Three Odd Couples in Classical Science

by Richard L. Lewis

In this discussion we will be dealing with pairs of entities that are seemingly so unlike that common sense and classical science—the one still taught in high school—would suggest they could not relate to each other;. Yet experimental science and experience tells us that they intimately do relate to each other. We will discuss three such disparate pairs, and how these odd couples intimately conjugate together as explained by contemporary science:

1. Mass and Spacetime

Mass is substantial, while space and time are both insubstantial. Yet they intimately relate to each other. In General Relativity, substantial mass determines how insubstantial spacetime curves; the curvature of spacetime determines how mass moves.

2. Particle and Wave

A particle is local and is described by real numbers (a linear measure only), while a wave is non-local and described by complex numbers (a combination of both linear and rotational measure). Quantum mechanics discovered that it was impossible to describe matter in solely particle terms, accuracy could only be obtained if physical entities had both particle and wave aspects—the *wavefunction*. In Quantum Mechanics, the local particle aspect and the global wave aspect are seamlessly combined: the internal wavefunction determines the probability of how the particle will move and interact; the interactions of the particle tell the wavefunction how to develop and change.

As asides, we will also mention how modern science has a different perspective on three classical problems: Abstract math governing substantial matter; The impossibility of interstellar travel ruled by an otherwise-generous speed limit of light: The historical and almost universal assertion that this physical realm is complemented by another, separate realm.

3. Mind and Body

The mind is insubstantial, while the body is substantial. Yet they relate. Our experience is that the mind tells the body what to do; the body tells the mind how to alter and change.

1. Mass & Spacetime

Classical View

Science emerged as a serious discipline during the Renaissance and embraced commonsense views about matter, time and space These views of classical science were radically altered in the 20^{th} century.

Solid Mass

From a everyday perspective, the solidity of matter is not in question. We do not spend time worrying that we will sink through the solid ground to be consumed by the molten lava beneath.

Famously, Bishop Berkeley's sophisticated argument in the 1700s suggesting the non-existence of solid matter was confuted by Samuel Johnson, striking his foot with mighty force against a large stone, declaiming, "I refute it thus!"

The discovery that all matter was constructed of minute atoms simply shifted the concept of 'solid material' to that of solid atoms:

Thus Sir Isaac Newton wrote in 1704, "It seems probable to me, that God in the beginning formed matter in solid, massy, hard, impenetrable, movable particles… even so very hard, as never to wear or break in pieces; no ordinary power being able to divide what God Himself made one in the first creation."

In Newtonian classical science, there are two measures of mass, both involving force:

1. Gravitational measure: how one mass attracts another mass. Newton stated that the force of attraction, F, was proportional to the product of the two masses, M, divided by the distance between them, d, squared. This equation he converted into an equality by a Gravitational Constant, G.
2. Inertial measure: how much force it takes to change the velocity of the mass. Newton also had an equation for this involving the rate of change in velocity, the acceleration, a, which in his co-invention of the calculus with Leibnitz, was the second derivative of change in location, x, with time, t.

• Gravity •

$$F = G\frac{M_1 M_2}{d^2}$$

• Inertia •

$$F = Ma$$

While these two measures are utterly different, it was quite a puzzle that they always gave identical measures: so doubling the gravitational mass always doubled the inertial mass; doubling the inertial mass always doubled the gravitational mass.

Space and Time

Early science adopted the commonsense view that space and time were utterly disparate. Space was the nothingness in which matter moved, such as here and there, while time was the nothingness that gave a sequence to what happened to matter, such as past and future.

Being so different, they were quantified by different units: space was measured with meters (except in the non-metric holdouts) and its multiples, while time was measured in seconds (used universally) and its multiples.

Movement through space over time did combine time and space into concepts such as *miles per hour*. The velocity of a mass was the rate of change in location over time, a first derivative in calculus.

$$v = \frac{dx}{dt}$$

$$\text{momentum} = mv$$

$$\text{energy} = \frac{1}{2}mv^2$$

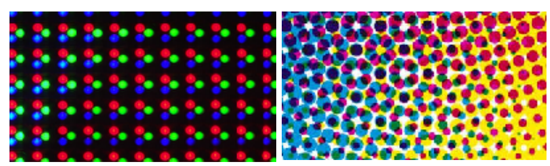
It was the inertial mass concept that introduced to science the concept of energy: a force moving through a distance did work, and this added two things to an accelerated mass as its velocity increased: kinetic energy and momentum. While momentum—both linear and angular—was relatively simple to understand, energy turned out to be so sophisticated that it could be transformed into heat energy, chemical energy, electrical energy, potential energy, kinetic energy, etc.

While neither of momentum or energy were considered as 'real things' they had the rather unexpected status of being one of the few quantities in nature that are absolutely conserved. Measured before and after any situation, careful measurement showed that these quantities were always identical before and after.

Energy was not considered a physical entity, however, more a quality of matter that could easily be transferred. This transfer of 'free' energy is determined by circumstances: a rubber ball falling down a slope releases gravitational potential free energy, but burning in a fire the ball releases a lot more chemical free energy.

Contemporary View

All of these classical assumptions about reality turned out to be, if not false, but just approximations to the underlying complexity. This is akin to looking at color photos on white paper or black computer screens. The impression of continuous color in either case is false: the white paper has colors removed by pixels of the subtractive colors—cyan, magenta and yellow—while the black screen has colors added by pixels of the additive colors—red, green and blue. In both situations the eye is incapable of resolving the tiny pixels and we observe continuous color.



