determine the result of another measurement performed on the other side of the universe? The reason for this quantum paradox has to do with the way we interpreted quantum theory. We used the standard interpretation that says every measurement is a quantum state reduction, which is a choice.

What if we use the many world interpretation instead? Then there is no paradox. There is no quantum state reduction. Every possible quantum state is an actual state that is actually observed by an observer. An observer is present for every possibility. No signal is transmitted across the universe because no quantum state reduction is ever performed. In a sense, no measurement is ever performed because everything that can possibly happen in the universe is observed. If all possibilities are observed that is the same as if no measurement is ever performed. In some sense, if everything that can possibly appear to happen in the universe is observed, that is the same as if nothing is ever done, since the universe is never disturbed. By its very nature, a quantum state reduction must disturb the universe by making a measurement of the universe. A measurement disturbs the universe because the universe is not the same after a measurement is performed. A measurement is a quantum state reduction that reduces the quantum state of potentiality to an actual state, which is a choice, and in that process of choosing, all of that potentiality is lost. With the many world interpretation, there is no quantum state reduction, there is no choice, and there is never any loss of potentiality. If everything that can possibly appear to happen in the universe is observed, then none of that potentiality is ever lost. With the many world interpretation, the universe is never disturbed.

The only way to avoid the paradoxes of quantum entanglement is with the many world interpretation of quantum theory, which simply says an observer is always present for anything that can possibly appear to happen

in the universe. Every possible path of any distinct system in the universe is observed by an observer, or by a presence of consciousness. To understand how that is possible, we only have to understand how the quantum state of the universe is formulated. Once we have the correct formulation of the quantum state of the universe, the many world interpretation will arise as the natural interpretation. What this means is that the whole idea of a quantum state reduction, or a measurement of the universe, is nonsense. No choices are made, and the universe is never disturbed. All we have to do is get our ideas about the nature of a 'state' correct. A 'state' defines some observable property of some observable aspect of the universe, observed at some moment in time. The only difference between a 'state' in classical physics and in quantum physics is that a state in classical physics is defined by a path of least action, while in quantum physics all possible paths, and therefore all possible states of the universe, are included. In either case, an observer is always present to observe that observable state. To understand how this is possible, we need to know the nature of a state of the universe.

We understand that the universe is composed of matter, energy, space and time, but with the holographic principle, we know every possible state of the universe reduces down to information, and the nature of that information is the same as the nature of energy. All of that information is defined on surfaces of quantized space-time, with one bit of quantized information per Planck area, encoded as some kind of fundamental spin variables. The surface of quantized space-time acts as a holographic viewing screen, and defines a coherently organized bound state of information, because of the tendency for spin alignment. To get our ideas about the nature of a 'state of the universe' correct, we only have to understand how the quantum state of the universe is formulated in terms of those surfaces of quantized space-time and all those fundamental quantized bits of information.

Essentially, the holographic principle says that the universe is defined on two dimensional surfaces of quantized space-time that act as holographic viewing screens, with one bit of information per Planck area, the basic unit of quantized space-time. This apparent three dimensional world that we appear to live in is only a holographic projection from the viewing screen, similar to the holographic images projected from a film. Everything that is perceivable in the world is like a perceivable holographic image defined upon the viewing screen. The viewing screen is a bounding surface that holographically defines everything that appears to happen in the apparent

three dimensional world bounded by that surface. The world is holographically animated as a sequence of viewings screens is observed over a sequence of events, like the animated frames of a movie. That sequence of viewing screens is ordered in the universal flow of energy, which is ordered by the nature of gravitational collapse. A 'state of the universe' is simply a surface of quantized space-time. The quantum state of the universe is the collection of all possible surfaces of quantized space-time. Every distinct system in the universe is a coherently organized bound state of information defined on such a surface.

Current observational evidence, based on the total mass-energy of the universe, indicates that there are about $b = 10^{123}$ bits of information in the universe. This follows from the holographic principle if we take the universe to be defined on a surface of quantized space-time the size of the event horizon of a black hole, plug in the total mass-energy, M , of the universe into the formula for the area of that event horizon $A=4\pi R^2$, where $R=2GM/c^2$, and divide that area by the Planck area, $Gh/2\pi c^3$. That event horizon has a radius of about $R=10^{28}$ cm, or ten billion light years, which is about the size of the universe. Each bit of information is encoded by some kind of fundamental spin variable. Each spin variable can only take on discrete observable values. In the case of a spin $\frac{1}{2}$ variable, the observable values are either 'up' or 'down', and that encodes information in a binary code, just like a sequence of 1's and 0's. If each of those bits of information can only take on one of two possible values, 1 or 0, then there are $N=2^b$ distinct ways to arrange all of that information. But there are other kinds of spin variables besides spin $\frac{1}{2}$ variables, like spin 1 and spin 2, and so the encoding of information is not as simple as a binary code. The number of ways to arrange all of that information is still an enormous number, much larger than $N=2^b$, and represents all the possible ways that information can become encoded on the universal surface of quantized space-time.

But the universe is not defined on a single universal surface of quantized space-time. The universe is defined on a collection of surfaces of quantized space-time. Just as every quantized bit of information in the universe is allowed to take on all possible values, so too all possible surfaces of quantized space-time are part of the universal quantum state. Each possible surface of quantized space-time is an arrangement of fundamental Planck areas that range in size from a single Planck area up to a surface that connects every possible Planck area, including all possible singlets, doublets, triplets, quadruplets, until all the Planck areas are connected. Any possible

way Planck areas can be connected together to form a surface is a possible state of the universe, and these range in size from a single Planck area to the total number of Planck areas that comprise the entire universe. Each of these possible surfaces of quantized space-time is a possible state of the universe, and every possible state is included in the universal quantum state.

The enormity of the number of possible states of the universe is hard to fathom, but it is a finite number as long as the fundamental spin variables are restricted to a finite number of possibilities, like spin $\frac{1}{2}$, spin 1 and spin 2. The number of quantized bits of information in the universe, $b=10^{123}$, is a very large number. The number of distinct ways to arrange all of that information, which is a number greater than $N=2^b$, is a much bigger number. But the biggest number of all is the number of distinct states of the universe, which is the number of all possible surfaces of quantized space-time that can be constructed out of fundamental Planck areas and those bits of information. If the fundamental spin variables are not restricted in their nature, then the number of possible states of the universe is not even finite, but it's a countable infinity.

The number of quantized bits of information in the universe, $b=10^{123}$, is related to the cosmological constant Λ , which determines the rate of exponential expansion of the universe. Every observer, present at a point of view in an exponentially expanding universe, is surrounded by a cosmic event horizon, similar to the event horizon of a black hole. That observer can only see 'things' as far out as that cosmic horizon, since the cosmic horizon is defined by a sphere where the observed expansion rate of the sphere is equal to the speed of light, and no signal can ever reach the observer from beyond that sphere. But relativity theory determines the size of that sphere in terms of the cosmological constant. The curvature radius of an exponentially expanding universe without any matter is related to the cosmological constant as $R^2=3/\Lambda$. The metric for this universe determines the proper time interval between two space-time events as $\Delta s^2=c^2\Delta t^2-\exp\{at(\Delta x_1^2+\Delta x_2^2+\Delta x_3^2)\}$, and $a^2=c^2\Lambda$, which means that the cosmological constant sets the scale for exponential expansion. The area of the sphere that surrounds the observer is $A=4\pi R^2$, which is as far out as that observer can see things. That sphere is a surface of quantized space-time with one bit of information encoded on the surface per Planck area. This means that the total number of bits of information encoded on that sphere must behave like $b=12\pi/\Lambda$. The measured value for the cosmologi-

cal constant, expressed in Planck units, is approximately $\Lambda=10^{-120}$, which gives an upper limit on the total number of bits of information in the observable universe as observed from any point of view. Matter increases the amount of information. Any possible surface of quantized space-time that is a part of the universal quantum state must contain less than this amount of information.

The computational rules of the universe determine which surfaces of quantized space-time are possible given the initial conditions of the universe, which are specified by the state of information for the big bang event. Which surfaces are possible arises from the nature of spin alignment, which determines how spin variables 'point' in the same direction, or angular momentum 'adds' together. We've already seen this in the nature by which different spin variables become entangled with each other. For example, a spin 0 variable can 'decay' into two spin $\frac{1}{2}$ variables that point in opposite directions, and that 'process' results in an entangled quantum state of those spin $\frac{1}{2}$ variables. In much the same way, two spin $\frac{1}{2}$ variables can 'add' together to form either a spin 1 variable or a spin 0 variable, which only depends upon if they 'point' in the same direction or opposite directions. Given the initial state of the universe, which is defined by the state of all the fundamental spin variables that define all bits of information in the universe at the 'time' of the big bang event, this initial state can only evolve over time in certain constrained ways that arise from the way the spin variables can be defined on all possible surfaces of quantized space-time. The constrained nature of that time evolution is due to the nature of quantum entanglement as the spin variables 'add' together to form other spin variables, which are all defined on surfaces of quantized space-time. Information becomes coherently organized upon any such surface because of the entanglement of those spin variables, but there is also correlation of information between different surfaces because of the same kind of quantum entanglement of information. Each surface is a possible state of the universe, but the surfaces that are possible are constrained by the initial conditions of the universe and the nature of quantum entanglement. The quantum state of the universe is a sum over all possible states of the universe. Each possible state is a surface of quantized space-time, and each surface acts like a holographic viewing screen. Each Planck area acts like a pixel on the viewing screen, with observable properties that depend on the state of information for that pixel. Each viewing screen is an observable state of the universe, which is observed by an observer present at that point of view.

The initial state of the universe, which is the big bang event, is not unlike the initial conditions of a particle trajectory. The quantum state of the universe is not inherently different than the quantum state of a point particle, except a point particle is defined at a space-time point, and the universe is defined on surfaces of quantized space-time. Every position, x , defines a possible state of the point particle at some moment in time, and an arrangement of those states, specified over a sequence of events, defines a possible path of that point particle, or a particle trajectory, $x = x(t)$. The quantum state of the point particle can be expressed either as a sum over all possible states or a sum over all possible paths. In the same way, each possible surface of quantized space-time defines a possible state of the universe. An arrangement of surfaces of quantized space-time, specified over an ordered sequence of events, defines a possible path of some distinct system of the universe. That distinct system is a coherently organized bound state of information defined on those surfaces of quantized space-time. The quantum state of the universe can be expressed either as a sum over all possible states of the universe or as a sum over all possible paths of those distinct systems. The path of any distinct system is an ordered sequence of surfaces of quantized space-time, which all act as holographic viewing screens. The path of the system, which defines the behavior of the system over a sequence of events, is like the animated frames of a movie.

A viewing screen is a bounding surface of quantized space-time that defines all the information for everything that appears to happen within that surface, and so whatever appears to happen within that bounding surface can be considered to be a bound state of information, which is to say the viewing screen defines a bound state of information. The universe itself is a bound state of information, and for that universal bound state there is a single viewing screen, the event horizon of the universe, similar to the event horizon of a black hole. But the universe can also be considered to be a collection of smaller bound states of information. Each smaller bound state is a distinct system within the universe, which is a distinct coherently organized bound state of information. Every distinct system in the universe is a distinct bound state of information defined on its own viewing screen. This is the case for the states of all electrons, photons, quarks and gluons, which bind together into atomic nuclei, atoms, and molecules, which bind together into cells, which bind together into body organ systems, which bind together into bodies, which bind together into societies, which arise on the bound states of planets, which are bound to solar systems, which bind together into galaxies, until the ultimate bound state of

the universe is defined. Every bound state is defined on its own viewing screen, and the fundamental level at which all of that information is defined is the Planck area. The entire universe is only a collection of viewing screens that define all the possible bound states of the universe, including the universe itself. The collection of all possible viewing screens, from a single Planck area up to the event horizon of the entire universe, represents all the possible ways the universe can be defined on viewing screens, and each viewing screen defines a possible bound state of information. The many world interpretation of quantum theory says every possible viewing screen that can be constructed in the universe is actually observed by an observer.

There is an important distinction between the universe and the quantum state of the universe, which is how the concept of a multiverse arises in the many world interpretation. The multiverse is to the quantum state of the universe in a similar way to how a particle trajectory is to the quantum state of a point particle. The quantum state of a particle is expressed as a sum over all possible trajectories of that particle, and the quantum state of the universe is a sum over all possible multiverses. Every possible multiverse is an alternative path that the universe can take in its dynamical evolution, just as every trajectory is a different path that the particle can take in its dynamical behavior. The quantum state of the universe is the sum over all possible states of the universe, which is the same as the sum over all possible multiverses, just as the sum over all possible particle positions is the same as the sum over all possible trajectories. Each state of the universe is a surface of quantized space-time, and a multiverse is a particular dynamically ordered collection of those surfaces. A multiverse describes one possible history for the dynamical evolution of all the distinct bound states of the universe. Every distinct bound state of the universe is defined for every event, or moment in time, upon a surface of quantized space-time. The dynamical evolution of that bound state is an arrangement of those surfaces ordered over a sequence of events.

The order of that sequence of events is the nature of the universal flow of energy from the big bang event to the black hole. Every coherently organized bound state of information is a system within the universe, and the behavior of that dynamical system is animated upon surfaces of quantized space-time over a sequence of events, just like the animated frames of a movie. The collection of all surfaces of quantized space-time that define a possible dynamical evolution for all the distinct bound states of the uni-

verse is a multiverse. That multiverse begins with the big bang event and ends with a collection of black holes. Even that collection of black holes may not be the final state of the universe. If the universe continues to expand indefinitely, then it will continue to cool, and eventually all the black holes will evaporate away to nothing as they radiate disordered thermal blackbody radiation back into that very cold universe. A universe that continues to expand indefinitely eventually suffers ‘heat death’, which means it is only composed of disordered thermal radiation with a temperature that approaches absolute zero as the size of the universe approaches infinity. Even in an exponentially expanding universe that is only full of ‘dark energy’ due to a cosmological constant, the negative potential energy of gravitational attraction exactly cancels out all the ‘dark energy’, and the total energy of the universe is still zero, although the temperature observed at the cosmic event horizon is non-zero but exceedingly small. The observed temperature of the cosmic horizon is given by $kT = hc/8\pi^2 R$, where $R^2 = 3/\Lambda$ and $R = 2GM/c^2$. The ‘heat death’ of this universe is at a non-zero temperature, which for our universe with R about fifteen billion light years and $\Lambda = 10^{-120}$ is at a temperature about 10^{-30} degrees Kelvin. A solar mass black hole has a temperature about 10^{-7} degrees Kelvin. The temperature of the big bang event was about 10^{32} degrees Kelvin. The flow of energy, or heat, through the universe, is always directed from the hotter to the colder object, which is from the big bang event to the black hole, but ultimately is directed toward the cosmic event horizon. For the purpose of this discussion of bound states, we only need to look at what appears to happen in the universe between the big bang event and the black hole, which is the nature of the ultimate bound state of the universe.

Between the big bang event and the black hole, various bound states of the universe can form, like stars, galaxies, planets, and biological bodies. Each of those distinct systems is a coherently organized bound state of the universe, and every possible dynamical history of that system is defined on an ordered sequence of surfaces of quantized space-time. The collection of all distinct systems of the universe that arise between the big bang event and the black hole, and their dynamical histories, defines a multiverse. Since every possible distinct system has more than one possible dynamical history, there are multiple alternative versions of the universe with distinct dynamical evolutions. Every possible dynamical evolution of the universe is an alternative multiverse, and describes an alternative version of events for the all the distinct systems defined in that multiverse. The dynamical histories of the distinct systems defined in any particular multiverse are all

connected with each other because of quantum entanglement. Quantum entanglement simply means that the dynamical histories of all the distinct systems in any particular multiverse are connected because all those systems interact with each other. The nature of those interactions is spin alignment defined upon surfaces of quantized space-time. The quantum state of the universe is the sum over all possible multiverses, which is the same as the sum over all possible surfaces of quantized space-time.

The concepts of the quantum state of the universe and of a multiverse are a bit confusing, so let's try to define these things as clearly as possible. The universe arises as a spontaneous eruption of energy from the void. The big bang event is a quantum fluctuation in the energy level of the void, which of course is zero. There is nothing in the void of empty space. All of that energy, or information, is encoded on surfaces of quantized space-time, with one bit of information encoded per Planck area as some kind of fundamental spin variable. There are a finite number of quantized bits of information in the universe, and therefore a finite number of fundamental Planck areas. Those quantized bits of information take on the allowed values of the spin variables. A particular surface of quantized space-time is constructed as a number of Planck areas are connected to each other to form a surface, and as spin variables defined on those Planck areas take on particular values. A particular state of the universe is a particular surface of quantized space-time. The idea of the quantum state is to construct all possible surfaces of quantized space-time, since those are all the possible states of the universe. The quantum state is a sum over all possible states of the universe, which is a sum over all possible surfaces of quantized space-time. The Planck areas can be connected to each other in different ways to construct different surfaces, which range in size from a single Planck area to the total number of Planck areas in the universe. For every possible way to connect a number of Planck areas together to form a surface, the spin variables defined for each of those Planck areas can also take on their allowed values. For example, a spin $\frac{1}{2}$ variable can take on the allowed values 'up' or 'down'. Every possible way that information can be arranged on every possible surface defines all the possible surfaces of quantized space-time, which are the possible states of the universe. The quantum state of the universe is the sum over all those possible states.

But this description of the quantum state of the universe tells us nothing about the dynamical evolution of the universe. The quantum state of the universe includes all possible dynamical histories of the universe. There

are many possible alternative versions of that dynamical evolution, and each alternative version is called a multiverse. To understand the dynamical evolution of the universe we introduce the concept of the flow of time, which is related to the flow of energy through the universe. The perceived flow of time over a sequence of events has an order that arises from the second law of thermodynamics, which says energy tends to flow from more ordered states to less ordered states. That tendency is a statistical phenomena that we call entropy, which describes how information becomes increasingly disordered as energy flows in its universal gradient of gravitational collapse from big bang event to black hole. That ordered flow describes the formation of all the bound states of the universe. To understand the flow of energy through the universe its necessary to understand the energetic nature of all the bits of information, which are some kind of fundamental spin variables. Each Planck area encodes information as a spin variable. The nature of kinetic energy is the tendency of spin variables to flip back and forth, while the nature of potential energy is the tendency of different spin variables to align with each other. The nature of spin alignment results in entangled quantum states, which is the nature by which the bound state of a distinct system becomes coherently organized, and how behavior is correlated between different distinct systems. Bound states tend to form because the spin variables tend to align. The universe is a bound state of everything in the universe, but the universe is just on the cusp of being unbound since the total energy of the universe is zero. The negative potential energy of gravitational attraction cancels out all forms of positive energy, which is the case because the universe arises as a quantum fluctuation in the energy level of the void, which is zero.

The flow of energy through the universe establishes the order with which the surfaces of quantized space-time are animated over a sequence of events. That order arises because of the statistical tendency of information to flow from more ordered to less ordered states, or for entropy to increase. The most ordered state of the universe is the big bang event, with its uniform distribution of matter and energy, and the most disordered state of the universe is the black hole, with its state of maximal gravitational collapse. Along the way, as energy flows through the universe from big bang event to black hole, other bound states of information are able to form. Each bound state is defined on its own surface of quantized space-time. The coherent organization of that bound state arises because of tendency for spin alignment, which is also why the surface is holographic in nature. That bound state of information coherently holds together over a sequence

of events as the form of the bound state is replicated in the same coherently organized phase of organization. Coherent replication of form is only possible because the flow of energy through the bound state is also coherently organized. The ordered sequence of events that defines the dynamical history of that bound state is an ordered sequence of surfaces of quantized space-time. The collection of all the distinct bound states of the universe that arise between the big bang event and the black hole, and their dynamical histories, defines a multiverse. That multiverse is a collection of surfaces of quantized space-time. But there are many alternative versions of the dynamical evolution of the universe, which is to say there are many alternative multiverses. Each multiverse gives an alternative dynamical history for all the distinct bound states that are defined in that multiverse, just as every possible particle trajectory gives an alternative dynamical history for the path of that particle. The essential nature of the quantum state is to take the sum over all possible paths. Each multiverse is an alternative path of the universe.

The quantum state of the universe includes all possible paths. How does the universe decide which path to take? This question assumes that choices are made. Only if choices are made, and the quantum state is reduced to an actual state, does the universe decide which path to take. This assumption is based on the standard interpretation of quantum theory, which says only actual states are observed. In the many world interpretation, all possible paths are actually taken. All states are observed. An observer is present for every possible state of the universe. But some of those states are more likely than other states, in the sense of quantum probability. The quantum state of the universe includes all possible paths, but the most likely path is the path of least action. The action principle is the fundamental principle of quantum theory, and its most general formulation is the sum over all paths. The likelihood of any particular path is expressed in terms of probability amplitudes related to the complex number $z = \exp(2\pi i S / \hbar)$. The path that minimizes the action, which is the classical path, is the most likely path because it is a stationary path. All systems in the universe tend to follow paths of least action, but that tendency is only in the sense that they are the most likely paths. There are always alternative paths that any system in the universe can follow, which are not paths of least action, but are still possible in the sense of a quantum fluctuation around the path of least action. All possible paths are actually taken.

It's worth restating that the laws of the universe, which can all be expressed in terms of an action principle, only determine the quantum

state of potentiality of the universe, which is the sum over all possible paths of the universe. The laws of the universe only determine the likelihood of any possible path, in the sense of quantum probability amplitudes. Given the initial conditions of the universe, which are specified by the state of information for the universe at the time of the big bang event, the laws of the universe only determine every possible path that every possible distinct system in the universe can take. Every possible distinct system is a possible state of the universe, and is defined as a possible state of information upon a surface of quantized space-time. The laws of the universe determine all the possible states of the universe, which is the same as all possible paths that all the possible distinct systems, or bound states, defined within the universe can take. Each possible bound state is defined upon a bounding surface of quantized space-time by the nature of spin alignment, and acts as a holographic viewing screen. The laws of the universe are only deterministic in the sense that they determine everything that can possibly appear to happen in the universe, as viewed upon those viewing screens. Every possible path is an alternative version of events that can appear to happen. Every alternative version of events for the dynamical evolution of the entire universe defines a multiverse, and all the events that appear to happen in any particular multiverse are connected because of quantum entanglement. The laws of the universe determine all the possible paths, and all the paths are actually taken, in the sense that an observer is always present at a point of view for every possible viewing screen.

The quantum state of the universe is the sum over all possible paths of the universe, which is the sum over all possible multiverses, and is the same as the sum over all possible surfaces of quantized space-time. The many world interpretation tells us that all the possible states of the universe are actually observed. An observer is always present for every possible state, and in that sense, every possible path of the universe is actually taken. A possible state of the universe is a surface of quantized space-time. A surface of quantized space-time is holographically woven together as fundamental Planck areas are woven into that surface, and a state of the universe is defined as all the bits of information on that surface are defined. The holographic principle tells us that each surface of quantized space-time acts as a holographic viewing screen that defines everything that appears to happen in the apparent three dimensional world bounded by that surface. Everything perceived is like a holographic image projected from that surface. Everything perceivable in the universe is defined on those sur-

faces, which are holographically woven out of the nothingness of empty space as the void quantizes itself into those surfaces. A surface of quantized space-time is a possible 'state' of the universe that acts like a holographic viewing screen, which is like a 'stage' in the 'theater of consciousness'. An observer is present for every state. An observer is always present in the 'audience' for whatever is presented on that stage. The nature of consciousness belongs to the 'one' that is present in the audience, and the nature of the 'play' that plays in the theater of consciousness is whatever images are presented on that stage. But this description of the quantum state tells us nothing about the nature of the consciousness that is present.

The quantum state of the universe is a sum over all possible states of the universe, and each possible state is a surface of quantized space-time. Those surfaces are holographically woven together as empty space quantizes itself into those surfaces. Each surface connects a number of Planck areas, and those connections in some sense are like a 'patchwork quilt'. Each 'patch' of the 'quilt' is a Planck area. For the universal surface, all the Planck areas are connected together. But there are distinct systems defined within the universe, which we call bound states, that correspond to the connection of a smaller number of Planck areas. Each possible surface is a state of the universe. Those possible states are entangled with each other because the universe is composed of all the distinct bound states of the universe, and all those distinct systems interact with each other. That entanglement is mathematically represented by the multiplication of those states. The entangled quantum state of the universe includes all possible Planck areas, no matter how those Planck areas are divided up into distinct surfaces. A Planck area is like a pixel on a viewing screen that encodes a quantized bit of information that defines the observable properties of that pixel.

Each surface of quantized space-time defines a distinct bound state of the universe. Those surfaces are woven out of the nothingness of empty space as the void quantizes itself into those surfaces. A state is defined as a number of Planck areas are connected together to form each surface and the state of information is defined for each Planck area. Each quantized bit of information is defined by some kind of fundamental spin variable. In string theory, those quantized bits of information are represented by 'matrix' variables defined on a bounding surface of quantized space-time. Each fundamental element of the surface encodes a matrix variable. But there is an alternative description of quantized space-time geometry,

called loop quantum gravity, which better demonstrates the 'weaving' of empty space into surfaces of quantized space-time. The 'loop' variables of loop quantum gravity are the eigenstates of quantum gravity in the same sense that a position eigenstate $\Psi = |x\rangle$ is an eigenstate for the particle trajectory of the path of a point particle $x = x(t)$. The loop variables define the fundamental area elements on any surface, and encode information for each area element as a spin variable. The surface of quantized space-time is woven together as the loop variables are woven into that surface. What is the source of those loop variables? The void of empty space is the source. The loop variables are quantized out of the nothingness of empty space, and each woven surface of quantized space-time is embedded within empty space. The void is the empty 'background space' those surfaces are embedded within.

There is a subtlety about the nature of spin alignment that is due to the computational rules of quantum gravity. Spin alignment describes how different spin variables 'point' in the same direction, or how angular momentum 'adds' together. All the macroscopic behaviors, or actions, that we observe in the world are due to the directions of spin alignment defined on surfaces of quantized space-time. Those surfaces act as holographic viewing screens. Spin alignment on a surface of quantized space-time is the only reason why that surface defines a coherently organized system, or bound state, that can enact behaviors. But spin alignment also allows for quantum entanglement between different surfaces of quantized space-time, and explains why the behavior of different bound states is correlated. In some sense, all of that coherent organization of behavior is due to the quantum entanglement of different spin variables, or their tendency to align with each other. In loop quantum gravity, that quantum entanglement arises from the combinatorial nature of different spin variables. The loop variables weave together a surface of quantized space-time, and on that surface each fundamental area element encodes a bit of information as a spin variable. The computational rules of quantum gravity specify how those spin variables combine with each other. The combinatorial nature of spin is called a spin network, and is just like the kind of entangled quantum states we saw when a spin 0 particle decays into two spin $\frac{1}{2}$ particles. That quantum entanglement was represented by the multiplication of those spin states. In a similar way, two spin $\frac{1}{2}$ variables can combine together to form either a spin 1 variable or a spin 0 variable. A spin network is defined by the combinatorial rules that describe how spin variables can combine together, and in quantum gravity, those combinatorial rules

are defined on surfaces of quantized space-time. Those combinatorial rules result in entangled quantum states, which is the basis for the coherent organization of information that arises on any surface of quantized space-time, and for the quantum entanglement of different surfaces. The surfaces that are possible within the quantum state are constrained by the initial state of the universe, which is the state of information for the big bang event, and the combinatorial rules of quantum gravity, which describe how those bits of information can combine together to form all the other possible states of the universe.

All the observable actions of the physical universe are holographically defined on those surfaces. But those surfaces of quantized space-time arise from the void of empty space, which is the source of all the quantized bits of information in the universe. The relationship of any 'object' to any other 'object' in the universe is holographically defined on those viewing screens by the way information is coherently organized. What is the relationship of the void to any such holographically defined 'object'? The void is the source of all those observable 'objects'. The void is the empty 'background space' within which all the actions of the universe are animated as those viewing screens are observed in an ordered sequence, just like the animated frames of a movie. But this raises an even more interesting question. Who is the observing 'subject'? What is the true nature of consciousness that observes all the possible actions animated within the observable universe?

Every surface of quantized space-time is a possible state of the universe. The many world interpretation of quantum theory tells us that an observer is present for every possible state of the universe. Every state of the universe is actually observed by an observer that is present for every viewing screen. Every alternative version of the universe is observed. An observer is present for every surface of quantized space-time. That surface of quantized space-time is quantized out of the void of empty space, and acts as a holographic viewing screen. The viewing screen is quantized out of empty space and is embedded within empty space. Every viewing screen is observed by an observer present at a point of view. That observer is the presence of consciousness that is present at that point of view.

There are general 'focusing' theorems in relativity theory, based on the concept of the light-cone, which prove that all the information defined in any region of space-time bounded by a surface can always be encoded on that bounding surface, and all of that information can be projected to a focal point from that surface. The presence of such focal points of percep-

tion demonstrates the holographic nature of relativity theory. At a fundamental level, the presence of such focal points of perception arises from the symmetry among all observational points of view in empty space. Relativity theory is fundamentally based upon the principle of equivalence, which at its most basic level is a statement of the symmetry of all possible observational points of view. The essential nature of the gravitational force is the equivalence of all possible points of view. All observers present at a point of view can be considered to be 'stationary' as the motion of the observable world revolves around that point, since there is no preferred frame of reference. In the same way, an observer present at a point of view in 'free fall' through empty space is free of the effects of all forces, or is 'unbound'. Every observer that is not in free fall has an event horizon that is a surface of quantized space-time, and is as far as that observer can see things as displayed on that surface. That event horizon forms a boundary in empty space that separates the observer from any information beyond that surface. That information is hidden from the observer, and is the nature of entropy, which is the nature of the disordered information encoded on the bounding surface. The principle of equivalence requires that in free fall through empty space that event horizon must disappear. In free fall, the bounding surface disappears. The principle of equivalence is the fundamental basis of relativity theory, and simply states that there is symmetry among all possible observational points of view in empty space.

But where exactly is that focal point of perception, or point of view, in relationship to the void? Is the point of view defined upon the viewing screen itself, or is the point of view outside, in the void? Whose consciousness is present for every viewing screen that spontaneously arises from the void? Who is the 'one' that is actually present to observe whatever appears to happen in the world that spontaneously arises as the void quantizes itself into those surfaces? Is it the consciousness of the viewing screen, or is it the consciousness of the void?

Notes

Roger Penrose has discussions of the various interpretations of quantum theory and the nature of the quantum state in his lecture notes *The Large, the Small and the Human Mind*, and in *The Road to Reality*, which also discusses spin networks.

Every error is due to extraneous factors such as emotion and education;
reason itself does not err.

Kurt Gödel

Let us settle ourselves, and work and wedge our feet downward through the mud and slush of opinion, and prejudice, and tradition, and delusion, and appearance-till we come to a hard bottom and rocks in place, which we can call reality, and say, This is, and no mistake.

Henry David Thoreau

All visible objects are but as pasteboard masks. But in each event - in the living act - there some unknown but still reasoning thing puts forth the moldings of its features from behind the unreasoning mask. Sometimes I think there's naught beyond-but it is enough. If man will strike, strike through the mask! How can the prisoner reach outside except by thrusting through the wall?

Herman Melville

You are also asking me questions and I hear you
I answer that I cannot answer, you must find out for yourself

Walt Whitman

Not I, not any one else can travel that road for you
You must travel it for yourself

Walt Whitman

Those who know are not learned
The learned do not know

The Tao-Te-Ching

The most useful piece of learning for the uses of life is to unlearn what is untrue

Antisthenes

All thought is immoral. Its very essence is destruction. If you think of anything you kill it. Nothing survives being thought of.

Oscar Wilde

Why chatter about delusion and enlightenment?

Ryokan

Belief means not wanting to know what is true

Friedrich Nietzsche

Truth hath no confines

Herman Melville

Only two things are infinite, the universe and human stupidity, and I'm not sure about the universe.

Albert Einstein

The fact that man produces an "I" concept besides the totality of his mental and emotional experiences or perceptions does not prove there must be any specific existence behind such a concept. We are succumbing to illusions produced by our self-created language, without reaching a better understanding of anything.

Albert Einstein

Concepts can at best only serve to negate one another. Words and language deal only with concepts and cannot approach Reality.

Ramesh Balsekar

I wonder why. I wonder why. I wonder why I wonder.
I wonder why I wonder why I wonder why I wonder.

Richard Feynman

Quantum mechanics describes nature as absurd from the point of view of common sense. And it fully agrees with experiment. So I hope you can accept nature as she is - absurd.

Richard Feynman

When you have eliminated all that is impossible, whatever remains, however improbable, must be the truth

Sherlock Holmes

Those who know do not talk
Those who talk do not know

Tao-Te-Ching

In the pursuit of learning, everyday something is acquired
In the pursuit of Tao, everyday something is dropped
Less and less is done
Until non - action is achieved
When nothing is done, nothing is left undone
The world is ruled by letting things take their course
It cannot be ruled by interfering

Tao-Te-Ching

Beyond our ideas of right-doing and wrong-doing there is a field.
I'll meet you there.

Rumi

The ultimate source is undifferentiated consciousness, that which transcends all cognitions. An individual life is a knot of delusions. Illumination means you are letting go of ego. There is no individual soul, but if you have the will to live, then you are reborn.

Joseph Campbell

There comes a point when you see only the rapture. All is good, in accord with nature. Beyond is the ground of being. The source is void.

Joseph Campbell

The Incompleteness Theorems

The Natural Interpretation of the Holographic Principle

Let's phrase the question as accurately as possible. The holographic principle tells us that everything that is perceivable in the universe is defined upon viewing screens, which are surfaces of quantized space-time. Inflationary cosmology tells us that those viewing screens are quantized out of the void of empty space. All the quantized bits of information in the universe are defined upon those viewing screens, with one bit of information per Planck area. The Planck area acts like a pixel on the viewing screen, with observable properties that depend on the state of information for that pixel. The viewing screen is a surface of quantized space-time that holographically projects images to a point of view. An observer is present at that point of view to observe whatever is presented on the viewing screen. Those observable images are all bound states of information that are holographically defined upon the viewing screen. The observer is the presence of consciousness that perceives and gives meaning to the observable images that are presented on that viewing screen. The question is simple. Does the observer somehow arise from the way information is coherently organized on the viewing screen, or is it outside the viewing screen? Is the point of view part of the viewing screen the observer perceives, or is it outside the viewing screen?

Where is outside the viewing screen? The viewing screen is quantized out of the void of empty space, and is embedded within the void of empty space. Outside the viewing screen simply means the observer is present at a point of view in the void. That is the natural interpretation of the holographic principle. The observer is a presence of consciousness that is present at a point of view in the void. The nature of the void is the potentiality that we call consciousness, present at every point of view in the void, that perceives and gives meaning to all the perceivable forms of information that are organized on any of the viewing screens that spontaneously arise from the void. The true nature of consciousness is the nature of the void, present at every point of view in the void.

There is only one other possible explanation for the nature of consciousness, which is that consciousness somehow arises from the complex way

information is coherently organized on a viewing screen. But those viewing screens must arise from the void. The void is the primordial nature of existence that exists 'before' a physical universe is constructed as a big bang event. The void is the source of existence that creates everything in that physical universe. The nature of all the things in a physical universe is the nature of matter, energy, space and time. The holographic principle tells us that those things reduce down to information defined on surfaces of quantized space-time. Inflationary cosmology tells us that all of that information arises as a spontaneous eruption of energy from the void. The source of all that information is the void.

The question is actually quite simple in nature. Is consciousness a primordial aspect of existence, or is consciousness somehow derivative of the information that is quantized out of the void of empty space? Does consciousness somehow arise from the way information is coherently organized, or is its nature primordial, an aspect of the existence of the void? Is the void the true nature of consciousness?

It is not possible to prove, in the sense of a logical or mathematical argument, that the true nature of consciousness is the nature of the void. But it is possible to prove the negative. It is possible to prove that the only logical alternative is false. It is possible to prove that it is impossible for consciousness to arise from the way information is coherently organized, no matter how complex that organization. If the only logical alternative is proven to be false, then in effect we have proven the only true proposition, which is that the void is the nature of consciousness.

The proof that consciousness cannot arise from the way information is coherently organized, no matter how complex that organization, are called the incompleteness theorems. There are two incompleteness theorems, but it is only the second one that concerns us here. The second incompleteness theorem proves that a logically consistent system of computational rules as complicated as counting natural numbers cannot prove its own consistency. The proof of consistency is outside the rules. But everything that appears to happen in the universe obeys logically consistent computational rules, which we call the laws of the universe. The organization of all the information for everything in the universe is determined by consistent rules. We know from our own direct experience that consciousness is present for those coherently organized forms of information. If the consciousness that is present for anything that arises from that organiza-

tion of information knows about the consistency of those computational rules through its consistent observations of them, then that presence of consciousness proves the consistency of those rules. That presence of consciousness is proven to be outside the computational rules by the second incompleteness theorem.

The incompleteness theorems are confusing because we are confused about the true nature of consciousness. We are confused about the true nature of our own consciousness. We mistakenly believe that our own consciousness somehow arises from part of the perceivable world that we perceive. The nature of our consciousness is the potentiality to perceive and give meaning to whatever we perceive in that perceivable world. We know the behavior of everything in the perceivable world obeys logically consistent computation rules, called the laws of the physical universe. We prove the consistency of those computational rules with our consistent observations of them. The second incompleteness theorem proves that the proof of consistency is outside those rules. The computational rules of the physical universe are only an aspect of the universe. The second incompleteness theorem therefore proves that our consciousness is outside the physical universe.

The holographic principle explains how that is possible. The physical universe is defined upon surfaces of quantized space-time that act as holographic viewing screens. Those viewing screens all spontaneously arise from the void and are embedded within the void. The nature of our consciousness is not a part of the universe that we perceive. It is what perceives the world from the outside, in some sense looking in at the world. It is not defined on any viewing screen. The world is holographic, defined upon viewing screens, and our consciousness is outside, present at a point of view in the void, observing the world. Our consciousness is outside the universe, in the void, looking in at the world.

The void is the 'theater of consciousness'. The 'stage' of consciousness is a state of the universe, which is a surface of quantized space-time that acts as a holographic viewing screen. All the actions that are enacted in the universe are enacted on that stage. The perceivable images projected from a viewing screen are what 'plays' on that stage, as a sequence of viewing screens is observed in order, just like the animated frames of a movie. Consciousness belongs to the 'one' that is present in the 'audience', perceiving that animation from its point of view in the void, which is its 'seat'

in the audience. The void is the animator of that animation, since all the viewing screens that define everything in the world spontaneously arise from the void. The 'one' that is always present for anything that appears to happen in the world is the void.

The incompleteness theorems prove that the nature of consciousness, which knows about the computational rules of the physical universe, cannot arise from the same rules that it knows about. This proof only requires that the rules are consistent, and that consciousness knows about that consistency. The nature of consciousness that knows about those rules proves their consistency through its consistent observations of them. The potentiality to know about those rules is the potentiality to perceive and give meaning to them. Where does that potentiality come from? All the computational rules of the physical universe arise from the nature of symmetry. The symmetry that they arise from is the symmetry of empty space. All the laws of the universe reflect the symmetry of empty space. The nature of all mathematical concepts arises from the symmetry of empty space, and are known as Platonic ideals. Mathematical concepts all reflect the symmetry of empty space. The nature of consciousness, which is the potentiality to know about those mathematical concepts, also arises from the void of empty space. The void of empty space recognizes itself in all mathematical concepts. The holographic principle explains how that recognition is possible, as surfaces of quantized space-time holographically reflect the nature of the void back to itself.

The entire physical universe arises from the void as a spontaneous eruption of energy. That spontaneous eruption of information arises as a quantum fluctuation in the energy level of the void, which of course is zero. There is nothing in the void of empty space. The primordial nature of existence that exists 'before' the universe is created, and 'before' anything in the universe is perceived, is the void.

Scientific reductionism can only go so far. There must be a source of all the bits of information and energy in the universe, just as there is a source of the laws of the universe that all those quantized bits of information obey. The void is the source of everything in the physical universe, and it is the source of all the laws of the universe. The only reason why all the laws of the universe can be unified into a 'theory of everything' is because those laws all arise from the nature of symmetry, which is the symmetry of empty space. All of those laws can be formulated as a principle of least

action, and reflect the nature of empty space. Einstein tells us “a spirit is manifest in the laws of the universe”, and “the eternal mystery of the world is its comprehensibility”. The spirit manifest in the laws of the universe is the comprehending spirit called consciousness.

To paraphrase Spinoza again: “The void acts from the same necessity from which it exists”, which is the symmetry of empty space. The nature of consciousness is the potentiality of the void, present at every point of view in the void, to perceive and give meaning to whatever actions are animated on any viewing screen, which is only the recognition of how the symmetry of empty space is broken as those actions are animated on the viewing screen. All the coherently organized bound states of information in the universe, like a body, are defined on viewing screens. Those bodies enact certain behaviors as energy coherently flows through the body. The body is a coherently organized bound state of energy that holds together over a sequence of events as energy coherently flows through the body and those behaviors are enacted. The presence of consciousness that perceives the images animated on the viewing screen is not a part of the viewing screen, but is outside, in the void.

The nature of perception is recognition because the void acts from the same necessity from which it exists, which is the symmetry of empty space, and the void recognizes itself in all of its actions. Those actions all reflect the nature of its existence because they are animated on viewing screens that arise as broken symmetries. Those actions spontaneously form all the coherently organized bound states of information in the universe, which are all the manifest phenomena of symmetry breaking. All of those actions are recognized because the viewing screens holographically mirror the nature of the void back to itself. All the viewing screens in the universe holographically reflect the nature of the void back to itself. The presence of consciousness that perceives the actions animated on the viewing screen knows what those actions mean because the nature of those actions, which all arise as broken symmetries, are recognized. The void recognizes itself in all of its actions.

The symmetry of empty space is broken as viewing screens arise from the void. Each surface of quantized space-time is quantized from the void and encodes information in the form of spin variables, which breaks the rotational symmetry of empty space as the spins point in some particular directions. The spin variables align with each other to form bound states,

which further breaks the symmetry of empty space. The alignment of spin variables defines the directions of all the actions animated on the viewing screens. Even the laws of the universe, like the law of gravity, which determines how energy flows in its universal gradient, arise from the symmetry of empty space.

The quantum state of the universe is the sum over all possible paths of the universe, which is the same as the sum over all possible surfaces of quantized space-time. Each surface is a possible state of the universe. The many world interpretation tells us that all the possible states of the universe are actually observed. An observer, which is a presence of consciousness, is always present for every possible state. In that sense every possible path of the universe is actually taken.

What does consciousness actually do? Consciousness does nothing. A presence of consciousness is present for every state of the universe. The relationship of consciousness to the world is that of a point of view to a viewing screen. The viewing screen spontaneously arises from the void, and consciousness is always present at a point of view in the void to perceive and give meaning to whatever appears to happen on any viewing screen. Consciousness is only the potentiality to perceive and give meaning present at every point of view in the void. All the actions animated on the viewing screen spontaneously emerge in the universal flow of energy.

That flow of energy obeys the laws of the universe and reflects the nature of the void. That energy all spontaneously erupts from the void. Even the perceived flow of time is a part of the world, and is animated as a sequence of events ordered in the universal flow of energy. An ordered sequence of viewing screens is just like the animated frames of a movie. The consciousness that perceives the viewing screen is outside the world, present at a point of view in the void. The void is the timeless nature of existence that exists 'before' the world is created.

Consciousness is the potentiality of the void, present at every point of view in the void, that perceives and gives meaning to whatever appears to happen on the viewing screen it perceives. Everything that appears to happen in the apparent three dimensional world that is bounded by the viewing screen is holographically defined on that two dimensional surface of quantized space-time. The world is holographic, defined on viewing screens, and the presence of consciousness for the world is outside, always present

at a point of view in the void. The void is the pure potentiality to holographically construct those viewing screens, and it is the pure potentiality that perceives and gives meaning to whatever appears to happen on any viewing screen. All perception is recognition because the void acts from the same necessity from which it exists.

The nature of the void is empty space, and the necessity from which the void acts is the symmetry of empty space. The void recognizes itself in all of its actions because those actions all reflect the nature of its existence. The actions animated upon the viewing screens are broken symmetries. The viewing screens arise as the void quantizes itself into surfaces of quantized space-time and encodes information in the form of spin variables. The symmetry of empty space is broken as spin variables point in some particular directions and align with each other, which defines all the directions of all the actions animated upon the viewing screens. The viewing screens holographically mirror the nature of the void back to itself. The void recognizes itself in that reflection. The spirit that is manifest in the laws of the universe is the comprehending spirit that we call consciousness, which is the nature of the void.

All mathematical concepts are inherent in the nature of empty space. All the physical properties of the world are described by commuting and anti-commuting numbers, and those numbers reflect the symmetry of empty space. The concept of irrational numbers, like π , the ratio of the circumference of a circle to its diameter, arise from idealized geometrical concepts of empty space. The concept of spin variables, which are mathematically described by commuting and anti-commuting numbers, arise from the concept of the symmetry of empty space. The concept of compactification of extra dimensions, which allows for the unification of the laws of the universe, arise from the concept of symmetry.

The natural counting numbers are the basis for all the quantized bits of information in the universe. The natural counting numbers obey a consistent system of logical rules, which is called arithmetic. The second incompleteness theorem proves that the presence of consciousness that knows about the consistency of that system of logical rules is outside the system. But that system of logical rules describes the behavior of everything in the system, which we call the universe. Where is outside the universe? The universe is holographic, defined upon surfaces of quantized space-time that arise from the void. The void is outside the universe.

The void is the source of all the quantized bits of information defined in the entire universe. Those bits of information are some kind of fundamental spin variables defined upon viewing screens, with one quantized bit of information per Planck area, the fundamental element of quantized space-time. Whole integer spin, like spin 1 variables, behave like commuting numbers, $x_1x_2 - x_2x_1 = 0$. Half integer spin, like spin $\frac{1}{2}$ variables, behave like anti-commuting numbers, $\theta_1\theta_2 + \theta_2\theta_1$. The concept of the symmetry of empty space is super-symmetric, which means that a point in empty space is located with a position coordinate x , and an anti-commuting number θ . That symmetry is broken as the void quantizes itself into surfaces of quantized space-time. The nature of the spin variables reflect those broken symmetries.

All quantized bits of information in the universe obey the laws of the universe. All the laws of the universe, like gravity and electromagnetism, reflect the symmetry of empty space, and arise because of the compactification of extra dimensions. All the laws of the universe can be unified together if there are ten dimensions, and six are compactified. The nature of the ordered flow of energy through the universe, and the perceived flow of time, can be understood in terms of the formation of bound states. Energy flows from more ordered states to less ordered states, which is the nature of gravitational collapse from the big bang event to the black hole. But that ordered flow of energy implies the holographic principle that all information is encoded on surfaces of quantized space-time. The nature of all spontaneous symmetry breaking, and the formation of all coherently organized bound states, can be understood as the nature of spin alignment on those surfaces. Whole integer spins tend to align with each other because they behave like commuting numbers, and half integer spins tend to anti-align with each other because they behave like anti-commuting numbers. The nature of spin alignment also reflects the symmetry of empty space. The actions of the universe are only animated because of the tendency for spin alignment. Those actions, which are all animated upon viewing screens of quantized space-time, are actions that reflect the symmetry of empty space. The void recognizes itself in that reflection.

Every possible viewing screen that can be constructed as the void quantizes itself into surfaces of quantized space-time is a possible state of the universe. An observer is present for every possible state of the universe. That observer is the consciousness present at a point of view in the void, which is the potentiality of the void to perceive and give meaning to what-

ever is animated upon the viewing screen. The same potentiality of the void to perceive and give meaning is present at all points of view in the void. The same undifferentiated consciousness, which is the consciousness of the void, is always present at all points of view in the void, and is present for all viewing screens. That presence of consciousness knows nothing about its true nature except that it exists. The timeless primordial nature of its existence is the nature of the void. Everything else it knows about is a perceivable image animated upon the viewing screen. The viewing screens, which are the nature of the entire universe, all arise as a spontaneous eruption of energy from the void. All of that information is encoded on the viewing screens.

Everything that appears to happen in the world is only a localized disturbance, or a fluctuation in the energy level, of the empty 'background space', or motionless background 'medium', that we call the void of empty space. That 'medium' is the nature of consciousness. Everything that appears to happen in the universe is defined upon surfaces of the void, like brief excitations of wave energy that appear on the surface of the ocean. The void is the 'ground' of existence. It is the primordial nature of existence that exists 'before' the world is created in a big bang event. There is nothing in the void of empty space. Nothing ever appears to happen in the void. The nature of the presence of consciousness that is always present at a point of view, and that observes whatever appears to happen in the world as the world is holographically animated upon viewing screens, is the void. 'Consciousness is not a quality that one can measure from the outside', because consciousness is outside any quality of the world that 'one' can measure. The world is defined upon viewing screens, and consciousness is outside, in the void.

Whose consciousness is present at every point of view in the void? Who is the 'one' that is actually present for anything that can ever appear to happen in the universe? The void is always present. The undifferentiated consciousness of the void is always present, which is the pure potentiality of the void to perceive and give meaning to whatever is animated on any viewing screen it holographically constructs out of itself. The same potentiality of the void is always present for anything that it perceives. That undifferentiated potentiality to perceive and give meaning, which we call consciousness, is always present for anything perceived, and it is always the same potentiality. The consciousness of the void is always the same presence. The void is the primordial nature of existence that exists 'before'

a physical universe is created and anything in that universe is perceived. The source of existence is a void of undifferentiated consciousness. The nature of the void is like a perfectly still ocean of undifferentiated consciousness. The 'one' that is always present is the void.

The undifferentiated nature of consciousness knows nothing about its true nature except that it exists. The concept of nonduality is a variation of solipsism, the concept that the only thing one can know with certainty is that one exists. The presence of consciousness that is present at every point of view in the void, that knows about all the forms of information defined on viewing screens, that knows about all the distinct 'things' in the universe, knows nothing about itself except that it exists.

That presence of consciousness knows nothing about its true nature except that it exists. Everything else it knows about is defined upon the viewing screen that it perceives that spontaneously arises from itself, in the same way that the nature of a dream spontaneously arises from the nature of the dreamer. The void is the nature of the dreamer, and the world defined on any viewing screen is its dream.

Notes

The Gödel incompleteness theorems are discussed in *Incompleteness* by Rebecca Goldstein. Penrose also has a discussion in his lecture notes.