Classical science had low resolution and dealt with commonsense reality. Contemporary science with its vastly enhanced resolution can observe the 'pixelation' complexities underlying our everyday experience.

The message is that our human senses are not equipped for revealing the nature of reality. For example, our senses tell us that both water and time-passing are smooth and continuous. Not so! Both are grainy; one on the atomic scale of 10^{-11} meters, the other on the Plank scale of 10^{-44} seconds.

Mass: Unit of Energy

On close examination, mass turned out not to be an immutable fact of nature. One of Einstein's great discoveries—using mathematics and not a microscope—was that mass and energy were exactly the same: mass was just a very, very large unit of energy. Albeit confined energy, not free energy in everyday experience, but energy that could be theoretically released.

A kilogram of mass (~2¼ lbs) is equal to 21,500,000,000,000 Calories. So eating 900 extra Calories a day adds ~1 ten-billionth of a gram in mass daily. While this sounds great for minimal weight-gain, the energy is actually chemical free energy which binds atoms into 100 grams (~⅓ lb) of fat daily; not such good news for health. Conversely, the energy released by the Hiroshima atomic bomb was ~0.7 grams of mass; also not good news for health.

$$E = mc^2$$
$$\left(\text{e.g. } 1\text{kg} = 21.5 \times 10^{12} \text{ Calories}\right)$$
$$C = \frac{5}{9}\left(F - 32\right)$$
$$\left(\text{e.g. } 100°\text{C} = 212°\text{F}\right)$$

Einstein's-revolutionary formula equating energy and mass is actually a simple change of units, and is akin to the formula for converting different temperature units.

Matter: Mostly Empty Space

Next to go was the concept of hard, massy spherical atoms. In the early 1900s it was revealed that most of the volume of an atom is filled with a haze of small-mass electrons (~1/2000th the mass of a hydrogen atom) while 99.9% of an atom's mass is packed into a minuscule nucleus at the atom's center. The diameter of the nucleus is ~1/100,000th that of the atom; the massive nucleus taking up just a millionth billionth the volume of the atom. This is akin to a pea floating centerfield at Yankee Stadium! The density of lead is a ponderous 11 gm/cc but the density of an atomic nucleus is ~10 trillion times more dense than this —like squeezing the mass of the Sun into something the size of Manhattan!

The lesson is that our senses are fooled to see what the Designer intended us to see; it takes great effort to reveal what is actually the mechanism, deep beneath the surface, that is generating the appearance of our everyday experience.

Spacetime: a Physical Entry That Can Twist and Bend

Einstein had two great insights—neither of which earned him his Nobel Prize for understanding the photoelectric effect—Special Relativity (involving constant velocity) and General Relativity (involving changing velocity).

In Special Relativity Einstein conjoined space and time into a coherent whole—spacetime—where their obvious difference was recognized by measuring time with real numbers and space with imaginary numbers, along with the speed-of-light constant *c* to keep the units the same. Spacetime had four axes— ±tc, ±ix, ±iy, ±iz — where the distance measure between two points, *d,* was the Pythagorean relation and recognizing that the square of imaginary numbers were minus-real numbers. This is the spacetime *metric* that measures separation between locations in spacetime.

$$d^2 = t^2c^2 + (xi)^2 + (yi)^2 + (zi)^2$$
$$d = \sqrt{t^2c^2 - x^2 - y^2 - z^2}$$

Note that the original concept was real space and imaginary time. Later, the understanding was that + time and –time axes were essentially different, while ±space axes were not. This is inherent in the symmetry of the mathematics of repeated multiplication—of crucial importance—where +1 is a cycle of 1, –1 is a cycle of 2, and ±i is a cycle of 4 circling the plane in anticlockwise (L) or clockwise (D) directions. While up and down are relative—depending of where you are on the Earth—past and present are irrefutably no matter where you are on the globe.

+1	+1	+1	+1	+1	one cycle
−1	+1	−1	+1	−1	two cycle
$+i$	−1	$-i$	+1	$+i$	L4 cycle
$-i$	−1	$+i$	+1	$-i$	D4 cycle

Cycles by repeated multiplication

So energy in the concentrated form of mass alters spacetime. For this to happen there must be something in common that can convey the relation. The simplest concept is that energy is a disturbance in spacetime. The physical world is constructed out of of two types of entities, disturbances in spacetime:

1. Fermions: the quanta (bits) of matter, such as the electron and quark
2. Bosons: the quanta of force, such as the photon and gluon.

Both types are tiny twists in the spatial components spacetime: fermions are non-oriented twists (e.g. Moebius twist) while the bosons are oriented twists. There are three types of spin-½ fermions and three types of spin-1 quantum bosons that differ in the number of spatial components that are twisted along the positive time axis: 1, 2, or all 3 (detailed in a later section).

According to Special Relativity, all these entities are moving at lightspeed through spacetime, although the components differ along which they travel: light photons speed solely along the spatial while atoms speed mainly along the time component. This movement disturbs spacetime and the ripples—like a duck sailing through water—are the cause of gravitational attraction. These ripples are call *gravitons*.

The relation between disturbing spacetime and energy is explicitly seen in photons, the bosons of light and the electromagnetic interaction.