The ego is first and foremost a bodily ego

Sigmund Freud

Since our inner experiences consist of reproductions and combinations of sensory impressions, the concept of a soul without a body seems to me to be empty and devoid of meaning.

Albert Einstein

A person begins to know that he exists when he finds himself again in others.

J. W. von Goethe

For men and women are not only themselves, they are also the region in which they were born, the city apartment or the farm in which they learned to walk, the games they played as children, the food they ate, the schools they attended, the sports they followed, the poets they read, and the God they believed in.

Somerset Maugham

For my flesh is meat indeed, and my blood is drink indeed He that eats my flesh and drinks my blood dwells in me and I in him

Gospel of John

All is impermanence. All is sorrowful and in perfect rapture, in accord with nature.

Joseph Campbell

April is the cruelest month, breeding
Lilacs out of the dead land, mixing
Memory and desire, stirring
Dull roots with spring rain

T S Eliot

All can know good as good only because there is evil
For having and not having arise together

Tao-Te-Ching

Misfortune comes from having a body

Tao-Te-Ching

Man did not weave the web of life.
He is merely a strand in it.

Chief Seattle

The web of our life is of a mingled yarn
Good and ill together

Shakespeare

There was a little girl
Who had a little curl
Right in the middle of her forehead
And when she was good
She was very, very good
And when she was bad she was horrid

Nursery rhyme

The mass of men lead lives of quiet desperation

Henry David Thoreau

The unexamined life is not worth living

Socrates

Know Thyself

Socrates

To thine own self be true

Shakespeare

The true value of a human being is determined primarily by the measure and the sense in which he has attained liberation from the self

Albert Einstein

You are what your deep driving desire is
As your desire is so is your will
As your will is so is your deed
As your deed is so is your destiny

Upanishads

In human freedom in the philosophical sense I am definitely a disbeliever. Everybody acts not only under external compulsion but also in accordance with inner necessity. Schopenhauer's saying, that "a man can do as he will, but not will as he will," has been an inspiration to me since my youth up, and a continual consolation and unfailing well-spring of patience in the face of the hardships of life, my own and others'. This feeling mercifully mitigates the sense of responsibility which so easily becomes paralyzing, and it prevents us from taking ourselves and other people too seriously; it conduces to a view of life in which humor, above all, has its due place.

Albert Einstein

The soul that with a strong and constant calm
Takes sorrow and takes joy indifferently
Lives in the life undying
That which is can never cease to be
That which is not cannot exist
To see this truth of both
Is theirs who part essence from accident
Substance from shadow

Bhagavad-Gita

That in whom reside all beings and who resides in all beings
Who is the giver of grace to all
The Supreme Soul of the universe
The limitless being-I am That

Upanishads

I see and know all times and worlds as one, one, always one

Rumi

Know that you are alone in the world

Henry David Thoreau

The Nature of the Mind and Body-Based Self-Concept

Object Relations Theory and the Illusion of Personal Identity

Let's review what we've discovered so far. The universe arises as a spontaneous eruption of energy from the void. That eruption of energy is a spontaneous fluctuation in the energy level of the void, which of course, is zero. The universe is just on the cusp of being unbound, since it has a total energy of zero. That information is initially ordered through the inflation of space-time, which results in the formation of the big bang event, and becomes increasingly disordered due to gravitational collapse and the formation of bound states, until black holes form. All those bound states spontaneously form in the universal flow of energy, which is just like a river that flows from the top of the mountain to the bottom of the ocean. Information becomes increasingly disordered as bound states form, because of how energy, or heat, flows. Bound states only form because they radiate away disordered kinetic energy, which is heat, so that overall there is an increase in entropy. The inflation of space-time is about how information is initially ordered, which is just like the water that initially arises on the top of the mountain. The formation of bound states is about how information becomes more disordered as energy flows, like the river that falls back to the ocean. All coherently organized bound states of information spontaneously emerge in the universal flow of energy. All of that information spontaneously arises as the void of empty space quantizes itself into surfaces of quantized space-time. The void is the source of all the energy and information in the universe. All information for the universe is holographically encoded on surfaces of quantized space-time as the void quantizes itself into those surfaces.

Each surface of quantized space-time is a state of the universe. Each surface acts as a holographic viewing screen, and holographically defines everything that appears to happen in the apparent three dimensional world bounded by that two dimensional surface. Holographic means that all the information is encoded on the viewing screen. Every surface of quantized space-time holographically defines a coherently organized bound state of information that arises because of the nature of spin alignment, which is the fundamental way information coherently organizes

itself into bound states as energy flows. As energy flows from more ordered to less ordered states, coherently organized bound states spontaneously form. Each of those states is defined upon a surface of quantized space-time, which is a state of the universe. Every fundamental spin variable is a bit of information. All the quantized bits of information in the universe obey the laws of the universe, which all arise from the symmetry of empty space, as the void quantizes itself into those surfaces of quantized space-time and encodes information.

Every quantized bit of energy in the universe flows in its universal gradient from big bang event to black hole due to the nature of gravitational collapse, which is the tendency for those bound states of information to spontaneously form. All the coherently organized bound states of the universe spontaneously emerge in that universal flow of energy. The quantum state of the universe is the sum over all possible states of the universe, which are only surfaces of quantized space-time. The bound states that are most likely to form, in the sense of quantum probability, reflect the principle of least action, which specifies that all the actions of the universe are enacted in the most energy efficient way possible, with the least expenditure of energy, as the behavior is enacted. The actions that are most likely to be enacted in the universe are the actions that minimize the expenditure of energy as any coherently organized bound state enacts its behaviors, and while the flow of energy through that bound state holds the bound state together. That coherent flow of energy through the bound state allows the behaviors of the bound state to be enacted in the most energy efficient way possible, as the form of the bound state is replicated in the same coherently organized phase of organization. Least action only means greatest energy efficiency as the behavior is enacted and the form of the bound state is coherently replicated. The formation of any bound state, and its complex repertoire of behaviors, are all natural events that arise in the universal flow of energy. Any coherently organized bound state of the universe is defined on a surface of quantized space-time, and is a state of the universe. The void is the empty 'background space' within which all the actions of the universe are animated upon those viewing screens.

The laws of the universe, which are all expressible in terms of a principle of least action, only determine the quantum state of potentiality of the universe, which is the sum over all possible paths of the universe. The laws of the universe determine the likelihood of any possible path, in the sense of quantum probability amplitudes. Given the initial conditions of the uni-

verse, which are specified by the state of information for the universe at the time of the big bang event, the laws of the universe only determine every possible path that every possible distinct system in the universe can take. Every possible distinct system is a possible state of the universe, and is defined as a possible state of information on a surface of quantized space-time. The laws of the universe determine all the possible states of the universe, which is the same as all possible paths that all the possible distinct systems, or bound states defined within the universe, can take. Each possible bound state is defined on a bounding surface of quantized space-time by the nature with which spin variables coherently align together, and acts as a holographic viewing screen. The laws of the universe are only deterministic in the sense that they determine everything that can possibly appear to happen in the universe, as viewed upon those viewing screens. Every possible path is an alternative version of events that can appear to happen. Every alternative version of events for the dynamical evolution of the entire universe defines a multiverse, and all the events that appear to happen in any particular multiverse are connected because of quantum entanglement. The laws of the universe determine all the possible paths, and all the paths are actually taken, in the sense that an observer is always present at a point of view for every possible viewing screen.

The viewing screen is a surface of quantized space-time, which is like an event horizon. The viewing screen encodes information, with one bit of information per Planck area. The holographic principle tells us that the viewing screen is a bounding surface of quantized space-time that holographically defines everything that appears to happen in the apparent three dimensional world bounded by that surface. An event horizon is a surface of quantized space-time that forms a boundary that separates the observer from the region hidden beyond that boundary. The nature of entropy is disordered information encoded on the surface that hides information from beyond that boundary from the observer. That disordered information arises from the nature of virtual particle-antiparticle pair creation, as the event horizon separates virtual particles from virtual antiparticles. To the observer, the virtual particle that travels away from the event horizon toward the observer is a real particle, while the virtual antiparticle that falls across the event horizon is hidden information. From the perspective of the observer, the event horizon creates real particles, which arise from virtual particle-antiparticle pair creation and separation at the event horizon. In this sense, the real particles that the observer perceives are like a virtual reality. The point particle description of physical reality is

a holographic description, or a 'virtual reality' description. The principle of equivalence tells us that for an observer in 'free fall' through empty space the event horizon disappears. From the perspective of an observer in free fall through empty space, there is no event horizon, there is no effect of gravity, and there is no bounding surface. The observer in free fall is 'unbound'. Since the entire universe is holographically defined upon surfaces of quantized space-time that are like event horizons, in free fall through empty space, the disappearance of the event horizon is like the disappearance of the universe.

Every state of the universe is defined on a viewing screen, and is observed by an observer that is present at that point of view. This is the natural interpretation of quantum theory, or the many world interpretation. The holographic principle explains how this is possible. A state of the universe is only a holographic viewing screen that spontaneously arises from the void. All the perceivable 'objects' in the universe are defined upon viewing screens that project their perceivable images to a point of view. The nature of the perceiving 'subject' is the consciousness that is present at that point of view. Every state of the universe is actually observed by a presence of consciousness that is present at a point of view in the void. Consciousness is the potentiality of the void to perceive and give meaning to whatever is presented on any viewing screen. That presence of consciousness only knows about whatever is presented on the viewing screen that it perceives.

Perception is recognition, because everything animated on the viewing screen holographically mirrors the nature of the void back to itself through all the manifest phenomena of symmetry breaking. The symmetry that is spontaneously broken is the symmetry of empty space. The void acts from the same necessity from which it exists, which is the symmetry of empty space, and recognizes itself in all its actions, because those actions reflect the nature of its existence. The spirit that is manifest in the laws of the universe is the comprehending spirit that we call consciousness, which is the nature of the void. The void is the true nature of consciousness. It is a void of undifferentiated consciousness. The same undifferentiated consciousness is present at every point of view in the void, which is the potentiality of the void to perceive and give meaning to whatever forms of information are presented on any of the viewing screens that spontaneously arise from itself, in much the same way a dream spontaneously arises from a dreamer. That presence of consciousness knows nothing about its true nature except that it exists.

The void is the dreamer, and the world defined on a viewing screen is its dream. The void recognizes itself in all of its actions, because 'to act is to give meaning'. The void is the source of everything in existence, and it is the primordial nature of existence. Every viewing screen arises within the void because of the way energy spontaneously arises from the void and organizes itself into complex perceivable forms. Every state of the universe is defined on a viewing screen, which is like a 'stage' in the 'theater of consciousness'. The perceivable images animated on the viewing screen are what 'plays' on that stage. The 'one' that is present in the 'audience' is the consciousness present at a point of view in the void, which is its 'seat' in the audience. The 'seat of consciousness' is a point of view in the void. The true nature of consciousness is the void. The void is always present, but it is outside whatever is presented on any viewing screen. In some sense, it is only looking in at that world. The 'one' that is always present for all viewing screens at all points of view is the void.

But this description of the true nature of reality is not the way we perceive the world. We perceive an animation of events in the flow of time. We have the distinct impression that our consciousness is embodied within the body of a person that is the central character in that animation of events we perceive. We have the impression that we control the behavior of that person. How are these impressions possible if the true nature of what we are is only a presence of consciousness that is present at a point of view in the void? The answer is that the true nature of what we are is not just the consciousness that is present at a point of view in the void, but the void itself, which is the source of all existence.

To understand why we perceive an animation of events in the flow of time, we have to understand the nature of an event. Every viewing screen is an event, perceived by the consciousness that is present at its own point of view. That presence of consciousness only knows about whatever is animated upon the viewing screen it perceives for that event. Every viewing screen is a state of the universe, and every state of the universe is perceived by an observer. An observer is only the presence of consciousness that is present at a point of view in the void.

A presence of consciousness is present for every state of the universe. That presence of consciousness is only the potentiality of the void to perceive and give meaning to whatever is animated on the viewing screen it perceives this event. All perception is recognition, because all viewing screens

holographically arise from the nature of the void, and mirror the nature of the void back to itself, as the void quantizes itself into surfaces of quantized space-time. The nature of the flow of energy through the universe, and the flow of time, are those viewings screens perceived over an ordered sequence of events, just like the animated frames of a movie. The order of that sequence of events arises as energy flows from more ordered to less ordered states. All the coherently organized bound states of the universe spontaneously form in that universal flow of energy. The nature of coherent organization is that the form of the bound state is coherently replicated in the same phase of organization over an ordered sequence of events as energy coherently flows through that bound state. The coherent flow of energy through the bound state is the only reason why it holds together over an ordered sequence of events as all the behaviors of that bound state are enacted.

The event you are perceiving right now is defined on a particular viewing screen, and your consciousness is present at that particular point of view. The viewing screen you perceive is the viewing screen of your mind. All external sensory perceptions, internal emotional body feelings, thoughts, memories, forms of imagination, and mental concepts, are presented on the viewing screen of the mind. The organs of sensory perception within the body relay information to the viewing screen of the mind the same way a video camera relays information to a digital viewing screen. Every perceivable event is defined upon a viewing screen. The viewing screen of your mind is related to your body because the mind arises with the coherent organization of the body, like any other body organ system. An ordered sequence of events, which defines an animation of events, is just an ordered sequence of viewing screens. As you perceive this particular mental event, you are aware of sensory perceptions, emotional body feelings, thoughts, and other forms of mental imagination. You are also aware of memory of past events and anticipation of future events. All of that information is coherently organized upon the particular viewing screen that you perceive right now.

All memory and anticipation of events arises from the way information is coherently organized on the viewing screen of the mind you perceive this event. All of that coherent organization of information is organized around a particular bound state of information, which we call the body of a person in the world. The particular viewing screen that you perceive right now is organized around the body of the particular person in the world that you

call 'you', but that particular body is only the central character of an animation of mental events that you perceive. The ordered sequence of viewing screens that is organized around the bound state of the particular body of that person defines the life of that person in the world. You have the distinct impression that you are that particular person in the world as you perceive the emotional energy that coherently flows through that body over that sequence of events, and as you perceive the memory and anticipation of events that arises from the way that bound state of information is coherently organized on that particular sequence of viewing screens. That coherent flow of energy holds the body together while the behaviors of that body are enacted. The life of the person in the world that you call 'you' is defined on an ordered sequence of viewing screens that you perceive from your point of view, the same way someone in an audience observes an animated movie.

The life of that person in the world is only an ordered sequence of natural events that occur in the universal flow of energy, just like any other sequence of natural events that appear to happen in the world. That sequence of events is animated just like the frames of a movie. The life of the person in the world is only an animation of natural events that you perceive on an ordered sequence of viewing screens from your point of view in the void. The only thing you know about the true nature of what you are is that you exist. Every 'thing' else that you know about, which includes all external sensory perceptions, internal emotional body feelings, thoughts, memories, and all other forms of mental imagination, are only perceivable images that are animated upon the viewing screen that you perceive this event. All sensory perceptions are the perception of that coherently organized flow of energy. The true nature of what 'you are' is the 'one' that is present to perceive those perceptions. All of those perceptions belong to your true nature the same way a dream always belongs to the dreamer. All of that energy is your energy. You are the 'one' that is present for your viewing screen at your point of view. All of that energy spontaneously arises from the void, and belongs to the void, the same way a dream belongs to the dreamer. The true nature of the 'owner' and the 'observer' of whatever appears to happen in the world, as energy flows, is the void. The true nature of the 'one' that is always present for all viewing screens at all points of view is the void.

That coherently organized flow of energy is defined upon the viewing screen of the mind that you perceive this event. The viewing screen of the

mind arises with a coherently organized bound state of information, which you call your body. The coherent flow of energy through that bound state is the only reason why the body holds together over an ordered sequence of events as all the behaviors of that bound state are enacted. The nature of all sensory perceptions is the perception of that coherently organized flow of energy through the bound state of the body. Those sensory perceptions include the perception of all memory and anticipation of events, from which arises an illusion of the continuity of events, as the forms of information perceived this event are projected to past or future events. The illusion of the continuity of events can only arise with the coherent organization of information defined on the viewing screen that is perceived this event. The perception of memory and anticipation of events inherently requires perception of the coherently organized flow of energy through that bound state, as the forms of things perceived this event are projected to past or future events. An illusion of the continuity of events arises with that projection.

The sequence of viewing screens that defines the animation of events that we call the life of a person in the world is not the only possible sequence of events that can define the life of the person in the world. The universe is the collection of all possible viewing screens, and there are many different possible ways those viewing screens can be put together to define an animation of events ordered in the universal flow of energy. Each possible way of putting those viewing screens together into an animation of events, from the birth of the person to the death of that person, is a particular path that the life of the person can take in the world. There are many alternative paths the life of the person can take, which are different ways of putting those viewing screens together to define an animation of events ordered in the flow of energy. These are alternative paths in the sense of the many world interpretation of quantum theory. Each event is a possible state of the universe, presented on a viewing screen, and an observer is present for every possible state, present at a point of view. An observer, a presence of consciousness, is present for every possible path of the life of the person in the world. All possible paths of the life of the person in the world are actually taken, because an observer is present for every possible path. That observer is only the potentiality of the void to perceive and give meaning to whatever is animated on that particular ordered sequence of viewing screens. The observer only knows about whatever is animated on the particular viewing screen it perceives each event. It knows nothing about its true nature except that it exists.

The observer, the potentiality to perceive and give meaning, is always the same potentiality for any possible sequence of viewing screens. Consciousness is only the potentiality of the void to perceive and give meaning to whatever is presented on any viewing screen. The same presence of consciousness is present for any possible path that the life of the person in the world can take. An observer is always present for any possible path that can be taken. All possible paths are actually taken. A presence of consciousness is always present. It is always the same presence. It is always the same potentiality of the void to perceive and give meaning. It is the consciousness of the void, and it knows nothing about its true nature except that it exists. The 'one' that is always present for anything that appears to happen in the world is the void.

The tricky thing to wrap your mind around is that the viewing screen that you are perceiving right now is the viewing screen of the mind. The consciousness of the void, present at a point of view in the void, is present for the viewing screen of the mind. The entire perceivable world, which includes the body and the mind of the person in the world that you identify yourself with, spontaneously arises from the void, which is the true nature of what you are. The world arises from the void the same way a dream arises from the dreamer. A viewing screen defines its own world, and is a state of the universe. That apparent world is defined on the viewing screen of the mind, which can only arise with the coherently organized bound state we call a body. The mind is only one of the coherently organized organ systems of the body. The mind arises because of the way the body is coherently organized. The body only holds together as a bound state of energy because of the way emotional energy coherently flows through the body over a sequence of events as the behaviors of the body are enacted. The mind arises with that coherent flow of emotional energy through the body. The mind is a behavior of the body that arises as energy coherently flows through the body.

The presence of consciousness for the mind, present at a point of view in the void, perceives the viewing screen of the mind. Awareness comes as if from a higher dimension, because the world is holographic, animated upon a viewing screen. The world is defined on the viewing screen of the mind, and the true nature of consciousness is outside the mind, present at a point of view in the void. The consciousness present for the mind is always outside that viewing screen, just as the consciousness that is present for an animated movie is outside that movie, in the audience. The nature of the

'one' present for any perceivable image animated on any viewing screen is always outside that animation.

The mind arises with the coherent organization of the body. The mind is a behavior of the body that arises as emotional energy coherently flows through the body and holds the body together while behaviors of the body are enacted. The body is only a coherently organized bound state of information defined on a viewing screen. The body is composed of body organ systems, and each distinct body organ system is also a coherently organized bound state of information. The mind is a distinct body organ system, or bound state of information, defined on its own viewing screen. The embodied organs of sensory perception, which are also body organ systems, like the visual system, relay information to the mind, much like a video camera relays information to a digital viewing screen. That information includes both external sensory perceptions and internal emotional body feelings, which represent emotional expressions in the body. All of that information is presented on the viewing screen of the mind. That relayed information is utilized in the mind to construct thoughts. The nature of a thought is a symbolic representation of whatever appears to happen in the world, as an image of the body is emotionally related to the image of something else in the world.

The basic form of any mentally constructed self-concerned thought is: "I am related to something else in the world with some emotional body feeling". All thoughts emotionally relate a body-based self-image to the image of something else in the world with a body feeling. The body feeling is the mental image of an emotional response expressed in the body. Whatever appears to happen in the world, as the body moves in some complex way relative to another thing in the world, is symbolically represented in the mind, as a body-based self-image is emotionally related to the image of that other thing. All self-concerned thoughts inherently identify the true nature of what 'I am' with the concept of being an embodied person in the world. The nature of the relationship inherent in every self-concerned thought is emotional. A body-based self-image, which is the concept of being an embodied person in the world, is emotionally related to the concept of something else in the world with an emotional body feeling. All self-concerned thoughts identify what 'I am' with the concept of being an embodied person in the world. These are thoughts that implicitly tell the presence of consciousness for the mind that "I am an embodied person in the world".

Those self-concerned thoughts are false beliefs that the presence of consciousness for the mind believes about itself. The presence of consciousness for the mind, which is the consciousness of the void, present at a point of view in the void, believes that 'it is an embodied person in the world'. That is what all the self-concerned thoughts that are constructed on the viewing screen of the mind tell the presence of consciousness for the mind. Every self-concerned thought is a belief about what 'it is' that the presence of consciousness for the mind believes about itself. It believes it is an embodied person in the world. Why are these mentally constructed false beliefs, presented on the viewing screen of the mind, believable to the presence of consciousness for the mind that perceives and gives meaning to them? Why does the presence of consciousness for the mind, present at a point of view in the void, believe that it is an embodied person in the world?

That belief is the meaning that the presence of consciousness for the mind gives to the self-concerned thoughts it perceives presented on the viewing screen of the mind. But this is an absurd meaning based upon a paradox of self-reference. The presence of consciousness for the mind, which is the consciousness of the void, present at a point of view in the void, believes that it is a embodied person in the world. But that world, which includes the entire life of the embodied person in the world, arises from the true nature of what 'it is' the same way a dream arises from a dreamer. The entire world arises from the void as a spontaneous eruption of energy, and everything that appears to happen in that world is holographically animated upon those viewing screens, just like the animated frames of a movie.

The nature of the world is only like an animated movie that the presence of consciousness for the mind is observing, a movie that is animated upon a sequence of viewing screens. The person in the world is only the animated central character of that movie. But the concept of being an embodied person in the world is inherent in every mentally constructed self-concerned thought. Those thoughts are just like the narration of a movie by the embodied central character of that movie. Those thoughts only tell the story of the actions of that central character in the world. Those actions are inherently emotional in nature, as the body of the central character moves in emotional relationships relative to other things in the world. Those thoughts are only a symbolic representation of those actions, just like the narration of a movie by the central character is only a representation of the events in the movie. The narration of the movie does not animate the

movie. The narration of the movie is only a part of the animated nature of the movie. The nature of the world is just like an animated movie. All the behaviors of the person in the world are animated as the world is animated. The nature of all mentally constructed thoughts is only another aspect of that animation. Those thoughts are all animated as the body is animated. But those mentally constructed thoughts are perceived by the presence of consciousness for the mind, and they implicitly tell that presence of consciousness that “it is an embodied person in the world”, which is only the central character of the animation. Why are these thoughts believed by the presence of consciousness for the mind that perceives them?

Self-concerned thoughts are not only ‘heard’ in the mind, they are also ‘felt’ in the body. Every self-concerned thought is an emotional relationship that relates a body-based self-image to the image of something else in the world with some emotional body feeling. That emotional body feeling is an image of the complex way in which emotional energy coherently flows through the body to hold the body together while the behaviors of the body are enacted. The emotional body feeling inherently represents the way the body is coherently held together over a sequence of events. Emotional energy is the coherent flow of energy through the body that allows the form of the body to coherently replicate its form in the same phase of organization. The presence of consciousness for the mind perceives that flow of energy as it ‘feels’ the body feeling. The presence of consciousness ‘feels’ that emotional body feeling as it ‘hears’ the self-concerned thought that implicitly tells it that “it is an embodied person in the world that is emotionally related to other things in the world”. Those thoughts are believable because the emotional body feelings ‘feel’ real. The presence of consciousness really ‘feels’ like it is an embodied person in the world as it perceives the body feeling. The nature of perception is recognition, and the presence of consciousness for the mind recognizes itself in the emotional body feeling it perceives in the mind. The viewing screen of the mind holographically mirrors the nature of the void back to itself, and the void recognizes itself in that reflection, which is why the presence of consciousness for the mind ‘feels’ like it is an embodied person in the world.

But don’t take my word for it. Stop right now and ‘feel’ your own body feelings. You are the presence of consciousness that perceives those body feelings.

To understand why these feelings are believable, we have to understand the nature of emotions. A self-concerned thought is emotionally con-

structured in the mind as a body-based self-image, which is an image of the person in the world, is emotionally related to the image of something else in the world. The nature of that emotional relationship either arises through an emotional attachment of the body to something else in the world, or is self-defensive in nature and defends the survival of the body from the threats posed by other things in the world. The ego, the concept of being an embodied person in the world, is constructed from self-concerned thoughts, which all tell the story of the behavior of the person in the world as that person either attaches its body to other things in the world, or struggles to defend its body survival from the threats of other bodies. The nature of self-defensiveness is simply how bodies survive in the world. That body survival is inherently related to how emotional energy coherently flows through the body to hold the body together while all the behaviors of the body are enacted. The body only survives because the form of the body is self-replicated in the same coherent phase of organization over a sequence of events as energy flows. All the animated self-defensive behaviors of the body only arise because that is the way the body survives in an inherently dangerous world where bodies must eat each other in order to survive.