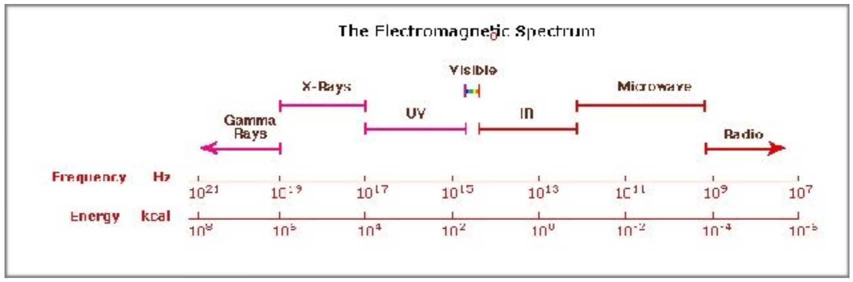
The photon has two axes of spatial components in an oriented twist; one is called electric and the other the magnetic. If the photon is speeding along the x axis, the electromagnetic axes in a twist are y and z. The energy in these twists is constantly oscillating from one to the other, and the number of oscillations in one second is called the frequency of the photon. The time period is the inverse of this: a frequency of 60/second has a time period of $1/60^{th}$ second.

In yet another example of how our sense perceptions of reality are contradicted by contemporary science; while we sense that existence is continuous, it is not; it is pixelated. The measure of existence is called *the action*, and it has the units of energy-in-time. As we have no sense whatsoever of the granularity of existence, it is obvious that the quanta of existence are tiny. A quantum of existence is called *Planck's Constant,* symbol *h,* and in human units it is 6.63×10^{-34} joule-seconds (a joule is ~⅕ calorie). So if a calorie of energy is around for a billionth trillionth trillionth of a second it is a real calorie. If, however it is around for a trillionth, trillionth, trillionth of a second it is not real, it is a *virtual* calorie and the Law of Conservation of Energy does not apply.

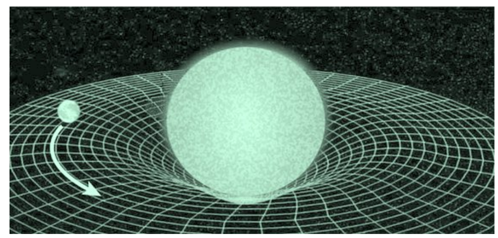
This leads to yet another non-intuitive aspect of the physical world: the empty vacuum is constantly flipping into virtual pairs of bosons on fermions which recombine before amounting to a quantum of existence. While not real, these effervescent quanta influence things: the understanding of the structure of the atom, for example, needs to include the ephemeral presence of these virtual particles to give accurate predictions.

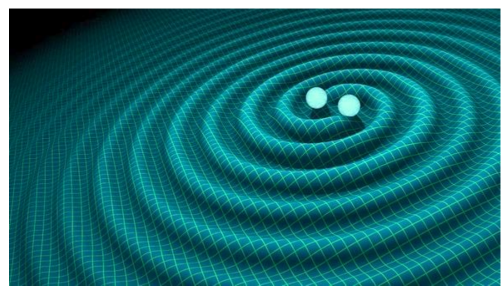
Theoretical scientists find arithmetic as prone to error as do most people: dealing with human units where Planck's Constant is 6.63×10^{-34} J sec or lightspeed is 299,792,458 m/sec is annoying, so they simplify things into simple Natural units where Planck's Constant h = 1 and lightspeed c = 1.

In these units, every type of photon has two things in common: they all move at a velocity of 1 and they all have 1 quantum of existence. Each photon has energy-in-time =1. If the energy is 60, the time period is 1/60; if the energy is 1,000,000 the time period is 1/1,000,000. Long time period = small energy (e.g radio waves; short time period = large energy (e.g. gamma rays), a relation discovered by Planck and usually expressed as E=hf. As the frequency, f, is just 1/T, this equation, E=h/T rearranges in natural units to: ET=1.



The basic message here is that while the slow oscillations of a radio wave hardly stress spacetime and hence have small energy; the frenetic ones of gamma rays stress spacetime and hence have a great deal of energy. The in-between oscillations of visible light are just right with sufficient energy to stimulate our eye pigments but not enough to destroy them.





All energy is disturbance of spacetime, and mass moving through spacetime creates ripples. These tiny ripples in spacetime are the 4th type of boson, the spin-2 gravitons that like photons in a laser, unite together statically to create the curvature in spacetime—a gravitational field—or dynamically to create a gravitational wave. Such a wave, though long expected, was only recently discovered. This first example being generated by the coalescence of two neutron stars.

The century-old concept of relativity is that there is no absolute standard by which to measure space and time. Recent developments, however, have revealed that there is an absolute measure of velocity through space and the passage of time. This universal reference frame is called the Cosmic Microwave Background (CMB). It provides a frame of reference for moving through the universe as the CMB is blue shifted in the direction to which we are moving, and red shifted in the direction from which we are moving.

Our galaxy is moving at 2.2-million kilometers an hour towards a concentration of matter dubbed the "Great Attractor," This is a concentration of many galaxies in intergalactic space at the center of the local Laniakea Supercluster, in which the Milky Way is located. This is notoriously difficult to observe in visible wavelengths due to the obscuring effects of our own galactic plane. Setting the speed of light at 1, however, this enormous velocity is just 2x10^{-3}. The time dilation is jus 1.000002 according to the equations of Special Relativity.

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Both inertial and gravitational mass involve energy moving in spacetime, so their equivalence is not so surprising in modern science. In this new view, spacetime and disturbances in spacetime—energy. mass—have an obvious base in common for relationship, so their couple is not so odd after all.

2. Particle & Wave

To understand the fundamental entities out of which the physical realm is constructed, we will need a brief math primer.

Complex Numbers

The natural world embraces two basic types of movement, of change and development:

1. Linear extension—straight motion
2. Angular rotation—circular motion

The arithmetic we are exposed to at the earliest education in mathematics is the natural counting numbers: 1, 2, 3…. Later, we learn about fractions, the ratios of numbers: ½, ⅔ , ¾… and the integers such as 0, –1, –2… Even later we grapple with the irrational numbers that have an infinite representation such as the algebraic $\sqrt{2}, \sqrt{3}, \sqrt{6}, \sqrt[3]{11}\ldots$ and the the transcendentals such as π, **e**, $\pi^{e}\ldots$ All of these are dealing with linear extension along the *real* number line. Along the way, we also encounter angular measure, such as 45°, 90°, 180°, 360°, which is treated in quite a separate manner to the linear measures.

Nature, however, does not treat these two measure separately. Mathematicians developed *complex numbers* to deal with both types of measures combined. A positive number such as +1 has a rotation of 0°; A negative number such as –1 has a rotation of ±180°. The number 1 when rotated by 90° counterclockwise is called +i, when clockwise, it is –i. As it is common knowledge that 90° + 90° = 180° it should not be a great surprise that ±*i*, when squared, equals minus one, and is thus *i* is the square-root of minus one.

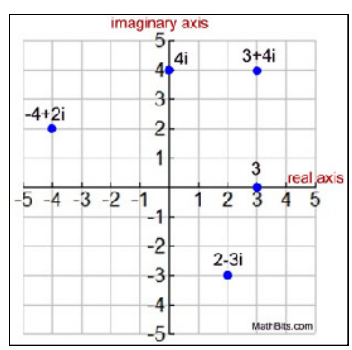
$$(+\boldsymbol{i})^2 = (-\boldsymbol{i})^2 = -1$$

degrees	radians
45	π/4
90	π/2
180	π
360	2π = 0

The angular rotation, like the linear size, is not restrained, it can be any angle with the caveat that 360° is a full circle, or back to 0°. The Babylonian-established degrees have been replaced in science and technology with the length around a unit circle, called radians.

While all the everyday real numbers—be they natural, integer, fractional, irrational or transcendent—can be diagrammed on the *real axis*, a 1-D line from minus infinity through zero to positive infinity, complex numbers cannot; they need a 2-D plane to be diagrammed, the complex plane.

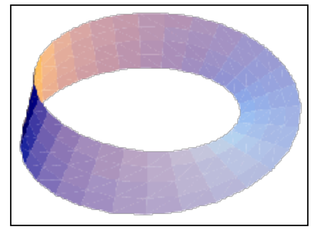
Rather unfortunately, these complex numbers are usually not encountered until university, or in more enlightened High Schools, in an AP math class. This is unfortunate for, in yet another of example of Nobel Laureate Eugene Wigner's "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," only the sophistication of complex numbers is capable of dealing with a plethora of situations in the theoretical and applied sciences and technologies.



For instance, all the recent miraculous developments in electronics have their root in the great dispute between Edison and Westinghouse over the usefulness of direct current (DC) or alternating current (AC). While AC had the advantage of being readily converted from high-voltage/low-current to low-voltage/high current situations—a flexibility lacking in DC—the AC circuits refused to obey the established electric laws such as Ohm's Law. It was only when complex arithmetic was used combining linear voltage with angular frequency that these problems were resolved and AC attained the prominence it has these days. (Note, that as *i* was already used in electric calculations to symbolize current, electronic theorists use *j,* not *i* to symbolize a 90° rotation.)

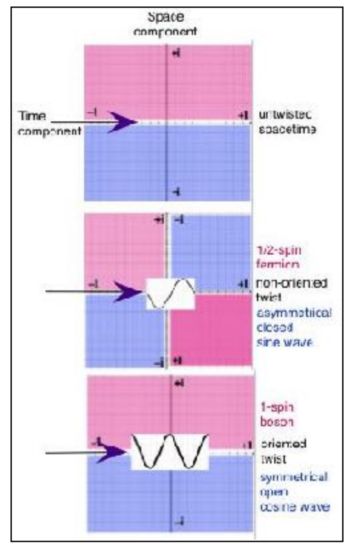
External Particle

We have already noted that spacetime has four complex dimensions but that only one component of each four is in the structure of spacetime: the real component for time, the imaginary components for the three space dimensions.



Twisted Spacetime

We have already discussed how spacetime can be curved; now we will discuss how spacetime can be twisted. As spacetime has to remain rectangular—a point to be disputed later—there are only two types of twist in a spatial component: a 180° and a 360° twist along the time axis.



If a circle of ribbon with two clearly defined sides is cut, one end twisted 180°, and the ends resealed, the result is a Moebius strip where there is only one side and you have to circle twice to get back to your original orientation. This is an example of a non-orientated result of a 180° twist-and-seal.

If, however, the cut end is rotated 360°, there are again two defined sides and a single circle will return the original orientation. This is an example of an orientated 360° twist-and-seal.

Given sufficient energy, the spatial components of spacetime can rotate-and-seal about the time component in either a non-oriented, an oriented manner. The non-oriented twists are asymmetrical closed waves—they have zero amplitude at the ends e.g. a sine wave. The oriented twists are symmetrical open waves—they have maximum amplitude at the ends e.g. a cosine wave.