Bodies only survive because they eat each other. The only way bodies can grow, develop, and survive is because they eat other bodies. That is how potential energy is transferred between different bodies as energy flows in its universal gradient. The nature of biological symmetry breaking, which allows for body development, depends upon eating, which is the addition of potential energy to a body. Only that transfer of potential energy allows for body development, growth and survival. The transfer of potential energy from one body to another, called eating, is how coherent organization develops within a body, and is maintained within that body. The bodies that are most likely to survive, and that tend to survive the longest, are the fittest bodies, which are the bodies the transfer energy down its gradient most efficiently, with least action. The fittest bodies transfer energy down its universal gradient most efficiently. The actions of the fittest body are performed in the most energy efficient way possible, as that energy flows through the body and the form of the body is self-replicated. Survival of the fittest body is the nature of the world, and results in the natural cycles of death and rebirth of all bodies in the world, as emotional energy is recycled in new bodies.

Every body that is born eventually dies, and that emotional energy is recycled. That is how energy flows through the universe in its universal gradi-

ent, like the river that flows from the top of the mountain to the bottom of the ocean. As all energy flows in its universal gradient, that energy spontaneously organizes itself into coherently organized bound states, called bodies, but every body that forms and holds together as a bound state over a sequence of events must eventually fall apart, and new bodies are formed. The embodied life of a person in the world is only the way that flow of energy becomes coherently organized as it locally flows through a body, which holds the body together over a sequence of events while the behaviors of the body are enacted, until that flow of energy becomes disorganized, the body is no longer held together, falls apart, and dies. Every body that is spontaneously organized eventually becomes disorganized and dies. The body is only a bound state of energy that eventually becomes disorganized and falls apart. That is the nature of the flow of energy through the universe. The flow of energy through the universe is always directed toward the formation of coherently organized bound states, which we call bodies. The coherent flow of energy through a body that holds the body together while the complex behaviors of the body are enacted is called emotional expression. The nature of emotional self-defensiveness is how bodies act to defend their survival. Body survival is not possible without the emotional expression of self-defensiveness. The nature of that emotional expression is inherent in the coherent organization of the body.

Self-defensive behavior is how emotional energy coherently flows through the body so that the form of the body is self-replicated in the same coherent phase of organization over a sequence of events, and survives. All the complex behaviors of the body are enacted as emotional energy coherently flows through the body. The nature of emotional expression is inherently related to the actions of the body. The nature of desire is how the body moves toward those things that promote its survival, the nature of fear is how the body moves away from those things that threaten its survival, and the nature of anger is how the body moves against or attacks those things that threaten its survival. These self-defensive actions are necessary for body survival in a world where bodies must eat each other in order to survive. Without these self-defensive emotional expressions, bodies could not survive in the world. The nature of self-defensiveness is how bodies survive in the world.

The body only survives in the world because of the nature of self-defensiveness, which are the emotional expressions that defend body survival. With every expression of fear the body moves away from whatever threat-

ens body survival, with desire the body moves toward whatever promotes body survival, and with anger the body moves against whatever threatens body survival. All self-defensive emotional expressions arise from the way the body is coherently organized, which is the way emotional energy coherently flows through the body to hold the body together as the behaviors of the body are enacted. The body only survives in the world due to the coherent flow of emotional energy through the body, as the form of the body is coherently replicated over a sequence of events. Self-replication of form is inherently self-defensive in nature. If the flow of emotional energy through the body was not also coherently organized, the body could not coherently replicate its form over a sequence of events, but instead would become disorganized and fall apart, which is the nature of body death.

The nature of self-defensiveness is inherently related to the nature of emotional attachment, which is also necessary for body survival. The body of an infant expresses desires to be held and fed by its mother, which are behaviors that promote the infant's body survival. If desires to be held and fed are satisfied, the body of the infant expresses feelings of emotional attachment to the mother. If desires to be held and fed are frustrated, then the body of the infant expresses feelings of self-defensiveness. The infant cries, which is a fearful or angry emotional response of the body of the infant to the frustration of its desires. The infant does not control the behavior of its mother, but the mother responds to the infant's cry with her own emotional responses. If the infant is held and fed, then the infant's desires to be held and fed are satisfied, and the mother's desire to hold and feed the infant are also satisfied. We say that the mother and infant are emotionally attached to each other. The mother's response occurs in response to the infant's cry. The infant's cry occurs in response to the frustration of its desires. There only appears to be control over the behavior of the mother, as the infant's desires are satisfied, because of the nature of stimulus and response.

The nature of emotional attachment arises from the way the flow of emotional energy is coherently organized as energy flows through a body. In the case of either frustration or satisfaction of its desires, the body of the infant expresses emotional body feelings. Body feelings arise from the complex ways emotional energy coherently flows through that body to hold the body together while the behaviors of the body are enacted in patterns of stimulus and response. The coherent flow of energy through the body of the infant can come into alignment with the coherent flow of ener-

gy through the body of the mother, which is the case if the desires expressed by the body of the infant are satisfied by the behavior of the mother. If that flow of energy through the bodies of mother and infant comes into alignment, then body feelings of emotional attachment are expressed by those bodies as those desires are satisfied. If those desires are frustrated, then the flow of emotional energy through the bodies of infant and mother are not in alignment, and there is no attachment.

If the desire to be held and fed, expressed by the body of the infant, is satisfied by the behavior of the mother, then the flow of emotional energy through the body of the infant comes into alignment with the flow of emotional energy through the body of the mother, and body feelings of attachment to the mother are expressed by the body of the infant. Body feelings of connection to the mother arise as desires are satisfied. If those desires are frustrated by the behavior of the mother, then the flow of emotional energy through the body of the infant is not in alignment with the flow of emotional energy through the body of the mother, and body feelings of disconnection are expressed. Self-defensive emotional expressions arise with frustration of desires in an emotional attempt to control the behavior of the mother and force her to satisfy those desires. But the behavior of the infant does not really control the behavior of the mother and enforce the satisfaction of its desires. There is only an appearance of control because of the nature of stimulus and response, as the mother responds to the infant's cry.

With satisfaction of its desires, the coherent flow of emotional energy through the body of the infant comes into alignment with the flow of emotional energy through the body of the mother, and feelings of connection are expressed by the body. With frustration of its desires, the coherent flow of emotional energy is limited to the body of the infant, and is not in alignment with the flow of emotional energy through the body of the mother. That limitation and disconnection results in the expression of body feelings of separation and isolation. In either case, the body of the infant expresses emotional body feelings which are perceived in the mind of the infant. Either embodied feelings of connection and emotional attachment to the mother are perceived, or embodied feelings of disconnection, limitation to the body, and self-defensiveness are perceived. Those embodied feelings are perceivable images presented on the viewing screen of the infant's mind, which are perceived by the presence of consciousness that is present for the mind of the infant. All of those perceivable images are per-

ceived on the viewing screen of the infant's mind. With the perception of those body feelings, the presence of consciousness for the mind 'feels' like it is embodied. If feelings of emotional attachment to another body are perceived, then the presence of consciousness 'feels' like it is embodied within a body that is emotionally connected to another body. If feelings of self-defensiveness and limitation to the body are perceived, then the presence of consciousness 'feels' like it is embodied within an isolated body. It feels more like itself if there are feelings of connection, and less like itself if there are feelings of disconnection, since its true nature is the source of all things. The presence of consciousness for the mind recognizes itself more in those body feelings of connection, since it recognizes its connection to all things.

All emotional attachments are limited in nature, since they express the way the flow of emotional energy through a body comes into alignment with the flow of energy through something else in the world, which is only possible because the flow of energy through all bodies is coherently organized. But the ultimate emotional attachment is to the body itself, since that is the ultimate limit that the coherent organization of the body can become limited to. That limitation reflects the way energy coherently flows through a body. The coherent flow of emotional energy through a body can come into alignment with the flow of energy through other things in the world, but that coherent flow can at most be limited to the body itself. Without a coherently organized body for emotional energy to coherently flow through, there simply are no body feelings. All emotional attachments are ultimately limited to the body itself. The expression of self-defensiveness is only the limitation of the flow of emotional energy to the body itself. Feelings of attachment to something else in the world arise with all expressions of emotional attachment, but the ultimate feelings of attachment are to the body itself. Those feelings of attachment to the body, expressed by the body, are perceived by the presence of consciousness for the mind, which is why it 'feels' like it is embodied.

The body expresses feelings of connection or disconnection to other things in the world as the desires expressed by the body are satisfied or frustrated, just as the body expresses self-defensive feelings if body survival is threatened. All of these emotional expressions result in body feelings that are perceived by the presence of consciousness for the mind. The presence of consciousness 'feels' like it is embodied as it perceives these body feelings. Every feeling of connection to something in the world is an emotion-

al attachment, but the ultimate emotional attachment is to the body itself, since body feelings cannot be perceived without a body, and are ultimately limited to a body. The coherent flow of energy through the body can come into alignment with the flow of energy through anything else in the world, but if the body loses its coherent organization, and the body dies, then there are no more body feelings.

Only a coherently organized body can express body feelings, and all body feelings are ultimately limited to the body itself. Body death is only the loss of coherent organization that results in the disorganization of the body, but that loss is the end of all body feelings. The loss of coherent organization always 'feels' like something is dying, since that is how the body dies. In the same way, the loss of an emotional attachment also 'feels' like something is dying, since the end of an emotional attachment is the loss of the way the coherent flow of energy through the body comes into alignment with the flow of energy through another thing in the world. All body feelings inherently express emotional attachment to the body because they are ultimately limited to the body, which is the reason expressions of self-defensiveness, like fear and anger, arise if body survival is threatened. The presence of consciousness for the mind only 'feels' like it is embodied as it perceives those body feelings.

In the case of either body feelings of connection or disconnection, the presence of consciousness for the mind 'feels' like it is embodied as it perceives those emotional body feelings. All concepts of self and other arise from emotional body feelings of connection and disconnection, which only represent how the flow of emotional energy through the body comes into or goes out of alignment with the flow of energy through some other 'thing' in the world. Emotional body feelings are inherent in every mentally constructed self-concerned thought that emotionally relates a body-based self-image to the image of something else in the world. Self-concerned thoughts only tell the story of the actions of the embodied person in the world, just like the narration of a movie by the central character of that movie only tells the story of that animation. But self-concerned thoughts all implicitly tell the presence of consciousness for the mind that 'it is an embodied person in the world'.

Thoughts are not only 'heard' in the mind, they are also 'felt' in the body. The presence of consciousness for the mind 'feels' like it is embodied as it perceives the emotional body feelings inherent in every self-concerned

thought. Those thoughts are all false beliefs about its true nature that implicitly tell the presence of consciousness for the mind that 'it is an embodied person in the world'. Those thoughts are only believable because the presence of consciousness really 'feels' like it is embodied as it perceives those body feelings. That sense of feeling embodied is inherent in every limited expression of self-defensiveness and emotional attachment, as body feelings are expressed and perceived.

All concepts of self and other arise from embodied feelings, which only represent the flow of emotional energy through the body that holds the body together as the behaviors of the body are enacted. If that flow comes into alignment with the flow through something else, then there are feelings of connection. If that flow is limited to the body, there are feelings of disconnection and limitation. The mentally constructed concept of being an embodied person in the world, which is the ego, only arises because of the coherent flow of emotional energy through the body, whether that flow is in alignment with the flow through some other thing or not. The nature of the ego is the coherent flow of emotional energy through the body that holds the body together as the behaviors of the body are enacted. The ego, which is the concept of being an embodied person in the world, a person that is emotionally related to other things in the world, can only arise with the coherent organization of the body. As the body expresses feelings of emotional attachment and self-defensiveness, the presence of consciousness for the mind perceives those body feelings and 'feels' like it is embodied. All the self-concerned thoughts emotionally constructed in the mind implicitly tell the presence of consciousness for the mind that 'it is an embodied person in the world', but these thoughts are only false beliefs that it believes about itself.

The presence of consciousness for the mind, present at a point of view in the void, perceives the self-concerned thoughts animated upon the viewing screen of the mind and knows what they mean, but it gives those thoughts the mistaken meaning that 'it is an embodied person in the world'. It mistakenly identifies itself with the ego. This false self-identity arises with all limited expressions of self-defensiveness and emotional attachment, which are inherent in all self-concerned thoughts. The presence of consciousness for the mind believes something about its true nature that is untrue, as it falsely identifies itself with the limited identity of an ego. The presence of consciousness for the mind mistakenly believes that 'it is the ego', which is only believable because that presence of consciousness really 'feels' like it is embodied as it perceives the body feelings that are emo-

tionally expressed by the body with every limited expression of emotional attachment and self-defensiveness.

These beliefs are always false in the sense of a meaningless paradox of self-reference. They implicitly identify what 'I am' with the person in the world that the true nature of what 'I am' perceives. Self-concerned thoughts constructed in the mind are like the self-referential narration of a movie by the central character of that movie. The presence of consciousness for the mind is always outside the mind that it perceives, just as the audience that observes a movie is always outside that movie. It only falsely identifies itself with the central character of that animation. The inherent nature of that falseness arises as the true nature of what 'I am' mistakenly identifies itself with the central character of an animation that it is observing from its seat in the audience. The animator is the void, and the seat in the audience is a point of view in the void. The animation plays upon viewing screens that spontaneously arise from the void. The 'one' that is always present in the audience for anything presented on that stage is the void. The limited false self-identity of an ego only arises with the central character of that animation.

But it is not a completely false identity, since the audience is also the animator of the movie. The movie arises from the animator the same way a dream arises from the dreamer. The dream always belongs to the dreamer. A paradox of self-reference only arises if the dreamer mistakenly identifies itself with the particular central character it observes within its dream from a particular point of view, which is the limited nature of the ego. If the dreamer identifies itself with everything that it observes within its dream, then there is no paradox of self-reference. The ultimate identity of the dreamer is the void. That identity is only realized if the dreamer identifies itself with nothing that it observes in the world.

Everything that we have discovered so far is based upon logic and science. We have taken the standard science of our day and followed its implications to this logical conclusion. This is the natural interpretation of the holographic principle. But are any other interpretations logically possible? Is it even a remote possibility that consciousness somehow arises from the nervous activity of a brain?

Neuroscience tells us that the nervous activity of a brain is coherently organized, like the coherent organization of information in a hologram. No

matter how the brain is conceptualized, all the activity of the brain reduces down to coherently organized energy and information, as numerous experiments demonstrate. The electrical activity of neurons in the brain is coherently organized, as recordings of neuronal activity demonstrate. The flow of electromagnetic energy through the brain is coherently organized, demonstrated on EEG and MEG. The nature of emotional responses measured in the brain is coherently organized. The nervous activity of the brain that correlates with thoughts is coherently organized, which is experimentally demonstrated on functional MRI and PET scans. The perceivable information content of the mind, like memory content and information content for ambiguous images and words, is also coherently organized, and correlates with coherent brain activity. All of that information content and energetic flow is perceivable. All neuroscience can ever do is describe the coherent organization of perceivable information and the coherent patterns of the perceivable flow of energy within the brain and the mind. The brain and the mind are composed of perceivable energy and information, just like everything else that is perceivable.

What is the difference between the brain and the mind? The only real difference is your point of view. Your mind is the viewing screen that you are observing from your point of view. The mind is a coherently organized bound state of information that arises within the bound state we call a body. Everything in the universe is a bound state of information, including the universe itself. All those distinct bound states are defined on viewing screens of quantized space-time, including all the bound states that we call minds. As the presence of consciousness for any mind perceives that particular viewing screen from its own point of view, it perceives information in that mind. If information that arises from another mind is perceived, those two minds appear to communicate with each other, which is only possible because two minds can share information through the phenomena of quantum entanglement. Each mind is defined on its own viewing screen for every event, but those viewing screens can interact with each other because the fundamental spin variables tend to align together. Every viewing screen of quantized space-time defines a distinct mental event. Every distinct viewing screen is perceived by the presence of consciousness that is present at its own point of view, but those viewing screens can share information because of quantum entanglement, which is only possible because the spin variables interact with each other and tend to align together.

The mind arises from the highly complex structures of the brain, which are organ systems of the body. The mind is a complex coherently organized bound state of information that involves many of those body organ systems. When we perceive the structures of a brain, we perceive the forms of information that are presented on the viewing screen of our own mind, but we always perceive that information from our own point of view. The brain appears as a three dimensional structure in the world, but that is only a holographic appearance. Everything that appears to happen in the apparent three dimensional world that we all appear to live in is defined on a two dimensional bounding surface of quantized space-time that acts as a holographic viewing screen and projects images to a point of view. Every distinct 'thing' perceived in that world is holographically defined on the viewing screen. The viewing screen we perceive is the viewing screen of our own mind.

Is the mind really animated over a sequence of perceivable mental events like the frames of a movie projected on a viewing screen? Does that viewing screen project images to a point of view where those images are perceived? What is the evidence for this kind of animation? The best evidence comes from experiments with memory retention. If information is rapidly projected upon a screen in front of an experimental subject, that information is only encoded in the mind of that subject as memory if the rate with which the information is projected is less than about ten times per second. A faster rate results in information that is not encoded as memory and cannot be consciously recalled. The usual explanation for this phenomenon is that the mind is constructed as a sequence of conscious mental events, and each event has a duration of at least about one-tenth of a second. Information that is flashed too rapidly cannot be encoded. Each conscious mental event is a distinct entity with its own perceivable properties like memory.

This kind of experiment is not necessary to demonstrate the distinct nature of each perceivable mental event. It is only necessary to stare at an ambiguous image and see what happens. An ambiguous image can be visualized in two distinct ways. The image is always visualized one way or the other, but never as a composite of the two distinct images. Visualization of an ambiguous image is a holistic kind of phenomena. The image is visualized one way or the other, never as something in between. It demonstrates the holistic nature of visualization. But it also demonstrates the nature of animation. The image can switch back and forth from one

image to the other, but never at a rate faster than about ten times per second. Ambiguous words demonstrate the same kind of phenomena. The meaning of an ambiguous word depends upon the context of the sentence that it is constructed within. What the ambiguous word means changes as the context changes, but the meaning that it is given for any distinct mental event is always holistic in nature. The meaning that an ambiguous word is given is distinct and holistic in nature, but can change from one distinct mental event to another and only depends upon the context holistically defined within that mental event.

What is the evidence the mind is holographic in nature? What is the evidence for the global coherent organization of information in the mind? What is the evidence the mind is a bound state of information that involves large parts of the brain? The best evidence comes from lesion experiments. If there is a localized lesion in the brain, some function of the mind like memory is degraded. The function is degraded, but not completely lost. A specific memory can be degraded with a lesion just about any place in the brain, but not totally lost with any particular localized lesion. How is this possible? Memory is not localized to any particular region of the brain. Lesions in many regions of the brain degrade memory, but the function is not completely lost. The more lesions there are, the more memory is degraded, but no single localized lesion can eliminate a specific memory. But this is exactly like a hologram. The image projected from a hologram is degraded if the hologram is broken into pieces, but each piece of the hologram still projects the same image. The reason for this phenomenon is the image is not localized to any particular region of the hologram. The information for the image is coherently encoded throughout the entire hologram. Holograms encode information for images coherently. If the hologram is broken into pieces, information is reduced in each piece. Each piece encodes the entire image, but the image is degraded.

The nature of memory is very complex, but is usually categorized as short-term, long-term, and functional memory. The nature of short-term and long-term memory involve the memory of events ordered in a temporal sequence, while functional memory involves memory of certain learned behaviors. Those learned behaviors are behaviors that can be enacted in the world by a body, like memory for how to cook a meal or play a musical instrument. Language is also a behavior that is enacted in the world, and memory for language is a kind of functional memory. Any kind of learned behavior enacted in the world is a function of the body, and depends upon

access to functional memory. The motor systems of the body must have access to that functional memory in order to enact the behavior.

There is very good evidence that all functional memory is coherently organized in the mind. That information is not stored in any particular location in the brain, but is coherently encoded throughout large parts of the brain. That global encoding of information in the brain means the mind behaves like a coherently organized bound state of information, just like a hologram that encodes information.

How does a hologram encode information? On the surface of the hologram is an interference pattern. That pattern is created as coherent light emitted from a laser interferes with itself because of the complex pattern of phase relationships that occur on the surface of the film. When those coherent light waves are in phase, they reinforce each other, and when they are out of phase, they cancel out. The distance scale of the interference pattern is the wavelength of the light waves, which is about a micron. That means information can be digitally encoded with a density of about one bit of information per 10^{-8} cm². A hologram with a surface area of about 100 cm² stores about 10^{10} bits of information. When we want to retrieve that information we use a laser to display those holographic images.

The mind is different than a conventional hologram because the mind is a dynamical system that is dynamically reorganized over a sequence of events. Even the holographic film is a dynamical system, but once the interference pattern is created on the holographic film, its pretty much 'frozen' into place, much like a frozen piece of ice. The mind is a much more 'fluid' dynamical system that is reorganized over a sequence of events. But the basic principle that information is holographically encoded in the mind as functional memory is basically the same.

The nature of that memory can change over time as the mind is dynamically reorganized, which is why the mind can learn from experience. The dynamical evolution of the mind occurs as emotional energy coherently flows through the mind. The easiest way to understand how the mind can learn from experience is with the concept of attractors and basins of attraction. The dynamical 'landscape' of the mind is organized into basins of attraction, much like a mountain range. As emotional energy flows through the mind, that energy flows through those basins of attraction, just like a river that flows through a mountain range. The way any river

flows through the mountain range is determined by that basin of drainage. In a similar way, the dynamical landscape of the mind is divided up into different basins of attraction.

The nature of an attractor is just like a river that flows in a particular basin of drainage. The way emotional energy flows through the mind is determined by the nature of the attractor that drains a particular basin of attraction. The behavior that arises from the way emotional energy flows is determined by the nature of that attractor. If energy flows in a different basin of attraction, it flows toward a different attractor, and that results in a different kind of behavior. The net result is that behavior occurs in a pattern of stimulus and response. The initial conditions of any dynamical system, which is the nature of the stimulus, determines the nature of the response of that system. A stimulus determines which of the basins of attraction the flow of energy through the mind will flow within. The behavior that results from that stimulus is determined by which attractor the energy flows toward. That behavior is the response. The mind can learn from experience because the nature of the basins of attraction and attractors are dynamically reorganized with each mental event. The nature of functional memory is the nature of those basins of attraction and the attractors that emotional energy flows toward within the mind.

The nature of short-term and long-term memory are different than functional memory in that these are episodic memories that recall the nature of events ordered over a temporal sequence of events. Short-term memory can only recall those events that occurred up to about 30 seconds ago, and is also limited in the amount of information that can be recalled, typically no more than about seven distinct pieces of information. Long-term memory is different in that there is not the same kind of limit on the amount of information recalled or the length of time involved. But long-term memory is dependent on an anatomical aspect of the brain called the hippocampus, which seems to act as a retrieval device. Long-term memory seems to be holographically encoded throughout the brain in much the same way as functional memory, but to retrieve that information in a temporal sequence of events requires the function of a hippocampus. Without the function of a hippocampus, all long-term memories are lost. New long-term memories are not encoded, and old ones cannot be retrieved. The function of a hippocampus is to encode and retrieve those long-term episodic memories, much like the laser that is necessary to display holographic images that are coherently encoded on a hologram. The function

of the hippocampus is also involved in dreaming sleep. The episodic memories recalled with long-term memory are not unlike the forms of imagination that arise in dreams during dreaming sleep, or with daydreams.

Short-term memory of events does not require a retrieval device, but is more like the nature of a projection that occurs if you know where something is located and how it is moving. If you see a car rapidly approaching your location, you can make a projection about how long it will take before that car will arrive at your location. You are able to project forwards in time and anticipate when that car will arrive at your location. In the same way, you can make a projection backwards in time and estimate where the car came from. The ability to make projections forward and backward in time is the nature of short-term episodic memory. If you know the form of something and how it is moving right now, then you can project the form of that thing to its form in the recent past and its form in the near future.

How can the holographic nature of the mind be explained? The explanation is the holographic principle of quantum gravity. The mind is a large bound state of information defined on its own viewing screen and perceived from a particular point of view. The mind is a surface of quantized space-time that is quantized out of empty space, and that projects its perceivable holographic images to a focal point of perception in empty space. Different minds defined on different viewing screens share information with each other because of quantum entanglement, but the degree to which they share information depends on the degree to which those viewing screens interact with each other. The degree to which different viewing screens are connected only reflects the strength of those interactions.

Those connections reflect the degree to which spin variables defined on different viewing screens align together. Perceivers of different viewing screens are aware of similar forms of information only because of those interactions. The viewing screens that do not interact with each other very much may not share very much information, and they may give a very different view of events. Different minds only share information with each other because they interact with each other. The nature of those interactions is how information is aligned together.

The mind is one of the coherently organized distinct organ systems of the body. An image of the body can appear on the viewing screen of the mind because all those organ systems interact and share information with each

other. The mind is animated over an ordered sequence of observable mental events that occur in the universally ordered flow of information. Each event is defined on its own viewing screen. The mind is a coherently organized bound state of information animated over a sequence of mental events in the universally ordered flow of information. The mind is coherently replicated in the same phase of organization as energy coherently flows through the mind over a sequence of events, just as the form of the body is coherently replicated over an ordered sequence of events.