Bosons

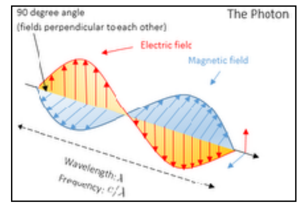
The oriented twists in spacetime are called bosons. As 1, 2, or all 3 spatial components can be twisted along the time component, there are three basic types of bosons, as tabled, each with its historical name. (I am calling the weak bosons 'wosons' to simplify nomenclature).

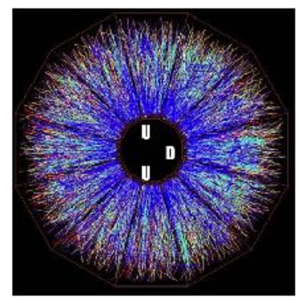
ORIENTED	
twisted spatial components	**Name**
1	woson
2	photon
3	gluon

The bosons are not as complex as the fermions. Being symmetrical, flipping the time axis changes nothing and there are no anti-bosons. They are, however, open waves with all their energy at the boundary. The abrupt change at the boundary is a huge distortion of spacetime which gives the simplest woson, the Z, an immense mass-energy of ~90,000,000,000eV.

Some of this energy energy can be used to ½-twist a second (electric) component generating slightly lower mass bosons with a positive or negative electric charge, the $W^{\pm}$ with mass-energy of 'only' 80,000,000,000eV. With such enormous energy, virtual wosons have the briefest flicker before amounting to a quanta of existence, and even at lightspeed, cannot get very far. This is why the halo of wosons that surrounds all fermions is tiny even on the scale of the atomic nucleus. Coupling with wosons is the Weak interaction of all fermions, and it is the infinitesimal reach of the halo that makes it so frail. Then again, it is this frailness that prevents our Sun from converting its hydrogen into helium in 10,000 years rather than the estimated 10 billion years it will take—5 billion more years—before its fuel runs out.

The photon has two open waves, and might be expected to outweigh the wosons. The reason it does not is that the energy resonates from one wave to another and is never in one long enough to create a real boundary in spacetime. The oscillation is such that the energy is never in one place to amount to a quanta of existence. The photon has no mass-energy, all its energy is in the oscillations of the two components, the disturbance in the equilibrium of spacetime. It is able to pass through spacetime along the spatial components at lightspeed, as do virtual photons who couple the electric and magnetic fundamental forces





The gluons have all their energy at their boundary, so all the mass-energy of a nucleon—and thus the atom—is in a shell surrounding the quarks which have cast off their color onto the gluons and reside peacefully in the core with only their electromagnetic charge making it into the larger world.

Fermions

The non-oriented twists in spacetime are called fermions. As 1, 2, or all 3 spatial components can be twisted, there are three basic types of fermions, as tabled, each with its historical name. Overlaid on this simple pattern are issues we will just briefly mention:

Antimatter: Being asymmetrical, if the time axis of the twist is reversed the fermion becomes an anti-fermion. Fermions and anti-fermions mutually untwist and annihilate into photons.

Charge: Spacetime attempts to shake off the ½-twist of the fermion which is topologically stable (unless it untwists with an antifermion) resulting in a cloud of corresponding virtual bosons surrounding it. In this sense, all fermions are actually composite, not elementary. The weak charge is the first twist (hence common to all fermions), the electromagnetic charge is two twists, and the chromomagnetic by three twists. It is the coupling with these virtual bosons that are the interactions of fermions.

NON-ORIENTED		
twisted spatials	Name	coupler
1	neutrino	wosons
2	electron	+photons
3	quark	+gluons

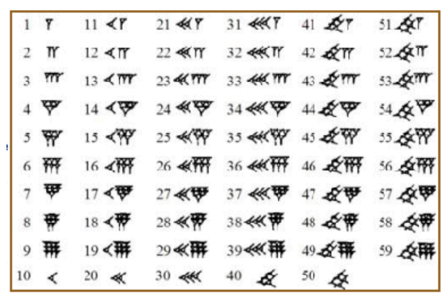
Mass: A single closed twist hardly disturbs spacetime and the neutrino has a minuscule mass-energy of ~1eV. Two twists are disturbing and the electron has a mass-energy of ~500,000eV. Three twists are so nasty that they pull spacetime out of its rectangular norm of 90° into an hexagonal form of 120°. This abuse is only tolerated because it is severely confined and neutralized by sets of complementary quarks. A single quark is an abomination that spacetime will not tolerate.

The set of complementary quarks united as a nucleon has a mass-energy of ~900,000,000eV. In going to the hexagonal form, one axis is unchanged, the #1 spin (magnetic) axis. As there are three possibilities—x, y, z,—there are three quantum *colors* to quarks—R, G, B. The electric #2 component is distorted in two possible ways when altering 90° rectangular spacetime to 120° hexagonal form—it can lose 60° resulting in a ⅓ electron charge (a D-quark), or it can gain 30° and reverse along the time axis resulting in ⅔ anti-electron charge (a U quark). Luckily for us, and unlike the other two generations, the D-quark has slightly more mass than the U-quark which allows protons (UUD) to be stable and neutrons (DDU) to be slightly unstable,

Generations: All fermions can be thought of being constructed on the single twist of the neutrino in 1 space component. A neutrino, however, can have its single twist in 2 components—called a muon-neutrino—or all three components—called a tau-neutrino. The other fermions are constructed on these bases giving the three generations of fermions: the electron family, the muon family and the tau family. As might be expected, the second and third generations are all more massive, the third-generation T-quark having ~170,000,000,000eV of mass-energy.