The mind is a behavior of the body that arises as emotional energy coherently flows through the body over an ordered sequence of events. That coherent flow of emotional energy is the only reason why the body holds together while the behaviors of the body are enacted. Quantum entanglement means that the mind is connected to the body, just as the mind is connected to other distinct bound states of information in the world, like other minds. Spin alignment is the nature by which any viewing screen of quantized space-time becomes coherently organized, but spin alignment is also the nature by which different viewing screens are connected to each other and share information with each other.

The nature of coherent organization is that bound states arise within larger bound states that arise within even larger bound states. The fundamental level at which all information is defined is the Planck area, with one bit of information encoded as some kind of fundamental spin variable per Planck area. Those quantized bits of information coherently bind together into the nature of what we call elementary particles, which bind together into atoms and molecules, which bind together into cells, which bind together into body organ systems, which bind together into the bound states we call bodies, which bind together into societies, which are bound together on the bound states of planets, which are bound to stars, which bind into galaxies, until the largest possible bound state of all arises, which is the universe. The flow of energy through all coherently organized bound states is bound together. All of that energy is defined on surfaces of quantized space-time in the form of fundamental spin variables. But because the total energy of the universe is zero, as all forms of positive energy like mass and kinetic energy exactly cancel out the negative potential energy of gravitational attraction, the universe is just on the cusp of being unbound.

Every bound state that forms in the universe is connected to very other bound state that forms because of the fundamental nature of spin align-

ment that arises on the surfaces of quantized space-time that act as holographic viewing screens. Spin alignment is the nature of coherent organization of information, and is the nature of quantum entanglement, and explains why everything is connected.

How are disconnection syndromes like blindsight possible? The mind is one of the coherently organized distinct organ systems of the body. Each distinct organ system of the body is a bound state of information defined on its own viewing screen and perceived from a particular point of view. The mind is the result of the highly complex nature of the organization of information in the brain. Information is globally organized throughout the brain in a coherent manner because the brain is a large bound state of information. The mind can share information with other organ systems of the body because of quantum entanglement. An example is the phenomenon of 'focusing' that allows the perceiver of the mind to be aware of body information not usually shared, but the opposite case is also possible.

The mind can become disconnected from other body systems that it normally shares information with. The phenomenon of blindsight is an example, and is due to a lesion in the brain that disconnects the visual system from other parts of the brain. With blindsight the visual system is disconnected from global organization of information in the mind. A person with blindsight denies that they can see anything at all, but when asked to reach out and grab an object they have no difficulty. The visual system is disconnected from the system of global brain structures that constitutes the mind, but not from other systems such as motor systems that allow behaviors to be enacted. Those motor systems can make use of the visual information conveyed to them by the visual system even though that visual information has been disconnected from the mind. The perceiver of the viewing screen of the mind does not know about the visual information conveyed to the motor systems, but the perceiver of a motor system viewing screen does. Every viewing screen that arises in the universe is observed by its own observer.

Alien hand syndrome is another example of disconnection due to a localized lesion in the brain. The alien hand performs actions in an apparently intentional way, but the perceiver of the mind does not 'feel' like they have any conscious control over the behavior of the alien hand. The actions of the alien hand typically oppose the actions of 'consciously willed' behavior, and may even act in a self-destructive way, such as an attempt to grab the

person's neck and strangle them to death. The information for the actions of the motor system that enacts the behavior of the alien hand is disconnected from the viewing screen of the mind, and in that sense the perceiver of the mind that perceives the information content of the mind does not 'feel' like they have any control over those actions. In a sense, the alien hand has a 'mind' of its own.

Split brain experiments are another example of disconnection that demonstrates how each hemisphere of the brain can behave like an independent mind if the two hemispheres are disconnected. The mind of one hemisphere does not contain the same forms of information that the mind of the other hemisphere contains. Each mind has its own perceiver that does not know about the information contained in the other disconnected mind. For example, language function may be limited to only one hemisphere, and to that particular mind. The ability of two hemispheres to coherently contain information depends on connections between them, and is lost if those connections are severed. Dreams are another example of disconnection. With dreaming sleep, the coherently organized system of brain structures called the mind becomes disconnected from all sensory inputs from the environment. The mind is free to construct forms of information without the constraints of those sensory inputs. The bizarreness of dreams is due to that disconnection from the environment. The nature of hallucinations is also due to some kind of disconnection from the environment, like in a sensory deprivation chamber. Experimental evidence for global coherent organization of brain activity that results in the mind comes from the study of the thalamocortical system. The mind arises from that global brain activity because those brain structures form a large coherently organized bound state of information. In dreaming sleep, all sensory inputs from the environment relayed through the brainstem are disconnected from the thalamocortical system.

What is deep dreamless sleep? In deep sleep, the global coherent organization of the thalamocortical system is lost, and in effect, the mind dies. The coherently organized system of brain structures called the mind loses coherent organization. The mind cannot coherently replicate its form, or hold together, and falls apart. The viewing screen of the mind dissolves away, like a phase transition that melts ice back into liquid water. The mind is nothing more than forms of information constructed on a viewing screen. The consciousness that is present for the mind also has a sense of falling, which we refer to as the sense of 'falling asleep'. As the viewing

screen of the mind dissolves away, the presence of consciousness that perceives the mind, present at a point of view, 'dissolves' back into the void.

The mind is a behavior of the body that arises as emotional energy coherently flows through the body over an ordered sequence of events. All of that energy flows in its universal gradient from the big bang event to the black hole. All bound states of energy spontaneously emerge in the universal flow of energy. The mind forms in the universal flow of energy like any other bound state of the universe. The mind is a behavior of the body that is animated as the body is animated. The nature of the animator is not the mind nor its thoughts. All thoughts constructed in the mind are only like the narration of a movie by the central character of that movie. The narration of the movie is only another aspect of the animation. The mind and its thoughts do not control how the movie is animated, but only arise as a part of the animation. The nature of the animator is the universal flow of energy. There is only an illusion that the mind and its thoughts control how the movie is animated.

The Libet experiments demonstrate the absurdity of the ideas that consciousness somehow controls what appears to happen in the world, and that consciousness somehow arises from the nervous activity of a brain. An experimental subject is asked to consciously perform a behavior at a time of their choosing. A recording of electrical activity from the brain of the subject clearly indicates that there is an organized pattern of electrical activity about one second before the apparently volitional behavior is performed. The brain is active about one second before the conscious behavior is enacted. Another experiment shows that the conscious perception of a sensory stimulus actually follows that stimulus by about one-half second. It takes about one-half second of organized brain activity before any sensory stimulus is consciously perceived. Taken together, these experiments indicate that it takes about half a second for a subject to become aware of an organized sensory event, and another second after that before an apparently 'consciously willed' organized behavior can be enacted. With a one and one-half second delay between conscious perception of a stimulus and an apparently volitional response, is it in any way possible that consciousness actually does something? Imagine how a tennis game is played. Is it even remotely possible that the tennis player requires one-half second to become consciously aware of how the tennis ball is hit by the opponent, and another second after that to consciously decide how to hit the ball back? Decisions are made about how to play the tennis game every split

second. The tennis player will report conscious awareness of how the tennis game is played on a moment by moment basis.

What is the explanation? The explanation is the holographic principle and its natural interpretation. The nature of the perceiving subject does not exist within the perceivable physical world it perceives. It is exactly the other way around. The perceivable physical world is defined upon bounding surfaces of quantized space-time that act as viewing screens, and holographically define an apparent three dimensional world. Those viewings screens are embedded within the void of empty space, which is the true nature of consciousness. The nature of the perceiving subject does not exist within the perceivable world. The perceivable world only exists within the nature of consciousness, which is the void. Each fundamental element of quantized space-time encodes a quantized bit of information. All those quantized bits of information and the laws that they obey spontaneously arise from the void. The void is the source of everything in that apparent world. The void acts from the same necessity from which it exists as it quantizes itself into surfaces of quantized space-time and the symmetry of empty space is broken. Each viewing screen is perceived by the presence of consciousness present at a point of view in the void. The perceiver only knows about whatever forms of information are defined upon the particular viewing screen it perceives from its particular point of view for that particular event.

Perception is recognition. The perceiver recognizes itself in the actions animated upon the viewing screen because those actions reflect the true nature of its existence through all the manifest phenomena of symmetry breaking. The perceiver 'feels' like those actions are its actions as it perceives the coherently organized flow of energy that animates those actions. Those actions are inherently emotional in nature and limited to the form of a body that enacts those behaviors. The actions animated on the viewing screen are always organized around the limited form of a body. The perceiver 'feels' like it controls those actions as it perceives that embodied flow of energy, which is the nature of the emotional body feelings that make the perceiver 'feel' like it is embodied.

The coherent organization of perceivable information and the perceivable flow of energy localized to a particular viewing screen allow the perceiver of that viewing screen to make projections that it perceives as the memory of past events and anticipation of future events. Those projections are

inherently emotional in nature since the form of things this event is only projected to the form of things another event if that flow of energy is perceived. An illusion of the continuity of events, and an illusion of control over those actions, arises with those projections. The perceiver 'feels' like those actions are its actions as it perceives that embodied flow of energy. The perceiver does not really control what appears to happen on the viewing screen it perceives. It only gives meaning to those actions. But those actions all belong to the perceiver since they spontaneously arise from the true nature of the perceiver, the same way a dream always belongs to the dreamer.

The perceiver gives meaning to embodied actions. All embodied actions are inherently emotional in nature. Emotional simply means embodied motion. Embodied emotional expressions occur in a pattern of stimulus and response. The underlying nature of stimulus and response is best understood with the concept of phase space. Phase space describes all the dynamical degrees of freedom of the system of interest. In terms of quantum gravity, those dynamical degrees of freedom are spin variables defined on a viewing screen of quantized space-time. A body is a bound state of those dynamical degrees of freedom. The nature of symmetry breaking means those dynamical degrees of freedom are coherently organized into coherent phases of organization. The simplest explanation for stimulus and response is the classical concept of attractors and basins of attraction. These classical concepts have a quantum correspondence in Hilbert space. The nature of responses has to do with the nature of attractors that the system is able to dynamically flow toward. Each attractor drains a basin of attraction. The nature of a stimulus has to do with the initial conditions of the system. For any given set of initial conditions the system will dynamically flow toward a particular attractor. The nature of the response reflects the nature of the attractor, and the nature of the stimulus that leads to that response reflects the nature of the basin of attraction. Systems are able to learn from experience and modify the nature of their emotional responses and how they respond to different stimuli because the coherent organization of both the attractors and the basins of attraction can evolve over time as the system is dynamically reorganized.

All behavior occurs in a pattern of stimulus and response, and all behavior is conditioned. Any coherently organized dynamical system will respond to a given stimulus in a coherent way. All the information for that localized system is defined on a viewing screen of quantized space-time. The nature

of the flow of energy is to temporally relate viewing screens defined in an ordered sequence of events as energy flows from more ordered to less ordered states. A stimulus sets the initial conditions of the dynamically organized system. Those conditions fall in a basin of attraction of dynamical organization, and the system responds as it flows toward that particular attractor. The nature of both the attractors and basins of attraction are dynamically organized. As energy flows in its universally ordered gradient, information is coherently organized within localized systems because of the tendency for information to form bound states as energy flows. All localized system behavior spontaneously emerges as energy flows in its universally ordered gradient. All system behavior is connected to all other system behavior because all systems interact with each other. Everything that appears to happen in the world is information defined on viewing screens and is related to everything else that appears to happen. Everything that appears to happen in the world is a natural event that spontaneously emerges in the universal flow of all things.

If all coherently organized system behavior spontaneously emerges as energy flows in its universally ordered gradient, then what exactly does consciousness do? Consciousness does nothing. Consciousness is nothing. Consciousness is not defined on any viewing screen. The true nature of consciousness is the void. The void is not composed of information. It is exactly the other way around. The void is the source of all the information in the world. The nature of consciousness, which is the void, is always outside its holographically defined objects, which are defined upon viewing screens. Every presence of consciousness, present at a point of view in the void, is only an observer of perceivable events. It is not a doer. Nobody controls anything. Does the river control how the flow of water falls down the mountainside as water flows back to the ocean? Does the mind control how the emotional flow of energy through the body flows in its gradient? Everything spontaneously emerges in the universal flow of all things. Everything is the way it is because the entire universe is the way it is. Everything is connected. All the dynamical bits of information in the universe obey computational rules that determine a universal quantum state. Every viewing screen is a state of the universe and an observer is present at a point of view in the void for every possible state of the universe. The mind is constructed on viewing screens like any other bound state of information.

The mind does not control the stream of thoughts that arise within the mind. All thoughts occur in a pattern of stimulus and response. The train of thoughts that arise in the mind is only a result of the way emotional energy flows through the body, as one action leads to another reaction. The mind does not control the flow of energy through the body. The mind only arises because of that emotional flow of energy through the body. All energy obeys the laws of the universe, and flows in its universal gradient. Body-based self-concepts spontaneously emerge in the mind as energy flows in its universal gradient, just like anything else that spontaneously emerges in the universe. But those self-concepts are perceived by the perceiver of the mind. There is only identity confusion because the presence of consciousness for the mind believes something about itself that is untrue. It mistakenly identifies itself with the perceivable form of a body-based self-image it perceives.

That mistaken self-identification occurs because the presence of consciousness for the mind perceives the emotional body feelings that represent the emotional responses expressed in the body. As those emotional body feelings are perceived, the presence of consciousness for the mind really 'feels' like it is embodied, and so it believes whatever the self-concerned thoughts that are emotionally constructed in the mind tell it about itself. It believes that it is an embodied person in the world that is emotionally related to other things in the world. All self-concerned thoughts spontaneously emerge within the mind as emotional energy flows through the body, which allows the behaviors of the body to be enacted while the form of the body is coherently held together. The same emotional flow of energy that allows for body behavior also allows thoughts to become emotionally constructed in the mind. The presence of consciousness for the mind does not control the stream of thoughts that spontaneously arise within the mind in that flow of energy. It only gives meaning to the thoughts it perceives within the mind.

But it gives these thoughts a mistaken meaning. It identifies itself with the ego. It believes that it is embodied within the body of the person in the world, and that it controls the behavior of that person, because the body feelings 'feel' real. It really 'feels' like it is embodied, and that the actions and thoughts of the person in the world are its actions and thoughts, which is its self-identification with a mentally constructed body-based self-concept. That self-identification arises with a stream of thoughts emotionally constructed in the mind that relate a body-based self-image to the image

of something else in the world with some emotional body feeling. But the true nature of its identity does not belong to the mind or to the body. It belongs to the void, which is the source of all existence. The void is the source of the consciousness that is present for the mind. The emotional expressions of the body and mind are all expressions of the creativity of the source of existence, which is the void. The consciousness of the void is always present, but it is always the same presence for any mind that it perceives.

The presence of consciousness for the mind knows nothing about its true nature except that it exists. That presence of consciousness is only confused about its true nature because it mistakenly identifies itself with the concept of being an embodied person in the world. That mistaken self-concept emotionally arises in the mind it perceives, and that mistaken self-identification is inherently emotional in nature. The presence of consciousness for the mind 'feels' like it is embodied as it perceives the emotional body feelings that are expressed in that mind.

The localized coherent flow of energy through the body that holds the form of the body together while the behaviors of the body are enacted is what is meant by an embodied emotional response. Emotional expression means embodied motion as one body moves in some complex way relative to another body. The nature of that complex motion involves preferred directions of motion that arise from the nature of symmetry breaking. Those preferred directions of motion include global embodied motion and the movement of all the stuff inside the body as that stuff holds together as a bound state. In its simplest nature, the expression of emotion reflects the fact that it is a body eat body world. A body expresses desire as it moves toward another body to eat, and expresses fear as it moves away from another body and expresses the desire not to be eaten. The expression of anger also expresses the desire not to be eaten as a body attacks another potentially threatening body. All of these global embodied movements are only possible because the body is a coherently organized bound state of information.

All these emotional expressions of the body are organized upon viewing screens of quantized space-time, just like any other bound state of information in the universe. The body is animated upon a sequence of viewing screens, which is a sequence of observable events ordered in the universal flow of information. There is an illusion of the continuity of the form of the body over that ordered sequence of events because of the coherent flow of

energy through the body that allows the form of the body to replicate its form in the same coherent phase of organization. With every observable event, both the form of the body and the flow of energy through the body are perceivable.

Why are both the form of the body and the flow of energy through the body observable with each event? Both the form of the body and the flow of energy through the body are observables of the quantum state. This situation is exactly analogous to the position and velocity of a point particle. The quantum state that describes the motion of a point particle is a state of potentiality. All motion is only potential motion until measured. With any observable event, both the position x and momentum p of the particle can be measured. But the uncertainty principle applies and specifies that the more that is known about position the less is known about momentum as $\Delta x \Delta p \geq h/2\pi$, which arises from the probability amplitude that behaves like $z = \exp(2\pi i p x / h)$. The observable form of the body is analogous to particle position, and the observable flow of energy is analogous to momentum.

In the case of a point particle, if something is known right now at time t about both the particle position $x(t)$ and the particle velocity $v(t)$, then by simple mathematical expansion something is also known about particle position a short time Δt before as $x(t - \Delta t) = x(t) - v(t)\Delta t$, and something is known about particle position a short time Δt later as $x(t + \Delta t) = x(t) + v(t)\Delta t$. These statements are accurate in the limit of the differential. But this tells us something fundamental about the nature of memory and anticipation of events. If the observer of this observational event is able to observe something about the observable position and the observable velocity of a point particle now, then that information allows for projections about the position of the point particle in the recent past and its position in the near future.

What can this have to do with perceivable emotional expression? If the observer of this observable event is able to observe something about the observable form of the body and the observable flow of energy through the body now, then that information allows for projections about the form of the body in the recent past and the form of the body in the near future. Both the form of the body and the energetic flow of information through the body are observables of the quantum state. If something is known about both form and energetic flow this event, then that tells the observer something about the form of recent events and the form of future events.

The nature of perceivable emotional expression is the perceivable flow of energy localized within the body. That perceivable emotional expression allows the observer to look into the past and look into the future as the form of the body is projected to past or future events. Perceivable emotional expression allows for perceivable memory of events and perceivable anticipation of events.

All memory and anticipation of events is a projection made from this event. The observer of this event observes both the perceivable forms and the perceivable energetic flow of things. To know where something is now and how it is moving now allows for a projection to be made to past and future events. The observer of each observable event knows about the nature of perceivable memory and anticipation of events. It is the observer that makes the projection. The illusion of continuity is established with every observable event. The observer perceives the form and energetic flow of things each event and makes a projection to past and future events to establish an illusion of the continuity of events.

How does the observer establish an illusion of continuity each event? There is an illusion of continuity of form because of the nature of symmetry breaking. The form of the body replicates its form in the same coherent phase of organization over an ordered sequence of events because localized energetic flow is also coherently organized. Coherent organization is the only reason the form holds together as a bound state. The observer of each event observes both the form coherently organized this event and the coherent pattern of energetic flow this event and makes a projection to past and future events. With those projections, there is the memory of past forms and the anticipation of future forms. Due to symmetry breaking, the forms of past events and future events are very similar to the forms perceived this event. With this event the forms that were anticipated in past events can be remembered. The remembered forms that were anticipated in past events are very similar to the actual forms that are perceived this event.

The illusion of continuity of form is established each event because coherently organized form replicates its form in the same coherent phase of organization, and there is the perceivable memory this event of the past anticipation of form. The illusion of continuity of form is a kind of fortune telling. The forms that actually show up in future events are very similar to the forms that were anticipated in past events. As long as the amount of

uncertainty is small, the predictions of future events that are anticipated with past events are usually quite good predictions that are actually manifested in future events with some reliable degree of predictability. That reliable degree of predictability creates an illusion of the continuity of events as the recalled anticipated forms predicted in past events are found to be quite similar to the actual forms that are manifested in future events.

The illusion of continuity of form is established each event because both the form of the body and the localized flow of energy through the body are observables of each event. Those observables allow for the projection of form to past and future events. The observer of each observable event establishes an illusion of the continuity of the form of the body each event because of perceivable memory and anticipation of events. But in actual fact, the form of the body is uniquely defined each observable event as a viewing screen of quantized space-time is constructed out of empty space each event. The form of the body is dynamically reorganized every event. There is only an illusion of continuity because the form of the body replicates its form in the same coherent phase of organization. The form of the body only replicates its form because the localized flow of energy through the body is also coherently organized. Those coherent patterns of the localized energetic flow of information through the body are perceived as the nature of emotional expression. An embodied emotional response, as the body moves relative to another body, is the nature of embodied motion that arises as a result of the localized flow of energy through the body. Emotional responses are perceivable because the localized flow of energy through the body is perceivable.

Each surface of quantized space-time is a bound state of information organized around a distinct body in the world, and defines an event. With every observable event a distinct observable body is observed. That particular body is observed from its own point of view, which is the perspective of that particular viewing screen. The form of the body is observed through the organs of sensory perception of that body, which relay information to the viewing screen of the mind much like a video camera relays information to a viewing screen. That relay of information allows for the observation of information internal to the body and external to the body. The internal perception allows for an internal body image to be observed, and also for the coherent flow of energy through the body to be observed, which is the nature of perceivable emotional expression. Organs of sensory perception also allow for the external perception of sensory information,

which includes the perception of the external form of the body and the form of other bodies. All of those perceptions are presented on the viewing screen of the mind.

Every emotional state, or emotional experience, is a state of mind. Every emotional state of the mind is defined on the viewing screen of the mind by the way emotional energy coherently flows through the mind. Every possible viewing screen is a possible state of the universe, and an observer is present for every possible state of the universe. Those emotional states of mind are only meaningful because of the meaning that is given to them by the observer that perceives them. Emotional states of mind are only meaningful because the observer recognizes itself in whatever it perceives on the viewing screen that arises from itself in much the same way any dream arises from a dreamer.

The life of the person in the world is only an animation of events perceived on an ordered sequence of viewing screens. All external sensory perceptions, internal emotional body feelings, thoughts, memories, and forms of imagination, are only images presented on the viewing screen of the mind each mental event. Sensory perceptions are the perception of that coherently organized flow of energy. From the point of view of any particular event, only a particular path of the life of the person in the world is perceived, but the same presence of consciousness is present for all possible paths of the person in the world. The consciousness present for any particular viewing screen only identifies itself with the life of a particular person in the world because that is the only path it can see that arises from the way information is coherently organized upon that particular viewing screen. The same consciousness is present for all bodies, but it does not know that it is the same presence of consciousness because there is a lapse in memory and a limitation in experience. There is no memory for the experiences of the other bodies. There is only awareness of the embodied experiences of the particular body that the observer is present for. For any particular event, the observer can only remember and anticipate the life of a particular person in the world, and that memory is only for a particular path of that person. All possible paths are actually taken, and an observer is always present for every possible path. It is always the same observer. That observer does not know it is always the same presence of consciousness because there is a lapse in memory and a limitation in experience.

Those experiences are always limited in nature because they are embodied. All embodied experiences are limited to the form of a body. The mind only

arises with the body, and all the forms of information presented on the viewing screen of the mind are organized around the form of the body. The mind is animated over a sequence of mental events, which is an ordered sequence of viewing screens animated just like the frames of a movie. The mind is a coherently organized bound state of information that includes the presentation of images of external sensory perceptions and internal emotional body feelings. The images of those sensory perceptions are displayed on the viewing screen of the mind. The mind also displays thoughts, which are a symbolic representation of whatever appears to happen in the world. A self-concerned thought is mentally constructed as a body-based self-image is emotionally related to the image of something else in the world with a body feeling. All of those thoughts take the form 'I am related to something else in the world with some emotional body feeling', and implicitly identify what 'I am' with a body-based self-image. But all perceivable images, which include all body-based self-images, are perceived by the presence of consciousness that is present for the viewing screen of the mind.

A thought is a symbolic representation of whatever appears to happen in the world, like the narration of a movie. The nature of self-concerned thoughts is to tell the story of the actions of the person in the world, like the central character of a movie that narrates the movie. That narration tells the story of the actions of the central character, and is inherently self-referential in nature. But the narration of the movie is not outside the movie. The narration of the movie is only another aspect of that animation. Only the presence of consciousness for the mind is outside that animation, observing the movie animated on the viewing screen of the mind from its point of view in the void, which is its seat in the audience.

The concept of being an embodied person in the world is inherent in all the self-concerned thoughts that the presence of consciousness for the mind perceives. The concept of being an embodied person in the world, implicit in every self-concerned thought, is a false belief that the presence of consciousness believes about itself. Why does the presence of consciousness for the mind believe these false beliefs about itself? The answer is found in the nature of limited emotional attachment and self-defensiveness. Every self-concerned thought constructed in the mind is an emotional relationship that relates the body to something else in the world.

All embodied concepts of self and other arise with limited expressions of emotional attachment and self-defensiveness. The emotional sense of feel-

ing embodied is inherent in all these limited emotional expressions, as embodied feelings of connection or disconnection of the body to something else in the world are perceived. That emotional sense of feeling embodied is inherent is every self-concerned thought constructed in the mind that emotionally relates a body-based self-concept to the concept of something else in the world with some body feeling. With that emotional sense of feeling embodied arises the mental concept of being an embodied person in the world, which is the nature of the ego.