All of the above can be summarized as: Both the quanta of matter and the quanta of interaction-force are localized disturbances in spacetime, a subset of a 4-D complex hypervolume. While scientists have had to accept that spacetime—an appearance of utterly empty space and time—is an aspect of reality that is more than just a nothingness, there is yet another aspect to our universe that has to be taken into account.

Mathematics



One of the Great Debates is whether the utterly abstract realm of mathematics is discovered or invented. Is mathematical truth an aspect of reality that can be explored and illuminated? or is it just a creation of the human mind, like a poem or a myth?

It is certainly true that in humanity's effort to understand this abstract realm, the symbolism, the language used, has varied with culture (such as the illustrated Sumerian symbols for the counting numbers). It was the ancient Greeks who perfected the method of proof. Before them, the Egyptians empirically knew that in a triangle with a right-angle enclosed by two sides equal to 3 and 4, the opposite side was always 5.

It took a Pythagorean genius, however, to prove that in any (flat) triangle with a right-angle enclosed by sides x and y, the opposite side, h, always obeyed the relation $x^2 + y^2 = h^2$—the Egyptian case was just an example: $3^2 + 4^2 = 5^2$ (9+16=25).

It was only 2,000 years later that the concept of a non-flat, curved space intruded and insisted on the bracketed caveat 'flat' to be added. But in a flat space, it could not be any other way.

Much of math is taken up with proof—showing that it could not be any other way. Take, for example, the statement that there is no fraction—a ratio of integers—that is exactly $\sqrt{2}$.

The proof of this statement has a few layers:

1. A *factor*, f, of a number, n, divides it with remainder of 0. Every number, n, has two trivial factors, 1 and n.
2. A prime number, p, has has only the trivial factors, 1 and p.
3. A composite number has a unique set of prime factors, p^n q^m …
4. The square of any number has a set of factors to an even power, p^2 or p^{2n} q^{2m}…
5. An even number has 2 as a factor. As dividing 0 by 2 leaves no remainder, 0 is an even number. An even number plus one is an odd number
6. An integer cannot have a prime factorization that includes both 2^n and 2^{n+1}

Using these, the proof is simple: Assume that $\sqrt{2}$ is a ratio of two integers, $\sqrt{2}=n/m$.

Squaring both sides, $2 = n^2/m^2$, all integers, and $2m^2=n^2$.

The integer on the left has an odd power of 2 in its prime factorization, the integer on the right an even power of 2 in its prime factorization. By point 6, this is impossible, so $\sqrt{2}$ cannot be the ratio of two integers.

Clearly, it cannot be any other way: a fraction can never, when squared, equal 2. Not even the most adamant of those who think that math is a human invention, however, when pressed would admit the possibility of 2 having a fraction as a square root even during the tumult of the Big Bang, and if pressed further, before the origin of our universe.

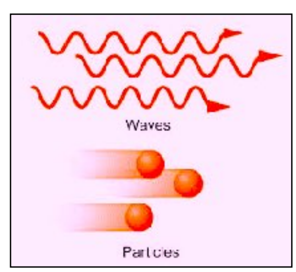
The reason why I am pressing for abstract math being an aspect of physical reality is that the next step in our discussion necessitates accepting the abstract realm as an actual aspect of physical reality.

Internal Wavefunction

Classical Physics, the beginnings of modern science, begrudgingly accepted that the behavior of matter was governed by abstract, mathematical laws. Some considered natural law to be created by God; others thought they were just precise descriptions of the way matter behaved. In either case, the assumption was that natural law acted directly on matter to determine/describe what would happen. This was a cause of great theological debate: If we were ruled by natural law where was there room for free will, personal responsibility, sin and redemption, etc.

Some took the patently ridiculous position—if God is a heavenly father as proclaimed by Jesus—that God had already determined who was a sinner and who was a saint. Others decided that there was no God and we created our own rules.

Neither position was needed because modern science discovered that natural law did not directly rule the physical world. Modern science found that there was an aspect of physical matter that was directly determined by natural law; but it was not matter itself.

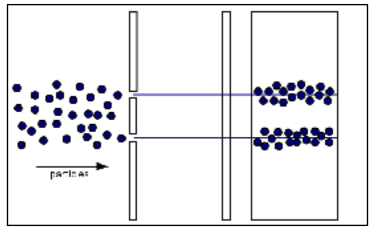


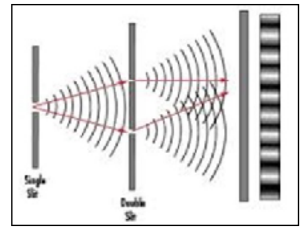
Particle and Wave

This novel aspect of physical reality uncovered by scientists in the early 1900s is called the *wavefunction*. In classical physics (and everyday experience) there is a clear distinction between a particle and a wave:

1. A particle is local, it can exist in only one location at a time, it has a position in space, it travels in one piece along a single trajectory, left alone it has a defined and constant mass.

2. A wave is non-local, it can exist in many locations at the same time, it does not have a defined position in space but spreads out over time and space, it has no mass but has energy in the wave motion that depends on the square of its amplitude.