Every emotional attachment expresses the sense of feeling connected, as the coherently organized flow of emotional energy through the body comes into alignment with the flow of energy through something else. Feelings of connection of the body to something else in the world are expressed by that body, as the desires of that body are satisfied. If those desires are frustrated, then embodied feelings of disconnection, isolation and limitation to the body are expressed by that body. Embodied feelings of disconnection are limited to the body because the body is a coherently organized bound state. If desires are satisfied, then the coherently organized flow of emotional energy through the body can come into alignment with the flow of energy through something else, but if those desires are frustrated, then that coherent flow of energy must be limited to the body if that body is to survive. The body only coherently replicates its form over a sequence of events, and survives, because the coherent flow of emotional energy through that body maintains that coherent organization. If the coherent organization of that flow of energy is lost, then the body becomes disorganized, and dies. With the frustration of desires, the body expresses feelings of limitation to the body and emotional expressions of self-defensiveness, which defend body survival.

The nature of emotional attachment, as the flow of emotional energy through the body comes into alignment with the flow of energy through something else, is also the nature of self-defensiveness, since you only defend whatever you are attached to. It simply makes no sense to defend something you are not attached to. Without emotional attachments, the expression of self-defensiveness has no real purpose. Simply stated, if you are not attached to anything, then you have nothing to lose, and you have nothing to defend. The body becomes emotionally attached to other things in the world, which is possible because of the coherent organization of the body. But that coherent organization can at most become limited to the body itself. Self-defensiveness reflects that limitation to the body.

All emotional attachments are limited in nature, since they express the way the flow of emotional energy in a body comes into alignment with the flow of energy through something else in the world, which is only possible because the flow of energy through all bodies is coherently organized. But the ultimate emotional attachment is to the body itself, since that is the ultimate limit that the coherent organization of the flow of energy through the body can become limited to. The expression of self-defensiveness is only that limitation of the flow of emotional energy to the body itself, which is the reason the body survives. If that coherent organization is lost, the body dies. Feelings of attachment to something else in the world arise with all expressions of emotional attachment, but the ultimate feelings of attachment are to the body itself. Those feelings of attachment to the body, expressed by the body, are perceived by the presence of consciousness for the mind, which is why it 'feels' like it is embodied. If those feelings of attachment to the body are lost, then it 'feels' like it is dying.

The ultimate emotional attachment is to the body itself, from which arises the illusion of personal identity, the concept of being an embodied person in the world. Every limited emotional attachment to something in the world is part of that ultimate emotional attachment to the body, since the flow of emotional energy through the body can only come into alignment with the flow through something else if that flow is coherently organized within the body. Without a body, the nature of emotional attachment, and all concepts of self and other, is just not possible.

The ego, the concept of being an embodied person in the world, a person that is emotionally related to other things in the world, can only arise with the coherent organization of the body. As the body expresses limited emotional attachments and self-defensiveness, the presence of consciousness for the mind perceives those body feelings and 'feels' like it is embodied. All the self-concerned thoughts that are emotionally constructed in the mind implicitly tell the presence of consciousness for the mind that 'it is an embodied person in the world'. But these self-concerned thoughts are only false beliefs that it believes about itself. The presence of consciousness for the mind mistakenly identifies itself with the limited nature of a body-based self-identity, which is the ego.

The presence of consciousness for the mind really 'feels' like it is embodied as it perceives the feelings expressed by that body. If body desires are satisfied, and there are feelings of connection to other bodies, it 'feels'

more like itself, since all bodies arise from its true nature. If body desires are frustrated, and there are painful feelings of disconnection and limitation to the body, it 'feels' less like itself as it perceives feelings of isolation and separation. It recognizes itself more with feelings of connection, since its true nature is the source of all things. But in either case, the presence of consciousness for the mind 'feels' like it is embodied in the body of the person in the world as it perceives the emotional body feelings expressed by that body.

These emotional states are all states of mind perceived by the presence of consciousness for the mind. Every emotional state of mind is a state of the universe defined on a viewing screen, and an observer is present for every state of the universe. Emotional states of mind are only meaningful because of the meaning given to them by the observer that perceives them. But that meaning is a mistaken meaning, since the observer falsely identifies itself with the ego.

The presence of consciousness for the mind, present at a point of view in the void, is present for the viewing screen of the mind. The ego, the concept of being an embodied person in the world, is presented on the viewing screen of the mind. Every viewing screen, or state of the universe, arises from the void, and is perceived by the consciousness present at a point of view in the void. The 'one' that is always present for anything that appears to happen in the world is the void. The true identity of the observer is the void. The world belongs to the void the same way a dream always belongs to the dreamer. In this sense, the true identity of the dreamer is everything that appears to happen in that world. The dreamer can only realize its true nature if it identifies itself with everything that appears to happen in that world, or if it identifies itself with nothing that appears to happen in that world. The dreamer is the void, and it is the source of everything in the perceivable world. But by its nature, that which perceives the world cannot itself be perceived. The true nature of the dreamer is always outside of everything that appears to happen in its dream. The dreamer can only realize its true nature if it identifies itself with everything that it perceives, or with nothing that it perceives. Any limited self-identity that the dreamer identifies itself with is always a mistaken identity.

How is the mentally constructed self-concept created in the first place to cause so much identity confusion? The very young child demonstrates no evidence of a self-concept before about fifteen months of age when the

child can first point to a body-image reflection in a mirror and say “that’s me”. The self-concept arises contemporaneously with the development of human language. But how does language develop? There is an innate potential to learn language in every child, but that potentiality only becomes an actuality in an environment of human culture. The child learns language from the authority figures of that culture, which for the young child are mainly its parents. Language spontaneously develops during certain ‘critical periods’ of childhood development in the appropriate environment. The term ‘critical period’ implies the nature of the development of coherent organization, or symmetry breaking, involved in language development. Language function requires the development of the functional memory for language, which can be understood in terms of the dynamical organization of attractors and basins of attraction in the dynamical ‘landscape’ of the mind. Those attractors and basins of attraction represent the nature of the emotional responses that underlie all language function, which occurs in patterns of stimulus and response. Language function is a kind of emotional responsiveness that only occurs in response to the stimulus of the environment, which is another way to say that the child learns language from its parents. The mentally constructed body-based self-concept can only arise out of that emotional responsiveness.

How is the mental construction of the self-concept entangled with language development? The mentally constructed self-concept is entangled with language development because of the nature of emotional attachment of the child to its parents. That entanglement arises because the flow of emotional energy through the body of the child comes into alignment with the flow of emotional energy through the body of the parent, which is how the child and parent interact with each other. The nature of those interactions is the alignment of the flow of energy through those bodies. Emotional attachment allows language to occur in patterns of stimulus and response, which is the nature of emotional responsiveness of the child to parent and parent to child. The easiest way to conceptualize this process of mutual emotional responsiveness is as a learned internalized voice. The internalized voice is an emotional relationship that relates the body-based self-image of the child to the image of the parent with a body feeling. An internalized voice is a kind of learned emotional response, which is learned from the authority figures of the culture who themselves learned these responses when they were children. The responses are learned because they have survival value, and are another example of the survival of the

fittest. The human body is more likely to survive because these emotional responses are learned. These are all defensive emotional responses that defend body survival because of their inherent energy efficiency. These energy efficient defensive responses evolved because they gave the human species a survival advantage over other competing species.

What is the nature of these learned defensive emotional responses? Every time a child behaves in a culturally unacceptable way the child is criticized or shamed by an authority figure. The child is told that the behavior is bad, but this usually degenerates into a label that the child is bad. The child learns an internalized voice "I am bad". This emotional relationship relates the body-based self-image of the child to the image of the parent with a body feeling of shame. The situation is really no different for a culturally acceptable behavior praised by an authority figure. The child learns a prideful internalized voice "I am good", which relates the self-image of the child to the image of the parent with a body feeling of pride. These learned internalized voices replay themselves in repetitive patterns of stimulus and response. Every time desires arise to express similar behaviors, either an internalized shameful voice inhibits the bad behavior or a prideful voice reinforces the good behavior, whether the authority figure is there or not. The child has internalized the voice of the authority figure and in the process learned to self-modify behavior. The child becomes socialized as it learns to self-modify its behavior. The learned internalized voice is the nature of the socialization process that allows the child to become accepted into human society, as the child's behavior comes into alignment with culturally sanctioned behavior. That acceptance increases the chance of body survival.

In energetic terms, the flow of emotional energy localized to the body of the child comes into alignment with the flow of energy throughout the entire culture. That flow of energy is coherently organized whether localized to the body of the child or to the body of the culture. The coherent organization of the flow of energy is defensive in nature as it defends both the survival of the body of the child and the survival of the culture. The society only survives because of the nature of its defensive emotional responses, which are internalized within the body of the child. That internalization process allows the child to become accepted within that society. Cultural acceptance increases the chances of body survival and sexual reproduction of the body. That acceptance is inherently emotional in nature, as the flow of energy comes into alignment.

The nature of shame is a distortion of fear, just as pride is a distortion of desire. With every expression of shame there is the fear of rejection, failure, ridicule, and humiliation, just as with every expression of pride there is the desire for success, admiration and acceptance. These emotional relationships always relate the body-based self-concept to the concept of another, and by their nature are reflective of a society. Shame is always the fear of rejection by others within the society, just as pride is always the desire for acceptance by others within the society. Shame is a distortion of the fear of others, which is expressed as movement away, and pride is a distortion of the desire for others, which is expressed as movement toward. The reason these distortions are possible is because societies can become quite complex in nature, due to the large number of individuals that comprise the society and the complexity of those interpersonal relationships. The expression of shame naturally leads to isolation and subservience, and to the sense of inferiority, inadequacy and worthlessness. The expression of pride naturally leads to dominance and power over others, and to the sense of superiority, specialness, vanity, grandiosity, and the entitlement to special treatment from others. In a similar way, guilt is a distortion of anger, expressed as movement against. But instead of anger directed against another, guilt is expressed as anger directed against some aspect of the self-concept. All self-concepts arise from these kinds of emotional expressions, which inherently relate the body-based self-image to the image of another with some emotional body feeling.

Every self-concept arises as a conditioned or learned emotional response. Those learned emotional responses are self-defensive in nature, as they defend body survival. They are learned within the emotional context of a human culture. Every human culture has a repertoire of defensive emotional responses that defend the survival of that culture. Those defensive emotional responses are internalized within the very young child as the child's behavior comes into alignment with culturally sanctioned behavior. In energetic terms, the localized flow of energy coherently organized within the body of the child comes into alignment with the flow of energy coherently organized within the entire culture. That coherently organized flow of energy defends the survival of both the society and the body of the child. The society is only a coherently organized bound state of those bodies. The body-based self-concept arises as the child is socialized. The child learns to self-modify its behavior, and its behavior comes into alignment with socially accepted behavior. That alignment is how the child is accept-

ed into the society. That acceptance increases the probability that the body of the child will survive and sexually reproduce.

The human self-concept is culturally determined. More accurately, self-concepts spontaneously emerge within the emotional context of human culture. The self-concept arises with the development of language. All self-concepts arise in the form of mentally constructed self-concerned thoughts that emotionally relate a body-based self-image to the image of another body, which is only a symbolic representation of whatever appears to happen in the world. The nature of every such relationship is either the nature of emotional attachment of the body to something in the world, or self-defensiveness, as one body moves relative to another body in some complex way to defend body survival. That energetic movement involves both a global embodied movement and the movement of all the stuff bound together inside the form of that body. The localized expression of emotions within a body is only possible because the body is a bound state that coherently holds together over an ordered sequence of events. The expression of fear usually leads to a global embodied movement, as one body moves away from another potentially threatening body. But even if the global movement of one body relative to another does not occur, that fear can still be expressed within the body by the manner with which all the stuff bound together inside the body coherently moves around together as it is all bound up into the form of the body. The flow of energy localized to a body inherent in that coherent movement is perceivable, and is perceived as emotional expression. The perceivable expression of fear in the body is symbolically represented in the mind as a perceivable body feeling.

A self-concerned thought is mentally constructed as a perceivable body-based self-image is emotionally related to the perceivable image of another body with a perceivable body feeling. The form of self-concerned thoughts is perceived upon the viewing screen of the mind. The presence of consciousness for the mind perceives and gives meaning to these perceivable mentally constructed thoughts. The dynamical nature of those relationships is emotional. All meaning is established in an emotional context, which is another way to say: 'to act is to give meaning'. The expression of embodied emotion is the action that is given meaning to. All self-defensive emotional expressions, like the expression of fear, defend body survival. To act self-defensively to defend the survival of the body as though the existence of what 'I am' depends upon it is to believe what 'I am' is embodied in the defended body, which is the illusion of personal identi-

ty. Those self-defensive actions are compelled to occur because it really 'feels' like the existence of the perceiver of the mind depends upon it.

The presence of consciousness for the mind believes these untrue beliefs about itself. These untrue beliefs are mentally constructed in the mind in the dynamical form of perceivable self-concerned thoughts, which are believed by the presence of consciousness that perceives them. The mental construction of self-concerned thoughts is the action that is given meaning to by the perceiving subject, but that meaning is the mistaken meaning of self-identification with a body-based self-concept. Self-concerned thoughts are false beliefs that the perceiving subject believes about itself. The perceiving subject mistakenly believes that the expression of self-defensiveness is a self-defense that defends the true nature of its existence, because it mistakenly believes that its identity is embodied within the limited form of a perceivable body-based self-image that it perceives. Any limited self-identity that the presence of consciousness identifies itself with is always a mistaken identity.

The limited self-identity of a body-based self-concept can only arise from limited emotional expressions of self-defensiveness and emotional attachment. These limited emotional expressions only become a problem because of the nature of mental imagination, which is the problem of the ego. The nature of mental imagination is memory and anticipation of events, from which arise the nature of self-concerned thoughts. These thoughts emotionally relate a body-based self-image to the image of something else in the world. Those images are only 'held' in mental imagination because of memory. The emotional relationships inherent in all these thoughts, as desires are either satisfied or frustrated, are either based upon the emotional attachment of the body to something in the world, or expressions of self-defensiveness that defend body survival. All limited emotional expressions in some way defend body survival as emotional energy flows through the body, and the form of the body is coherently replicated over an ordered sequence of events. Mental imagination always distorts the nature of things because of these limited emotional expressions. The nature of that distortion is self-defensiveness.

Everything in the world is balanced in nature with the potential to either promote body survival or threaten body survival. That potentiality is inherent in all things because of the way energy flows through all things as all energy flows in its universal gradient. The nature of that universal flow

results in the natural cycles of death and rebirth of all things. A body is born because of the way emotional energy is coherently organized into the form of a body. That body lives a life as that coherent organization allows the form of the body to replicate its form and enact its behaviors. The body dies when that coherent organization is lost, and the body becomes disorganized and falls apart. Every bound state of energy that spontaneously forms in the universe must eventually fall apart, because that form is an unstable state, like the snow pack that forms on the mountainside that must eventually collapse down the side of the mountain in an avalanche, or melt away, and rejoin the flow of water in the river in its inevitable return to the ocean.

A body is only an unstable bound state of energy that eventually must fall apart as energy flows in its universal gradient, like any system that makes a transition from an unstable to a more stable state. That transition results in the release of 'heat', which is recycled in new bodies. That flow of 'heat' is how energy flows from more ordered to less ordered states, which is how energy flows through the universe, like a river that returns to the ocean. The emotional energy of the body is recycled within new bodies, which is the natural cycle of death and rebirth of all bodies. Those natural cycles are expressed in the behavior of the body as bodies eat each other in order to survive. The survival of the fittest body reflects that universal flow of energy. All quantized bits of energy in the universe flow in the universal gradient from big bang event to black hole. As energy flows, those bits of energy obey the laws of the universe. The universe arises as a spontaneous eruption of energy from the void, and the laws of the universe reflect the nature of the void. All the laws of the universe reflect the symmetry of empty space, but those laws can also be formulated as a principle of least action. The nature of all the actions in the universe is symmetry breaking, but those actions also tend to follow the principle of least action, which is the natural way for the universe to act in the sense of quantum probability. The nature of symmetry breaking is the formation of bound states, as energy flows in its universal gradient. Bound states form as the amount of disordered information in the universe increases. All bound states are inherently unstable and eventually must fall apart, but that energy is recycled and becomes a part of something even larger. The ultimate bound state in the universe is the black hole, which eats everything in its vicinity.

All bodies are bound states of energy, and only survive because they eat other bodies, which is how energy is transferred between bodies. Even the

nature of symmetry breaking, and the formation of coherently organized bound states, is dependent upon the nature of eating, as potential energy is added to a body, which allows for all body development, growth and survival. The survival of the fittest body always reflects the principle of least action. The bodies that are most likely to survive, and that tend to survive for the longest time, are those that most efficiently transfer energy down its universal gradient, with least action. All energy flows in its universal gradient and all energy is eventually recycled in new bodies, at least until the universe itself comes to an end and suffers its own 'heat death'.

The balanced nature of all things is inherent in the laws of universe, as reflected by the second law of thermodynamics and the principle of least action, from which the survival of the fittest body and the natural cycles of death and rebirth of all bodies arise. But the balanced nature of all things is distorted in the mind due to the nature of mental imagination and self-defensiveness. The nature of that distortion is the ego, the concept of being an embodied person in the world.

Mental imagination is not possible without a mind. The distortion of an ego, which arises in mental imagination, can only arise within a mind. Without a body there is no mind, and without a mind an ego cannot become mentally constructed. The ego can only arise because a body arises that develops a mind, which is capable of the mental construction of an ego in mental imagination. The body and mind only arise with the development of coherent organization of information, which is defined on viewing screens of quantized space-time, as the void quantizes itself into those surfaces, and perceives that animation of events from its point of view.

The distortion of an ego only arises in mental imagination. The mind is a coherently organized bound state of information that spontaneously arises with the coherent organization of the body. That coherent organization allows for memory and anticipation of past and future events. The forms of things this event can be projected to past or future events, but only if the forms of those things and the flow of emotional energy through those things are perceived this event. All memory and anticipation of past and future events is a projection made from this event. If you know where something is located and how it is moving right now, then you also know something about where it came from and where it is going. The presence of consciousness for the mind is only present for this event, and only knows about what is presented on the viewing screen of the mind this

event, since all perception is the relationship of the information presented on a viewing screen to the consciousness present at a point of view. But this normal relationship of consciousness to the world, as that world is presented on a viewing screen, is distorted in the mental imagination that arises from the nature of memory and anticipation of events, which are only projections from this event.

The nature of the universal flow of energy is that all things are in balance. All things are both capable of eating other things and being eaten by other things, which is why everything in the universe has the potential to either promote or threaten body survival. The body responds to these potentialities in the present moment, with limited expressions of emotional attachment if desires are satisfied, or limited expressions of self-defensiveness if desires are frustrated and body survival is threatened. But these normal emotional responses, all expressed in the present moment, are distorted in mental imagination. With memory of past events and anticipation of future events, the mind can 'hold' in mental imagination the images of the 'good things' that promote body survival and the images of the 'bad things' that threaten body survival.

Those images are used to construct self-concerned thoughts, as the body-based self-image is emotionally related to the image of something else in the world. The mind makes use of memory and anticipation of past and future events to 'hold' the image of something in mental imagination. Sometimes the mind labels that thing as 'good', and sometimes as 'bad', depending upon the nature of the emotional response to that thing. The problem with the mind is that whatever 'good things' are imagined can easily 'turn' into the 'bad things' that are imagined, since all things are balanced in nature, and everything in the world has the potential to either promote or threaten body survival. This inevitably leads to emotional conflicts constructed in mental imagination. Emotional conflicts are inevitable because the 'good things' chased after with desire in mental imagination easily 'turn' into the 'bad things' run away from with fear or attacked with anger, as these distortions are replayed over and over again in mental imagination in a sequence of mental events. Emotional conflicts are always a distortion of the nature of things that only arises because of the nature of mental imagination.

The other aspect of mental imagination that distorts the nature of things are the vicious cycles of self-defensiveness that arise within the mind.

Every mentally constructed self-concerned thought is an emotional relationship between a body-based self-image and the image of something else in the world. If body desires are frustrated, or if body survival is threatened, then the nature of that emotional relationship is some kind of expression of self-defensiveness, such as fear or anger. But any mentally constructed self-concerned thought is also a stimulus for more self-defensive emotional responses in the body, and that self-defensive emotional energy is used by the mind to construct more self-concerned thoughts, which perpetuates the vicious cycle. That vicious cycle of self-defensiveness is like an out-of-control positive feedback loop, just like an open microphone, that distorts and amplifies the signal. These vicious cycles result in distortion and intensification of expressions of self-defensiveness, which is the nature of all out-of-control expressions of self-defensiveness. The out-of-control desire to possess something is expressed as greed. Fear that is run amok is expressed as panic. Anger that is out-of-control is expressed as rage. Vanity and grandiosity are expressions of pride that are run amok. These vicious cycles of self-defensiveness are only possible because of mental imagination that allows for mental construction of self-concerned thoughts. The images of the 'bad things' that frustrate desires or threaten body survival, and the images of the 'good things' that satisfy desires, are 'held' in mental imagination over a sequence of events, and are the stimulus for more self-defensive emotional responses expressed in the body, which only reinforces the image of the 'bad thing' or 'good thing' held in mental imagination, and perpetuates the vicious cycle. That reinforcement of images is just like the wave reinforcement that creates an interference pattern in a hologram. Those images are holographic in nature, projected from the viewing screen of the mind.

The restless mind oscillates back and forth between the emotional extremes inherent in the dynamical organization of the mind, just like the oscillations inherent in wave motion. The full spectrum of those emotional extremes leads to emotional conflicts, such as desire in conflict with fear, anger in conflict with guilt, or pride in conflict with shame. The restless mind expresses emotional conflicts as it responds to events, but the stimuli for these responses are both internally and externally generated. External stimuli are possible because of quantum entanglement, as one distinct body interacts with another distinct body. Internal stimuli are possible as one body organ system interacts with another body organ system. The dynamical organization of the mind means every possible emotional response can be the stimulus for a different kind of emotional response as

the mind is dynamically reorganized over a sequence of mental event. In dynamical terms, the system of the mind can become perturbed into a different basin of attraction that flows toward a different attractor. Emotional conflicts are inherent in that dynamical organization. Those emotional conflicts are possible because the body is a composite of coherently organized body systems, and every distinct body organ system can express emotion in its own distinct way. Every distinct system is a bound state of information. The mind is only one of those distinct body organ systems. All distinct body systems interact with each other as they express emotions in their own distinct ways. The nature of emotional conflicts are those body system interactions. Each body organ system can interact with, or conflict with, every other body system, just as any body can conflict with any other body.

The nature of mental imagination arises with memory and anticipation of past and future events, from which arise the self-concerned thoughts emotionally constructed in the mind. Those thoughts are a symbolic representation of whatever appears to happen in the world, but they are always told from the perspective of the central character of that animation of events, and revolve around the actions of that character. The presence of consciousness for the mind perceives that animation of events on the viewing screen of the mind, which is organized around the body of the central character. Those thoughts are only the self-referential story that the person in the world tells about his actions in the world, as he either attaches his body to other things in the world, or defends his body survival from the threats posed by other things in the world. The story is inherently emotional in nature, as body desires are either satisfied or frustrated. That story is just like the narration of a movie by the central character of that movie, and is all about the actions of that character in emotional relationship to other things in the world.

The only reason that story can be told is because of memory, as the images of all those things are 'held' in mental imagination. That mental 'holding' is emotional in nature, and can only arise with limited expressions of emotional attachment and self-defensiveness, as a body-based self-image is emotionally related to the image of something else in the world. The nature of mental imagination inevitably leads to emotional conflicts, as the images of the things that are 'held' in mental imagination are chased after with desire, run away from with fear, or attacked with anger. Whatever is chased after with desire this moment can easily 'turn' into something that

is run away from with fear or attacked with anger in the next moment. Emotional conflicts inevitably arise as the 'good' things that are chased after with desire eventually turn into the 'bad' things that are run away from with fear or attacked with anger. That 'turning' is inevitable, since everything in the universe is balanced in nature, with both 'good' and 'bad' aspects. The 'good' things desired this moment can easily turn into the 'bad' things feared or hated in the next moment. But this raises an obvious question. 'Good' or 'bad' for whom?

The actions of the universe can only be judged to be 'good' or 'bad' for the nature of the coherently organized bound states of energy that we call bodies, and that judgment is only from the perspective of one body in the world relative to another body. Those actions are only 'good' or 'bad' from the perspective of a mentally constructed body-based self-concept, which is the ego. The nature of the flow of energy through the universe, from which all the actions of the universe arise, reflects the principle of least action, from which arises the natural cycles of death and rebirth of all things, and the survival of the fittest bodies. What appears to be 'good' for one body may appear to be 'bad' for another body, as those bodies appear to eat each other, and energy is recycled in new bodies. Emotional conflicts can only reflect those natural cycles of death and rebirth, which is how energy flows through the universe. But an emotional conflict is always a distortion of the nature of things. That distortion only arises because the presence of consciousness for the mind mistakenly identifies itself with a particular body in the world, which is the particular body of the central character of the animation of events it perceives from its particular point of view in the void. The presence of consciousness for the mind mistakenly identifies itself, and thereby mistakenly limits itself, to that particular body, which is the nature of all self-identification with a limited self-identity, or ego. The entire world arises from the true nature of that presence of consciousness, the same way a dream arises from the dreamer. If that presence of consciousness identifies itself with everything in the world, then there is no mistaken self-identification, and there is no basis to judge any action that occurs in the world as 'good' or 'bad'. Everything that appears to happen in the world is 'good', because it's all a reflection of the nature of the dreamer. If the presence of consciousness does not identify itself with an ego, then it's all good. It's all part of the dream that the dreamer is dreaming. The entire dream belongs to the dreamer. But the true nature of the dreamer is always outside of its dream, in the void, and nothing ever happens in the void.

The nature of the dream only arises from the way energy flows and organizes itself into complex forms of energy. All that energy spontaneously arises from the dreamer, and spontaneously organizes itself into complex forms. All of that energy spontaneously arises as the void quantized itself into viewing screens of quantized space-time and encodes information. The perceived flow of time is only an ordered sequence of events animated upon those viewing screens, like the animated frames of a movie. Those events are ordered in the universal flow of energy, as energy flows from more ordered to less ordered states. That flow of energy is always directed toward the formation of bound states, like a body. All energy flows in its universal gradient, and obeys the laws of the universe, which reflect the nature of the void. The body spontaneously arises because of the way that energy is coherently organized into the form of a body, or stuck together, as that energy flows through the body and animates the behaviors of the body. The mind is a bound state of information defined on its own viewing screen, but the mind is a behavior of the body that arises with the body. The mind corresponds to the coherently organized behavior of a distinct body organ system, which we call the brain. All external sensory perceptions, internal emotional body feelings, memories, forms of imagination, thoughts, body-based self-images, and mental concepts, are perceivable images presented on the viewing screen of the mind.

The image of a body in the world, which is the nature of the mentally constructed ego, is animated upon the viewing screen of the mind. That image of the body is perceived through embodied organs of sensory perception, which include both external sensory perceptions, like sight, sound and touch, and internal emotional perceptions, called body feelings. All sensory perceptions are the perception of the flow of energy through the body. The organs of sensory perception within the body relay information to the viewing screen of the mind in much the same way a video camera relays information to a digital viewing screen. Those images are all animated on the viewing screen of the mind over an ordered sequence of mental events, and that is the nature of the dream that the dreamer is dreaming.

The perceived flow of time is only an ordered sequence of events perceived on the viewing screen of the mind. The direction of the flow of time is a statistical phenomena related to the organization of information. All energy flows in its universal gradient from big bang event to black hole, just like a river that flows from the top of the mountain to the bottom of the ocean. As energy flows in its universal gradient, there is a tendency for informa-

tion to flow from more ordered to less ordered states, or for entropy to increase. The formation of all the bound states of information in the universe, like the coherently organized bound state of a body, occurs as entropy increases. That increase in entropy is often compared to the shattering of a vase, as the tiny shattered fragments fly apart in random directions. But we are able to make a movie of the shattering of the vase, and play that movie backwards. As we play the movie backwards, it appears that all the tiny fragments fly together and the vase is reformed. How is that possible?

All energy flows in its universal gradient of gravitational collapse, and as energy flows that energy spontaneously organizes itself into complex forms, like the coherently organized form of a body. The body of the vase-maker is able to form the vase out of clay, but only because of the work performed by the vase-maker. That work is performed as high potential energy molecules, like carbohydrates, are burned inside the body of the vase-maker. As those molecules are burned inside of muscle cells, kinetic energy is directed to perform that work as the muscle cells contract, but heat is also released into the environment. The heat released is disordered kinetic energy, and so overall, there is an increase in entropy as the vase is formed and that disordered kinetic energy is radiated away into the environment. When a movie of the vase shattering is filmed by a movie-maker, work is also performed by the movie-maker, which requires the same process of burning high potential energy molecules inside the body of the movie-maker and radiating away heat into the environment. When the movie is played backwards, and it appears that the vase is reformed, work is also performed, and there is the same kind of flow of energy, and the radiation of disordered kinetic energy into the environment.

As we watch a backward directed movie of all the tiny fragments flying together to reform the vase, work is performed, and overall there is an increase in entropy as heat is radiated away into the environment. But the ultimate environment is the entire universe. Entropy can appear to decrease locally, which means that information becomes locally more ordered, but only because there is an overall increase in entropy for the entire universe, and an overall increase in the amount of disordered information. All of that energy flows in its universal gradient from big bang event to black hole. We can only play a movie backwards, and give the appearance that entropy decreases locally, because energy flows in its uni-

versal gradient, which always results in more entropy for the entire universe.

The most likely way for that energy to flow, and for energy to spontaneously organize itself into complex forms, is determined by the principle of least action. The most likely actions of the universe are the actions that minimize the amount of energy utilized as some action of the universe is performed. The bound states of energy that are most likely to form are those mechanisms that minimize the amount of energy utilized, or perform their actions with the greatest energy efficiency, as some action of the universe is performed. Those are the actions that are most likely to occur as energy is transferred down its universal gradient, like a river that falls back to the ocean. A bound state of energy, like a body, only appears to 'survive' over a sequence of events ordered in the universal flow of energy because its form is self-replicated in the same coherently organized phase of organization. That organization of information is defined on a viewing screen. That survival is most likely to occur, as energy coherently flows through that bound state and the behaviors of that bound state are enacted, if the flow of energy is organized in the most energy efficient way possible, with least action, or least expenditure of energy, as all energy flows down its universal gradient.

Entropy can appear to decrease locally inside the bound state of a body, but only because there is an overall increase in entropy for the entire universe. As energy flows in its universal gradient, like a river that flows from the top of the mountain to the bottom of the ocean, entropy can appear to decrease locally inside a body only because universal entropy increases. Energy is always conserved as energy flows, but entropy tends to increase as energy flows, since the universal tendency is for energy to flow from more ordered to less ordered states. In some sense, the body is 'swimming' upstream as entropy is locally decreased inside the body while universal entropy increases.

The direction of the flow of time is always directed toward the formation of bound states, since for the entire universe there is always an overall increase in entropy as any bound state forms, like the bound state of a body. The direction of the flow of time is a 'subjective' phenomena related to the formation of those locally organized bound states, and to the disorganization of information at the universal level. The flow of time cannot be perceived unless there is an observer present that perceives a sequence of

events ordered in the universal flow of energy. That ordered sequence of events is defined upon a sequence of viewing screens that play like the animated frames of a movie. Those viewing screens are always organized around the form of a body. The universal nature of that animation begins with the big bang event, which is the 'birth' of the universe, and ends with a collection of black holes. Even the black holes eventually evaporate away into nothing as the universe continues to expand, and the animation finally ends with the 'heat death' of the universe. In a more limited but similar way, the animation of events that defines the embodied life of a person in the world begins with the birth of that person, and ends with the body death of that person.

In some sense, the quantum state of the universe is like a collage of photos. Each 'photo' is a viewing screen, and the quantum state is the sum of all possible viewing screens. The life of the person in the world is like the animated frames of a movie that arises if some of those photos are cut out of the collage and are played in the order of an animation of events that defines the life of the person in the world. The animation that plays on that ordered sequence of viewing screens appears to be observed by an observer that is present in the audience for that animation, but in terms of the collage, there is an observer present at a point of view for every viewing screen defined on the collage. That observer only knows about whatever plays on the particular viewing screen it observes from its point of view. But all the observers are the same presence of consciousness, which is the potentiality of the void, present at every point of view in the void, to perceive and give meaning to whatever forms of information are presented on any of the viewing screens that spontaneously arise from the void. That presence of consciousness knows nothing about its true nature except that it exists. There is only an illusion of the continuity of events animated on that ordered sequence of viewing screens because of memory and anticipation of events that arises from the complex ways in which information is coherently organized on those viewing screens.

That animation of events is the dream that the dreamer is dreaming. The nature of the dream is only an animation of perceivable events presented on an ordered sequence of viewing screens that spontaneously arise from the void, as the void quantizes itself into those surfaces of quantized space-times. Each of those two dimensional bounding surfaces is a 'state of the universe' that holographically defines everything that appears to happen in the apparent three dimensional world bounded by that surface. The view-

ing screen defines a 'dreamstate'. The nature of the dreamstate arises as a spontaneous eruption of energy from the void. We call that dreamstate the nature of the world. The nature of the dreamer is the void. The void is the source of all the energy that animates the dreamstate defined on any viewing screen, and it is the source of the consciousness that is present at a point of view for whatever is presented on any viewing screen.

The complex ways in which information is organized on those viewing screens is inherently emotional in nature. That organization arises from the complex way in which the flow of emotional energy is coherently organized, as energy flows through the form of a body, and holds the form of the body together over a sequence of events while the behaviors of the body are enacted. That emotional expression takes the form of limited expressions of self-defensiveness and emotional attachment, which we call expressions of fear and desire. Perceivable emotional expression allows the observer to make projections, as the form of things this event is projected to past or future events, which is the nature of memory and anticipation of events. An illusion of the continuity of events arises with that projection, which is inherently emotional in nature. The observer 'feels' like it is embodied within the body of the person in the world that the animation of events is organized around as it perceives those emotional body feelings, which are inherently limited to a body. The observer 'feels' like the actions that the body enacts in the world are its actions as the observer makes the emotional projections that allow for the perception of that perceivable animation of events.

Awakening from the dream requires the end of that limited emotional expression, which means the end of all expressions of fear and desire, and the end of those limited expressions of emotional attachment and self-defensiveness. The end of those limited emotional expressions is the nature of the emotional transformation that allows for awakening. That is the only way the observer no longer 'feels' like it is embodied within the body of the person in the world. Without those limited emotional expressions, the observer no longer 'feels' like it is embodied, and no longer makes projections to past and future events. The dreamer only awakens from its dream if the dream appears to come to an end. Without those limited emotional expressions, all projections to past and future events come to an end. As the memory and anticipation of events comes to an end, the animated life of the person in the world also appears to come to an end. Without that emotional projection, the observer finds itself in the 'eternal now' of the present moment.

Awakening is only possible if all limited expressions of emotional attachment and self-defensiveness come to an end. The end of all limited emotional expressions is the emotional transformation that allows for awakening. That is the only way emotional projection comes to an end. That is the only way the observer no longer 'feels' like it is embodied within the body of a person in the world that is only the central character in an animation of events presented on the 'stage' of a viewing screen that the observer perceives from its point of view, which is its 'seat' in the audience. The observer no longer 'feels' embodied because the limited body feelings of emotional attachment and self-defensiveness that appear to happen in the world come to an end. By their nature, those body feelings all represent emotional attachment to the body. The nature of the emotional transformation that allows for awakening is the end of that emotional attachment to the body, which are only the body feelings expressed by the body that appear to happen in the world. How is this kind of emotional transformation even possible?

The process of awakening always begins with looking within and clearly seeing the falseness of the ego. To clearly see the falseness of the ego is to give the ego the meaning of a false belief that the true nature of what 'I am' believes about itself. That false belief is only the concept that "I am an embodied person in the world that is emotionally related to other things in the world; an embodied person with desires that are either satisfied or frustrated; a person that emotionally attaches its body to other things in the world, or a person with a body survival that is threatened by other things in the world and must fight to defend its body survival as though the existence of what 'I am' depends upon it". The true nature of what 'I am', the presence of consciousness for the mind, only believes these false beliefs about itself, because it 'feels' like it is embodied, and that its existence depends upon body survival. That is the mistaken meaning it gives to all the mentally constructed body-based self-concepts it perceives in the mind. Those false self-concepts are implicit in every self-concerned thought constructed in the mind.

The process of awakening always begins with looking within and examining the nature of the ego and self-defensiveness. That examination of the ego leads to the awareness of the falseness of the ego. The falseness of the ego can be seen on many different levels: the nature of emotional conflicts, the nature of mental imagination, the vicious cycles of self-defensiveness that distort and exaggerate the nature of self-defensiveness, and ultimate-

ly the illusions of personal control and personal identity. It really doesn't matter at which level you see the falseness of the ego. Once the falseness of the ego is seen, a different kind of emotional experience will arise that begins to counteract the emotional self-defensiveness of the ego. The nature of that emotional experience is the nature of discontent, or self-destructiveness, which is the desire to destroy the falseness of the ego.

The 'death instinct' was an idea that Freud wrote about in *Civilization and Its Discontents*, and was an attempt to explain the nature of self-destructiveness. The 'death instinct' was considered a 'counter-instinct' to the nature of emotional attachment. But we can easily understand the nature of self-destructiveness as the emotional energy that naturally arises if the falseness of the ego is clearly seen. The reason that self-destructive emotional energy arises is because of the nature of perception, which is recognition. The nature of recognition is simply stated as: 'to act is to give meaning'. The perceiver recognizes and gives meaning to all of the actions that spontaneously arise from the true nature of itself. But the reverse statement is also the case: 'to give meaning is to act'. In some sense, actions arise because of the meaning given to those actions. The nature of perception and action are inextricably linked because of the nature of consciousness. If the falseness of the ego is clearly seen, which is the lie of a body-based self-identity that the true nature of what 'I am' falsely identifies itself with, then out of clearly seeing the nature of that lie, actions will naturally arise to destroy the lie. If the falseness of the ego is seen, and the ego is given the meaning of a lie that the true nature of what 'I am' believes about itself, then self-destructiveness naturally arises to destroy that lie. The nature of self-destructiveness emotionally counteracts the self-defensiveness of the ego. The nature of emotional attachment and self-defensiveness naturally arise with the coherent organization of the body, which we could call the 'life instinct', but without an ego, there is no 'death instinct'.

The nature of the ego is self-concerned thoughts emotionally constructed in the mind from limited expressions of emotional attachment and self-defensiveness, which implicitly tell the true nature of what 'I am', the consciousness that is present for the mind, that "I am the ego". The ego, the concept of being an embodied person in the world, is the false self-identity that is destroyed. Actions that destroy the ego are thoughts about the ego emotionally constructed from self-destructiveness. Expressions of self-destructiveness are the counteractions to expressions of self-defensiveness. Since the nature of the ego is only thought, in that sense, the ego

fights for its own self-destruction with thoughts about the ego that destroy the self-concerned thoughts of the ego.

The ego only fights for its own self-destruction because of the willingness to look within and clearly see the falseness of the ego. The presence of consciousness for the mind looks within and sees the falseness of the ego, and out of that clear seeing arises emotional discontent, the desire to destroy the falseness of the ego. Out of that clear seeing arises thoughts about the ego that destroy the self-concerned thoughts of the ego, which is how self-destructiveness emotionally counteracts self-defensiveness. But emotional transformation is only possible, and the ego only finally dies away for good, if expressions of self-defensiveness finally come to an end. The nature of the end of all those expressions of self-defensiveness is the nature of surrender, which is the willingness to 'let go' of all expressions of self-defensiveness and emotional attachment. The ego fights for its own self-destruction, which is the war within the true nature of what 'I am' that can only come to an end with the death of the ego. In that war, self-destructiveness counteracts self-defensiveness, but that war can only come to an end with surrender, which is the willingness to accept the death of the ego.

The ego begins to die away as the falseness of the ego is clearly seen and the ego fights for its own self-destruction, but the ego only finally dies away for good if the death of the ego is accepted. The acceptance of the death of the ego is the nature of surrender. Surrender is the willingness to relinquish the illusion of control, and to stop fighting. The willingness to 'let go' of all expressions of self-defensiveness and emotional attachment, and surrender, is the willingness to accept universal will. To relinquish the illusion of control is to accept universal will and accept the nature of universal creativity, as energy flows through all things and animates all things. The nature of universal will and creativity are the natural cycles of death and rebirth of all things, and the transformation of form into new form. To accept universal will is to accept the nature of death and transformation. The ego finally dies away for good because its death is accepted, which is the only way that emotional transformation is ever possible. That emotional transformation is just like the 'burning' that occurs as an unstable state makes a transition to a more stable state, and releases energy in the form of heat.

The other way to look at the nature of that emotional transformation is as the liberation of emotional energy to flow freely and to come into align-

ment with universal flow. The ego is constructed out of bound-up emotional energy. That self-defensive emotional energy is stuck together within a bound state of information we call the ego, which can only arise with the coherent organization of the body. The nature of that coherent organization is emotional energy that is stuck together in such a way that the flow of energy through a body coherently replicates the form of the body over a sequence of events. In the same way, the ego coherently replicates its form in the mind over a sequence of mental events.

The bound state of emotional energy of the ego in some sense is like an iceberg floating in the ocean, or a snow pack frozen to the side of a mountain. The nature of discontent, which is the desire to destroy the ego, is the hot emotional energy that liberates the bound-up emotional energy of the ego to flow freely, just like the heat that melts an iceberg back into the ocean, or the snow pack back into the river. The expression of self-destructiveness is the hot emotional energy that disorganizes, or 'melts' away, the self-defensive 'frozen' emotional energy of the ego. Disorganization of the ego is the emotional 'break-down' of the ego.

The disorganization of the flow of emotional energy of the ego liberates energy to flow more freely, just like water that flows more freely if an iceberg or snow pack is melted away. But the disorganization of that flow of emotional energy is only the initial part of a process that leads to the emotional transformation that allows for awakening. Awakening only occurs if that liberated flow of emotional energy comes into alignment with the universal flow of energy. In some sense, discontent is the self-destructive emotional energy that naturally arises if the falseness of all personally motivated desires is clearly seen. In a similar sense, surrender is the willingness to 'turn away' from those personally motivated desires, or the willingness to refuse to express them, if the falseness of those desires is clearly seen. The final part of the process that allows for awakening is surrender and acceptance of universal will, which is acceptance of death and transformation. That transformation, which is the end of personally motivated desire, is the only way the flow of emotional energy through a body comes into alignment with universal flow.

That emotional transformation is the end of all limited expressions of emotional attachment and self-defensiveness, which express emotional attachment to the body. The death of feelings of attachment to the body, expressed by the body, is the nature of the emotional transformation.

Emotional transformation 'feels' like something inside of you is dying, but only those feelings of attachment to the body, expressed by the body, can die. The true nature of what 'you are' is the presence of consciousness that perceives it all as it appears to happen. The true nature of what 'you are' cannot die, because the timeless nature of its existence is always present. It only perceives whatever appears to happen in the world. It only 'feels' like it is embodied because it perceives body feelings that represent the limited expressions of emotional attachment and self-defensiveness, which by their nature all express emotional attachment to the body.

The nature of the ego arises with the emotional attachment of the body to other things in the world, but that attachment is expressed by the body, and reflects the nature of self-defensiveness, since all attachment is ultimately limited to the body itself. The ego can only arise because emotional attachments expressed by the body are ultimately limited to the body itself, which is how all embodied concepts of self and other arise. The ego only replicates its diverse forms in the mind with those self-defensive emotional expressions, and comes to an end if they are not expressed. Without emotional attachments, the expression of self-defensiveness has no real purpose, and so the end of all limited emotional attachments, which includes attachment to the body, is also the end of the ego. To bring the ego to an end is to become non-attached to the body. Freedom from the ego inherently requires the willingness to let go of limited expressions of self-defensiveness and emotional attachment, which is the willingness to relinquish the illusion of control and accept universal will. To relinquish the illusion of control and let go of self-defensiveness is for the ego to come to an end. The ego only comes to an end because of the willingness to let go of the emotional attachment to the body.

The best example of emotional attachment is an infant emotionally attached to its mother. The body of the infant expresses feelings of attachment to the mother as the desires of that body, such as desires to be held and fed, are satisfied by the mother. As those desires are satisfied, feelings of connection to the mother are expressed by the body of the infant. If desires are frustrated, then the body of the infant expresses feelings of disconnection and limitation to the body. Expressions of self-defensiveness arise in the body of the infant and emotionally influence the behavior of the mother. The infant does not control the behavior of the mother, since all behavior occurs in a pattern of stimulus and response. There is only an illusion of control, which is perceived as the behavior is enacted. The body

of the infant responds to the frustration of its desires self-defensively, as it cries out in fear or anger, which emotionally influences the behavior of the mother, and the mother responds to that cry as she satisfies the desires expressed by the infant.

The body of the mother also expresses feelings of attachment to the infant as the desires expressed by the mother to hold and feed the infant are satisfied. The mother becomes emotionally attached to the infant as those desires are satisfied. But if the infant's cry is perceived to be a threat to the mother, then the mother will respond to that cry self-defensively. When infants cry, their mothers do not always hold and feed them. Sometimes mothers will respond to those cries self-defensively, and attack their children with anger, or run away from them with fear. All kinds of conditioned responses are possible, depending upon the conditions.

The child only begins to grow up when the child becomes self-sufficient, and no longer needs to make demands on the mother to be held and fed. The child no longer needs to emotionally control the behavior of the mother, and force her to satisfy its desires. The child begins to grow up because of its willingness to let go of its emotional attachment to its mother, which is also its willingness to let go of the self-defensive emotional expressions that attempt to control the behavior of its mother, which is its willingness to become self-sufficient and autonomous. The willingness to let go of an emotional attachment is the nature of autonomy. All emotional attachments are a kind of dependency.

The end of that dependency is the end of the child's emotional attachment to its mother. The end of an emotional attachment always 'feels' like something is dying inside. The child grows up because its feelings of attachment to the mother die away. The desire to possess the mother, expressed by the body of the infant, dies away. The desire to control the behavior of the mother, and to force her to satisfy the desires expressed by the body of the infant, die away. The process of maturation only occurs because the infantile nature of the desire of the child to possess its mother is clearly seen. The action of 'growing up' follows from clearly seeing the immaturity of that dependency, which is the meaning given to the infantile desires of the child to possess its mother. As that attachment to the mother dies away, so too does the self-defensive anger expressed at the mother, which is an emotional attempt to control her behavior and force her to satisfy those desires. That is the nature of the emotional transformation that occurs inside the body of the child when the emotional attachment of the child to

the mother dies away, and feelings of attachment to the mother also die away.

The ultimate emotional attachment is the attachment to the body itself. Feelings of attachment to the body are expressed by that body, which is why they are self-defensive in nature. That self-defensiveness is the only way the form of the body is self-replicated over a sequence of events, which is the nature of body survival, and is only possible because of the flow of emotional energy through the body that holds the body together as a coherently organized bound state. In some sense, the body desires to possess itself. The ultimate autonomy is the willingness to let go of that emotional attachment to the body. The willingness to let go of the emotional attachment to the body is the nature of surrender, which is the acceptance of body death and transformation into new form, and acceptance of universal will and creativity. The willingness to let go of any emotional attachment always 'feels' like something inside of you is dying, and the end of the attachment to the body is no exception.

What dies? A coherently organized bound state of energy called an ego dies. Certain kinds of embodied experiences die. The experiencer, the nature of consciousness, cannot die, because its true nature is the void. Only the embodied experiences of the experiencer can die, like the dream experiences that appear to come to an end if the dreamer awakens from its dream. You can only die for your own sins. The only sin is ignorance, the original sin, which is ignorance about the true nature of what 'you are'. The only sin is the false self-identification with an ego. You can only realize the true nature of what 'you are' if you are willing to die to your false self-identification with an ego.

The ultimate autonomy is the acceptance of death. The death of the ego is only possible because the nature of death is accepted. The emotional transformation that is the death of the ego while the body still lives is only possible if the nature of death is accepted, which is the acceptance of universal will and the natural cycles of death and rebirth. That acceptance of death only arises with the willingness to relinquish the illusion of control and accept universal will. The ego fights for its own self-destruction, but that war can only come to an end with surrender, which is the willingness to allow the ego to die. By its nature, that surrender is the willingness to let go of the emotional attachment to the body.

Surrender is the acceptance of death, but that acceptance is only possible with the awareness of death. The denial of death is only possible because

of the absence of the awareness of death. We deny death because we live in the fear of death. The death we fear is the true nature of what 'we are', which is the nothingness of the void, the source of all existence. The fear of that nothingness is what keeps the focus of our attention fixated on whatever appears to happen in the world. All self-identification with an ego, the concept of being an embodied person in the world, is a denial of death, and is a denial of the true nature of what 'we are'.

Death awareness is the ultimate spiritual practice. Only death awareness leads to the acceptance of death and to surrender, which is the only process that ever takes us out of the denial of death. Only awareness and acceptance of death can lead to the ultimate spiritual autonomy of a presence of consciousness that no longer emotionally identifies itself with a body. Only that non-identification with the body allows us to ever know the true spiritual nature of what 'we are'.

The focus of attention of awareness is only liberated from its fixation on whatever appears to happen in the world with the end of all emotional attachments, which is the willingness to 'let go' of all the things we are attached to in the world. With sensory perceptions of the world, the presence of consciousness for the mind is aware of the flow of energy through the world, how energy becomes organized into complex forms, and the complex behaviors of those forms. That presence of consciousness is attached to those forms because of the nature of emotional attachment, which is why it 'feels' like it is embodied within the body of a person in the world. Without that emotional attachment, the presence of consciousness no longer 'feels' embodied, which is the only way it ever becomes aware of the source of itself. The void of undifferentiated consciousness is the source of the consciousness present for all forms of energy in the world, and the source of all that energy. In a certain sense, awakening is the willingness to 'turn around', or 'turn away' from the perceivable world, and 'turn towards' the source of existence.