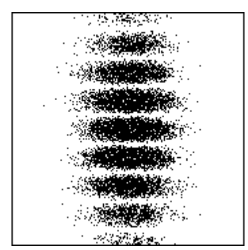


The simple experiment defining the difference between particle and wave is the double *slit experiment*. A stream of particles hitting a barrier with two slits in it will create two piles on the other side. A wave will divide into two waves that will interfere with each other—where they are out of phase the combination is diminished, where they are in phase the combination will be enhanced.

The results distinguish between the two: particles create two defined bands, waves create an interference patterns. This experiment is successful with macroscopic entities; it clearly distinguishes the behavior of shotgun pellets and water waves. It failed miserably, however, with entities at microscopic levels. When asked questions such as: Is light composed of particles or waves? Are electrons particles or waves? Is the buckminsterfullerene molecule, a cage of 60 carbon atoms, a particle or a wave? In all such cases, the answer came back: They all behave as both particle and wave.

In the 1600s, Newton, the esteemed founder of classical physics, speculated that light was a stream of particles, while Huygens dissented with his argument that light was a wave. It was only in the 1800s that Thomas Young settled this debate—apparently—in favor of waves with his double slit experiment. A beam of light when passed through a double slit created a distinctive interference pattern at the detector; case proved.

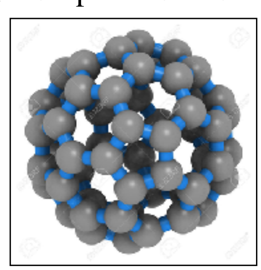
Not so! Later experiments with faint beams of light and very sensitive advanced detectors revealed that light arrived at a single location, as would be expected of particles, and it was only with the arrival of a multitude of spots that the interference patter emerged.



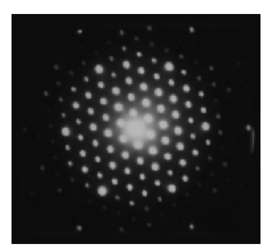
Single photon diffraction

Dots that appeared when a single slit was opened, were absent when both slits were opened—it seemed the light particle, given the name *photon,* interfered with itself passing through the double slits.

Electrons were long considered as particles; they always were located at a single location. Yet experiments with slits just atomic distances apart—as in a crystalline lattice—showed that electrons also had a wave-like aspect complementing their particle-like aspect.



Buckminsterfullerene



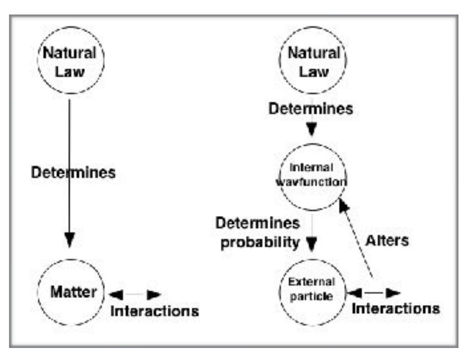
Electron diffraction pattern of a crystal

Einstein actually receive his Nobel Prize, not for the great insights of Special and General Relativity, but for explaining the photoelectric effect with the concept of particulate photons. The puzzle he solved was that an intense beam of red light could not liberate an electron from a metal; but a faint beam of blue light could. While it took a great deal of experimental expertise to show that the eminently-particle buckminsterfullerene, a molecule of 60 atoms, also showed a diffraction pattern when passing through a double-slit experiment, the race is still on to show wave-particle duality in an entity as complex as a virus—millions of atoms—or even a bacterium—billions of atoms.

Even such simple situations as light being reflected from a plate of different thicknesses of transparent glass seemed to suggest that the light had prior knowledge of how thick the glass was before ‘deciding’ whether to reflect or pass on through the glass—some thicknesses had zero reflection while others had maximal reflection.

The concept that all fundamental entities had the behavior characteristic of both particles and waves is known as *wave-particle duality.* This counterintuitive aspect of physical reality is described with delightful exuberance in ‘QED: The Strange Theory of Light and Matter’ by Nobel laureate Richard Feynman (although he does underestimate his audience’s ability to embrace complex numbers) so there is no need to go into detail here; a summary will suffice:

1. Physical entities have two aspects: a external aspect that is fully described by real numbers—the particle; and an internal aspect that can only be accurately described by complex numbers—the wavefunction.
2. The particle aspect is localized in spacetime, the wavefunction is not.
3. The square of the magnitude of the wavefunction at a spacetime location determines exactly the probability that the particle will be at that location.
4. Interactions of composite systems are the coupling with its subsystems. For fermions, these are the halo of virtual bosons that engird it.
5. While the probability of interaction between entities depends on the internal wavefunction, the primary determinant is the spatial closeness of the particle aspects so that the wavefunctions significantly overlap.
6. The wavefunction has absolute control over the particle. If the wavefunction determines that there is a 50% probability of being in location A and a 50% probability of being in location B, the particle will spend half the time in A and half its time in B even if the locations are lightyears apart in space. This is the phenomena known as *entanglement*.
7. Interactions of the particle alter the wavefunction in ways determined by natural law.
8. The wavefunction of a composite system is the composite of the wavefunctions of all its subsystems.
9. Causality: The natural law determines the wavefunction; the wavefunction determines the history of the particle; the location of the particle determines its interactions; the interactions determine the development of the wavefunction. This is more sophisticated a view than classical physics where natural law was thought to determine directly what happens to matter (with its obvious problems for our precious sense of free will).



Conclusion

We have described how all the constituents of matter are actually energetic disturbances to the 4-D complex dimensions of spacetime, and the externals that we interact with. The wavefunction is a 5th complex dimension that has a common base for interacting with the 4 complex dimensions of spacetime. Particle and wave are not such an odd couple after all.