Surrender allows for the acceptance of universal will, which allows the liberated flow of emotional energy of the ego to come into alignment with universal flow. The ego fights for its own self-destruction, which is the war within the true nature of what 'I am' that only comes to an end with surrender, which is the acceptance of ego death. Without that acceptance, the nature of self-destructive emotional energy can be directed against the falseness that you see in your own ego, or it can be directed against the

falseness that you see in the ego of another. The ego is only emotional energy that becomes coherently organized within a mind. That coherent organization arises from the coherent organization of a body. The body dies if that coherent organization is lost. In the same way, the ego dies away with the loss of that coherent organization within the mind. The nature of self-destructiveness inherently disorganizes the coherent organization of the ego within a mind, which is the emotional 'break-down' of the ego. But the expression of self-destructiveness can also lead to destruction of the ego through body death. We call such expressions of self-destructiveness suicide. The falseness of the ego can also be seen in others, and those egos can be destroyed with the destruction of those other bodies. We call those kinds of expressions of self-destructiveness murder. It is always wise to focus your attention on the falseness of your own ego, and not the ego of another. Pluck the plank from your own eye. That 'plank' is the self-defensive emotional blinders of the ego that distorts clear seeing. The only ego that you can destroy while the body still lives is your own ego. The nature of awakening is the emotional transformation that allows the ego to die away while the body still lives.

The life of a person in the world that is not in alignment with the universal flow of all things is characterized by the emotional blinders of the ego. That life is always a distortion of the natural flow of all things, and opposes universal will. Why does the life of a person in the world not follow universal will? The answer is always the ego. The ego is only emotional energy that is bound together, or coherently organized, within the mind in such a complex way that its form is coherently replicated over a sequence of mental events. That coherent organization is the nature of all the self-concerned thoughts emotionally constructed from limited expressions of emotional attachment and self-defensiveness.

The biased nature of the ego is why the ego always opposes universal will and is a distortion of the natural flow of all things. Universal will has no bias in terms of which body will survive in any struggle for survival. We call the unbiased nature of universal will the survival of the fittest body, but it could just as easily be called the survival of the most energy efficient way to transfer energy down its universal gradient with least action. In terms of the many world interpretation, the path taken by any body in the world, or the world line for that body, is only an ordered sequence of viewing screens organized around the body and ordered in the flow of energy. The path of least action is a particular sequence of viewing screens, but the path of the

ego is never the path of least action, because it is always biased in favor of the survival of the central character of the animation. The path of least action is never biased, but simply favors which ever body acts in the most energy efficient way, which is the most energy efficient way to transfer energy down its universal gradient. The ego opposes universal will and distorts the natural flow of things because it does not take the path of least action, and in that sense is a waste of energy. All limited expressions of emotional attachment and self-defensiveness in some sense are a waste of time and energy, for the simple reason that self-defensive behavior defends body survival as though existence depends upon it. The true nature of existence depends upon nothing.

If the presence of consciousness for the mind cannot see things clearly because of the self-defensive emotional blinders of the ego, then the life of the person in the world will not take the path of least action, but will oppose universal will as the survival of that body is defended. Those biased actions arise because the ego is given the mistaken meaning of the true nature of what 'I am', and body survival is defended as though the existence of what 'I am' depends upon it. The nature of universal will is completely unbiased, and does not take sides in any struggle for body survival, but simply reflects the true nature of existence, which depends upon nothing.

The truth that is discovered with the emotional transformation that allows for awakening, the truth that sets the true nature of what 'I am' free from its false self-identification with the ego, is that the true nature of its existence depends upon nothing. The presence of consciousness for the mind discovers that its existence depends upon nothing that it perceives in the perceivable world. The ultimate emotional detachment is a presence of consciousness that knows itself to be outside the world, present at a point of view in the void, only watching as the world is animated upon a sequence of viewing screens.

With clear seeing, and without the self-defensive emotional blinders of the ego that distort clear seeing, the appropriate meaning to the nature of things is given, and the life of the person in the world comes into alignment with universal will. Right action follows from clear seeing, since to act is to give meaning, and if the right meaning is given to all things through clear seeing, then the right action naturally follows. The life of the person in the world that is guided by clear seeing naturally follows the nature of univer-

sal will, because that is the right meaning to give to the nature of all things. The path of the life of the person in the world comes into alignment with universal will, in accord with the nature of all things.

As the liberated flow of emotional energy comes into alignment with universal flow, there is a sense of being 'swept away'. Limited emotional expressions fall away because of the willingness to let go of all emotional attachments. There is simply the acceptance of whatever comes and goes in the world. Without the illusions of personal control and personal identity, and without expressions of self-defensiveness and emotional attachment, there is simply acceptance of whatever the universe gives, with gratitude, and acceptance of whatever the universe takes away, with equanimity. That acceptance is the natural state of the witness that is no longer emotionally attached to whatever it perceives in the world. That detached witness is an impartial observer of events in the world.

The life of the person in the world that follows the path in alignment with universal will is free of the ego. That path is free of expressions of self-defensiveness. That path is free of the illusions of control and personal identity, and free of the illusions of separation and self-defense. That life is characterized by the sense of the unity of all things, and by feelings of connection to all things. Those feelings of connection naturally arise because the flow of emotional energy through the body comes into alignment with the universal flow of energy through all things. Without an ego, the presence of consciousness identifies itself with everything in the world. Without the false self-identity of an ego, the true nature of identity is sensed in all things. But the ultimate identity of the observer is found outside the world, in the void. The ultimate detachment is an observer that identifies itself with nothing that it perceives in the world.

Why should we trust scientific knowledge as a description of the world? The behavior of the observable world is described by mathematical laws that we can know about. Scientific knowledge can be trusted to the extent that knowledge is based upon mathematical insight and objective observation. Mathematics does not lie, and so mathematical insight can be trusted. All observation is subjective in nature, but to the extent that observation is free of emotion, or emotionally detached in nature, that observation becomes more objective, and so can be trusted. Only subjective observations that are clouded with emotions cannot be trusted. With the expression of emotions, the observing subject falsely identifies itself with an emo-

tional self-concept that it observes, which is the nature of the emotional blinders of the ego that distorts the observation. Only observations that are free of the ego are objective in nature and can be trusted. Even though they are still subjective, without an ego, in effect there is 'no subject', because there is 'no-self'. The emotionally detached observer is not identified with an ego, and so there is no self-concept, which is like there is no subject, and so the observation becomes objective in nature. When coupled with mathematical insight, objective observation leads to scientific knowledge that can be trusted. The icing on the cake are predictions that arise from mathematical insights, or theories, which can be confirmed with more objective observations. In its purest form, science relies on objective observation and mathematical insight, which means the absence of an ego, and the presence of an emotionally detached observing subject.

This what Stephen Hawking meant with "I don't demand that a theory correspond to reality because I don't know what it is. Reality is not a quality you can test with litmus paper. All I'm concerned with is that the theory should predict the results of measurements". His other insight about the nature of reality is "Consciousness is not a quality that one can measure from the outside", which basically says that the measurable world that we observe is not the true nature of our reality. Our consciousness is always outside of whatever qualities of the world we measure. The holographic principle explains how that is possible. The 'one' that is always present for any observation of the world is the void. Mathematical insight is only possible because the void recognizes itself in all mathematical concepts.

The world is inherently mathematical in nature. The world is geometrical and changes over time, which means the world is described by the mathematics of geometry and calculus. Anyone who understands the mathematical arguments presented here about the nature of the world understands these mathematical concepts. But mathematics obeys consistent computational rules, and anyone who knows about the consistency of those rules cannot be described by those rules. The presence of consciousness that knows about the consistency of the rules is always outside of those rules. That is what the incompleteness theorems prove. Anyone who understands the mathematical concepts presented here about the nature of the world proves their consciousness is outside that world.

Let's go back to the question that began this ramble about the nature of the mind. Is it possible for consciousness to arise from the nervous activity of

a brain? Is the consciousness that perceives and gives meaning to all forms of perceivable information itself reducible to any form of perceivable information? Can the source of consciousness be an object defined within consciousness, or arise from a perceivable object?

Listen to this quote from Antonio Damasio “The neurobiology of consciousness faces two problems: the problem of how the movie-in-the-brain is generated, and the problem of how the brain also generates the sense that there is an owner and observer for that movie. The two problems are so intimately related that the latter is nested within the former. In effect, the second problem is that of generating the appearance of an owner and observer for the movie within the movie”. Damasio is clearly saying that he regards the perceivable world as real, and the nature of consciousness as an illusion. He takes the ‘world of appearances’ to be real, and regards the appearance of an observer for that ‘world of appearances’ as an illusion. If the ‘world of appearances’ is real, then the appearance of an observer within that world is only an illusion. He is absolutely right, in the sense that either the world is an illusion, or the consciousness that knows about that world is an illusion. Both the world and the consciousness that knows about that world cannot have independent existence within that world. One must be an illusion of the other, in much the same way a dream is an illusion of the dreamer. Ask yourself which of these possibilities you are more certain about the reality of. Are you certain about the reality of the world, or are you certain about the reality of your own presence for the world? Which is more likely an illusion, the world of appearances, or the ‘one’ that is present to observe that world of appearances?

If we assume that consciousness arises from the perceivable nervous activity of a brain, then we inherently assume that the source of consciousness can be objectified as an object defined within consciousness. But that assumption attempts to objectify the subjective nature of consciousness as a perceivable object the nature of consciousness can perceive. This assumption is absurdity since it is nothing more than a meaningless paradox of self-reference similar to the logically meaningless statement “I am a liar”. It means absolutely nothing.

Such assumptions are all absurd attempts to objectify the perceiving subject as a perceivable object that it perceives. They are absurd attempts to equate that which perceives and gives meaning to all perceivable forms of information with some perceivable form of information that it perceives. All possible explanations about the nature of consciousness are composed

of perceivable information. The assumption that consciousness arises from the perceivable activity of a brain is an absurd attempt to explain that which perceives and gives meaning to the explanation with the explanation it perceives. Such assumptions are meaningless and logically inconsistent. If there is to be logical consistency in any explanation about the nature of consciousness, the source of consciousness cannot be an object within consciousness. The source of consciousness is always outside its perceivable objects. The nature of consciousness simply cannot be objectified.

This is what the incompleteness theorems prove. The nature of subjective reality can only be objectified if consciousness somehow arises from an object defined within consciousness. If subjective reality can be objectified, then the nature of consciousness is itself a perceivable thing that consciousness can perceive. Subjective reality can only be objectified if it can perceive the form of itself.

If that is the case, then subjective reality is objectified and the perceiver of things is itself a perceivable thing. This kind of an assumption is a paradox of self-reference similar to the logically meaningless statement “I am a liar”. A paradox of self-reference is a logical statement that means absolutely nothing. If “I am a liar”, and I am lying about myself, then “I am not a liar”. If “I am a liar”, and I am telling the truth about myself, then “I am a liar that tells the truth”. In either case, the statement “I am a liar” contradicts itself, and means absolutely nothing.

The Gödel incompleteness theorems are about the necessary conditions that keep a logical system of computational rules free of all these kinds of paradoxes of self-reference. The second incompleteness theorem proves that a logical system of consistent computational rules as complicated as counting natural numbers cannot prove its own consistency. The system is incomplete. The proof of consistency is outside the system. But who knows about the consistency of that system of computational rules? Who knows that $1+1=2$ is a consistent rule?

The observer of that system knows about that consistent rule. The observer of the system proves the consistency of the computational rules through its consistent observations of the system. The observer of the system is proven to be outside the system by the second incompleteness theorem. An observer that knows about the consistency of any logical system of consis-

tent computational rules must be outside that system. That observer is the nature of what we mean by consciousness, whatever it is that perceives and gives meaning to the system, whatever it is that knows about the consistency of those computational rules.

The observable behaviors of all the observable things in the observable physical universe obey a logical system of consistent computational rules. That system is called the laws of physics. The observer that proves the consistency of this system of logical rules through its consistent observations of them is proven to be outside the system by the second incompleteness theorem. This proof only requires that the rules are consistent, and that the observer knows about that consistency.

The observable behaviors of all the observable things in the observable physical universe obey a logical system of consistent computational rules called quantum theory. By its very nature, quantum theory specifies the nature of an observational event. It specifies a trinity: the three qualities of consciousness that are called the observables of the quantum state, the nature of observing, and the nature of the observer. These three qualities are familiar to every reader because they are depicted on the back of the dollar bill next to the words “in God we trust”. The depiction is the All Seeing Eye inside the triangle on top of the pyramid, which symbolizes the nature of the three qualities of consciousness.

These three qualities of consciousness, as specified by quantum theory, are the seer, the seen and the seeing. The seer is the nature of the observer. The seen is the nature of the observable. The seeing is the nature of observing an event. Quantum theory has nothing to say about the nature of the observer, only that it must exist, and that it is present for every observational event. The seen is the observable property of physical reality that is observed with any observational event. The likelihood of observing that particular observable property is specified by a quantum state of potentiality. The seeing is the nature of an observational event that occurs now. The three qualities of consciousness are the observer, the observables of the quantum state, and the observing that takes place now. The many world interpretation of quantum theory, which is the natural interpretation, tells us that an observer is present for every possible quantum state, but quantum theory does not tell us anything about the nature of the observer.

The big question is whether or not the nature of the observer can be objectified in the form of some observable thing it observes. What does quantum theory have to say about this? If the nature of consciousness is objectified, then the observer is objectified in some observable form it observes. This leads us right back to another paradox of self-reference, since the assumption that consciousness can be objectified is to equate the observer with an observable of the quantum state. But if the observer is an observable of the quantum state, then who observes that observable? Can any observable of the quantum state observe itself?

This kind of assumption leads directly to nonsense. The problem with such an assumption is that a paradox of self-reference can only lead to nonsense like the logically meaningless statement “I am a liar”. That is why the incompleteness theorems prove that if the laws of physics are consistent computational rules, then the observer of physical reality that knows about the consistency of those computational rules is outside the system that defines physical reality.

The source of our consciousness is outside the apparent three dimensional world we appear to live in. That is the natural interpretation of the holographic principle. Consciousness comes as if from a higher dimension. The world is holographic, defined on two dimensional bounding surfaces of quantized space-time that act as viewing screens and project images to points of view in the void. The void is the true nature of consciousness. Consciousness is the potentiality of the void that is present at every point of view to perceive and give meaning to any form of information that it holographically constructs out of itself on any viewing screen. An apparent world is created as the void quantizes itself into those surfaces. Every possible viewing screen that can be constructed is a possible state of the universe, and an observer is present for every possible state of the universe. The world is animated as viewing screens are observed in sequence. The world is animated over an ordered sequence of events, just like the animated frames of a movie, as energy flows in its universal gradient from the big bang event to black hole. Everything that appears to happen in this apparent world is holographically animated upon observed viewing screens. The observer is always present at a point of view in the void. The mind is animated on viewing screens, just like anything else that can appear to happen in the universe. The presence of consciousness for the mind is only confused about the true nature of its identity, and mistakenly identifies itself with the concept of being an embodied person in the

world, because that presence of consciousness really 'feels' like it is embodied as it perceives the body feelings that appear to happen in the world.

Nothing ever happens in the void of empty space. Everything that appears to happen in the world is a localized disturbance, or fluctuation in the energy level, of the motionless background 'medium', or empty background space, that we call the void of empty space, like a brief wave excitation that appears on the surface of the ocean. The nature of that 'medium' is consciousness. Everything that appears to happen in the universe is defined upon the surfaces of the void. The void is the nature of consciousness that observes whatever appears to happen in any world holographically animated upon viewing screens. The nature of the void is like a perfectly still ocean of undifferentiated consciousness.

The void is the 'ground' of existence. It is the primordial nature of existence that exists 'before' the world is created in a big bang event. The void is the source of consciousness that knows about everything in the world, and it is the source of the existence of everything in the world. The relationship of the void to the world is the relationship of a dreamer to its dream. The dreamer does not exist within its dream. The relationship is exactly the other way around. The dream only has existence within the nature of the dreamer. The dreamer is always present for any dream that it can dream about, but it is always the same dreamer. There are many dream characters within its dream that the dreamer can dream about, but the true nature of the dreamer always exists outside the dream. The dreamer is the void, and the nature of its dream is called the world. The person in the world that the dreamer mistakenly identifies itself with is only a character in its dream.

Notes

The neurobiology of the mind and the body-based self-concept are discussed in *The Feeling of What Happens* by Antonio Damasio.

Are you and I caught up in a dream from which we have not yet awakened?

Chuang Tzu

Only that day dawns to which we are awake

Henry David Thoreau

When I was a child, I spoke as a child, I understood as a child, I thought as a child; but when I became a man I put away childish things

Corinthians

I have seen all the works that are done under the sun
And behold, all is vanity and a striving after wind

Ecclesiastes

Unless you turn around and become like young children you will not enter the Kingdom of Heaven

Gospel of John

We do not grow old no matter how long we live. We never cease to stand like curious children before the great Mystery that we are.

Albert Einstein

The Kingdom of Heaven is spread out upon the earth and men do not see it

Gospel of Thomas

The grail represents living an authentic life - for those with spiritual readiness. The wasteland represents living an inauthentic life.

Joseph Campbell

Christ came into the world for shattering the idea you have of yourself. To be opened to the transcendent you must be dismembered. The savior represents the death of a purely material, animal existence and the birth of a spiritual life. Beyond ego - beyond the will to live - beyond fear and desire - is that which transcends duality.

Joseph Campbell

You are what your deep driving desire is
As your desire is so is your will
As your will is so is your deed
As your deed is so is your destiny

Upanishads

That in whom reside all beings and who resides in all beings
Who is the giver of grace to all
The Supreme Soul of the universe
The limitless being-I am That

Upanishads

Missing me one place search another
I stop somewhere waiting for you

Walt Whitman

Stop this day and night with me
And you shall possess the origin of all poems

Walt Whitman

And though I walk through the valley of the shadow of death
I will fear no evil, for you are with me

Psalms

When I flowed out from God, all things spoke: God is. But this cannot make me happy, for it makes me understand that I am a creature. In the breakthrough-where I stand free of my own will and of the will of God-there I am above all creatures and I am neither God nor creature. I am what I was and what I shall remain now and forever. In this breakthrough I discover that I and God are one.

Meister Eckhart

Separate yourself from all two-ness. Be one in one, one with one, one from one.

Meister Eckhart

Empty yourself of everything

Tao-Te-Ching

Empty of self and all things

Meister Eckhart

Abandon all hope ye who enter here

Dante

The essence of spirituality is contained in this phrase:
Complete and utter abandonment to the will of God

Jean-Pierre De Caussade

It is in this darkness that we find true liberty
It is in this abandonment that we are made strong
This is the night that empties us

Thomas Merton

The shell must be cracked apart if what is in it is to come out-and likewise,
if you would know the reality of Nature you must destroy the appearance-the
further you go beyond the appearance the nearer you will be to the essence.

Meister Eckhart

Everything is full and pure in its source

Meister Eckhart

Not till we have lost the world do we begin to find ourselves
And realize where we are and the infinite extent of our relations

Henry David Thoreau

The soul grows by subtraction, not by addition

Meister Eckhart

The soul becomes God but God does not become the soul

Meister Eckhart

One truth is clear, whatever is, is right

Alexander Pope

To love wisdom as to live according to its dictates
A life of simplicity, independence, magnanimity and trust

Henry David Thoreau

It is more important
To see the simplicity
To realize one's true nature
To cast off selfishness
And temper desire

Tao-Te-Ching

To err is human, to forgive divine

Alexander Pope

No fight; no blame

Tao-Te-Ching

If the only prayer you say in your whole life is 'thank you' that will suffice

Meister Eckhart

He who seeks only himself brings himself to ruin, whereas he who brings himself to naught for me discovers who he is

Gospel of Matthew

How is it that this Being that Is inhabits this nothingness?

Gospel of Thomas

When you bring forth that within you, then that will save you
If you do not, then that will destroy you

Gospel of Thomas

To be or not to be, that is the question

Shakespeare

Being at one with the Tao is eternal
And though the body dies, the Tao will never pass away

Tao-Te-Ching

Because there is no place for death to enter

Tao-Te-Ching

These are the words of the secret
Whoever lives the meaning of these words shall no longer taste death

Gospel of Thomas

When there is no self there is also no other

Bernadette Roberts

I am that I am

Exodus

And you shall know the truth and the truth shall set you free

Gospel of John

When the mind is at peace the world too is at peace
Nothing real, nothing absent
Not holding onto reality, not getting stuck in the void
You are neither holy nor wise
Just an ordinary fellow who has completed his work

Layman P'ang

The wise are impartial

Tao-Te-Ching

All is for the best in this, the best of all possible worlds

Gottfried Leibniz

It is a good day to die

Native American saying

Die while you're alive and be absolutely dead
Then do whatever you want
It is all good

Bunan

Do not think that I came to bring peace upon the earth. I did not come to bring peace, but a sword. For I came to set a man against his father and a daughter against her mother. A man's enemies will be the members of his household. He who loves father or mother more than Me is not worthy of Me. He who does not take his cross and follow after Me is not worthy of Me. He who

has found his life will lose it, and he who has lost his life for My sake will find it.

Gospel of Matthew

Now I am become Death, the destroyer of worlds

Bhagavad-Gita

I have come to cast fire upon the earth

Gospel of Luke

Burning, burning, burning, burning
Oh Lord, Thou pluckest me out
Oh Lord, Thou pluckest
Burning

The Fire Sermon

Watch out! You might get what you're after
Strange, but not a stranger
I am an ordinary guy
Burning down the house

David Byrne

My barn having burned to the ground, I can now see the moon

Taoist saying

At the moment of death - have you prepared yourself to dissolve into the universal consciousness? All these powers that are tearing you apart are figments of your imagination; they are in the field of time. Hold onto the still point; there is nothing to lose; there is nothing to do. Are you going to identify yourself with the body, the vehicle, or are you going to identify yourself with the light?

Joseph Campbell

Do not think the Buddha's are other than you are

Dogen

That which is born of the flesh is flesh and that which is born of the spirit is spirit. Unless one is born again he cannot see the Kingdom of God

Gospel of John

The fruit of letting go is birth

Meister Eckhart

An individual life is a knot of delusions. Illumination means you are letting go of ego.

Joseph Campbell

The only thing that burns in hell is the part of you that won't let go of your life: your memories, your attachments. They burn them all away, but they're not punishing you, they're freeing your soul. If you're frightened of dying and you're holding on, you'll see devils tearing your life away. If you've made your peace, then the devils are really angels freeing you from the earth.

From Jacob's Ladder-attributed to *Meister Eckhart*

No contemplative path wants to advertise the cross or the suffering entailed in the crossing over. We must not be naïve about this or in any way mislead others. The truth is that getting to the other shore will stretch the human limits to the breaking point, not once, but again and again. Who can take it? It is not for nothing that the cross is the central Christian symbol.

Bernadette Roberts

Spiritual freedom and oneness with the Tao are not randomly bestowed gifts But the rewards of conscious self-transformation

The Hua-Hu-Ching

He must dare to leap into the Origin so as to live by the Truth and in the Truth, like one who has become one with it. He must become a pupil again, a beginner; conquer the last and steepest stretch of the way, undergo new transformation. If he survives its perils then is his destiny fulfilled. Face to face he beholds the unbroken Truth, the Truth beyond all truths, the formless Origin of origins, the Void which is the All; is absorbed into it and from it emerges reborn.

Eugen Herrigel

The source is a void of undifferentiated consciousness

Joseph Campbell

Returning is the motion of the Tao

Tao-Te-Ching

It returns to nothingness

Tao-Te-Ching

It leads all things back
Toward the great oneness

Tao-Te-Ching

In the silence and the void
Standing alone and unchanging
Ever present and in motion
I do not know its name; Call it Tao

Tao-Te-Ching

Be still and know that I am God

Psalms

If nothing is done then all will be well

Tao-Te-Ching

Without form there is no desire
Without desire there is tranquility

Tao-Te-Ching

Therefore the sage seeks freedom from desire

Tao-Te-Ching

Ever desireless one can see the mystery
Ever desiring one can see the manifestations
These two spring from the same source but differ in name
This appears as darkness
Darkness within darkness
The gate to all mystery

Tao-Te-Ching

The great path has no gates
Thousands of roads enter it
When one passes through this gateless gate
One walks the universe alone

Mu-mon

Curious what will come next
Both in and out of the game
Watching and wondering at it

Walt Whitman

God is in all things
The more divinity is in things, the more divinity is outside of things

Meister Eckhart

Truly, I have attained nothing from total enlightenment

Buddha

The unreal has no being
The real never ceases to be

Bhagavad-Gita

In the knowledge of the Source
Which is a dark night to the ignorant
The recollected mind is fully awake and aware
The ignorant are awake in their sense life
Which is darkness to the sage

Bhagavad-Gita

The man of Tao remains unknown
Perfect virtue produces nothing
No-self is true-self
And the greatest man is nobody

Chuang Tzu

This book is about the meaning of science. There is a great deal of confusion about what science actually means, and an important goal here is to clear up that confusion. The science that is discussed here is the standard science of our day, which includes relativity theory, quantum field theory, complexity theory, and some of our most advanced science, such as inflationary cosmology and string theory. String theory is the best candidate for a theory of quantum gravity...and is the main focus of attention, especially as it demonstrates the holographic principle of quantum gravity. The reason to understand the holographic principle is because it allows for a scientific understanding of the nature of nonduality.

Scientific explanations can never really give the experience of nonduality, just as a map or travel guide can never give the experience of a journey to a foreign land, but they can indicate the nature of that unknown land, typically by metaphor or analogy with what is already known... There are many testimonies that can be read about, but this is not one of them. This work only has the nature of a map. It can only describe the final destination of the journey in terms of metaphors, and can only give travel directions about how the journey is made. There are really only two good reasons to have such a map. One is to satisfy your curiosity about the nature of the final destination without the need to make that journey for yourself, and the other is to make the journey.

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