While not Odd Couples, modern science has opened a new vista for dealing with concepts anathema to classical concepts: Space travel; Two realms in the cosmos; The unreasonable effectiveness of Math in science.

Interstellar Migration

As an aside, we should note that the phenomenon of entanglement just mentioned opens up a new perspective on travel to the distant stars and galaxies. In classical science, lightspeed is the maximum for travel between two locations. While 67,000,000 mph is extremely fast by earthly standards, for traveling beyond the solar system it is way too slow, taking 4 years just to reach our nearest-neighbor star. Theory also states that we will have to travel at less than this maximum so it would take longer.

Entangled pairs are created by many natural processes throughout the universe. Our Earth is constantly being bombarded by entangled particles from the rest of the universe. Only one of an entangled pair reaches us, of course, while its partner has been traveling in the opposite direction at lightspeed (for photons) or slightly less (for protons etc.). Interstellar space is such an excellent vacuum that such a pair can travel for billions of years without interacting and losing their entangled connection. So the one hitting the Earth can have an entangled partner for off in our galaxy or in any galaxy billions of lightyears away. Most, of course, will be somewhere in the vast, empty interstellar and intergalactic space. But a few will be close to somewhere special, another solar system.

All we need is to capture the local one, open up its interstellar connection, and leap across these vast distances. Ignoring all the obvious technical details that need to be solved, the most immediate challenge is that the Earth's atmosphere is a potent agent of decoherence ruining any entangled partner hitting it. Fortuitously, the Moon does not have this barrier to interstellar transport, all the entangled particles reach its surface with their connections intact.

This implies that research into entanglement should take place on the Moon. This makes sense as billions of dollars are spent on Earth generating and maintaining a lengthy vacuum hard enough for experiments to proceed. On the Moon, the opposite is true: a hard vacuum is all around for thousands of miles, while the challenge is keeping the scientists warm and breathing in a cosy habitat. For this to be feasible, we will have to abandon clumsy and expensive rockets for a space elevator to make the Moon a convenient destination.

Physical and Spiritual

In the brief mentions of mathematics, we noted that spacetime, the Natural Law that governs the behavior of fundamental entities, the Natural Patterns that govern the forms and behaviors of atoms and molecules, are all described by complex numbers.

The oddest is spacetime, where the metric that governs separation in the physical realm—the components illustrated in red—only involves four components, half of the eight existing with four complex dimensions. The (+1t)-component is involved in the structure of matter, while the (–1t)-component is involved in the structure of anti-matter. The oddity is what happened to the four missing components, the ones illustrated in blue.

spacetime	Re	Im
x	+1 −1	±i
y	+1 −1	±i
z	+1 −1	±i
t	+1 −1	±i

Luckily in this day and age we do not have to look for for an answer. For modern science has discovered that the cosmos has two distinct, but complementary, components.

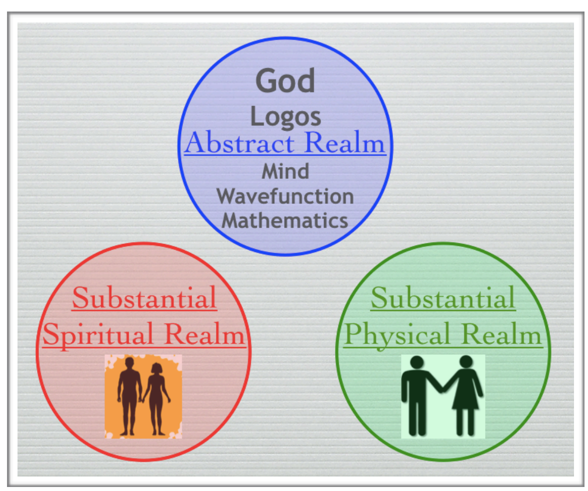
Approximately 30% of the cosmos is the visible, physical universe of visible regular matter that has a distinct tendency to clump together under the influence of gravity.

The other 70% is invisible *dark energy* that has the opposite tendency to expand under the influence of what can only be called anti-gravity.

While it is pure speculation for the time being, we can assume that the metric of this dark energy universe is the blue components absent from the physical universe.

While some sciences are speculating about a multiverse of 10^{500} of which ours is but one with the goldilocks luck to be just right for life to exist and flourish, most cultures in history have adhered to the religious concept that there one other realm, a spiritual universe, in which humans inhabit after their physical development is finished. The Occam view—do not unnecessarily multiply entities—is much preferred in science. For this reason, we will assume that the one spiritual realm that religions teach about and the one scientific universe of dark energy with its complementary metric are really discussing the same thing.

This duality in the cosmos was theoretically noted by one of the most significant physicists of the 20th century, Paul Dirac, winner of the 1933 Nobel Prize in Physics He combined Einstein's relativity with quantum mechanics in famous equation that has stood the test of time. It has two solutions, one positive energy and regular gravitational matter, the other negative energy and anti-gravitational matter. When anti-matter was discovered, it was assumed that this corresponded to the second solution. This is faulty, as anti-matter has positive energy and regular gravity. One prediction of this second solution was tachyons, particles where lightspeed was a lower limit, that when they gained negative energy they slowed down asymptotically to lightspeed.



Significantly, this does correspond to an aspect of the spiritual realm as taught by many religions as the Golden Rule. Taking selfishly from others, using them for your own benefit, increase your energy. This slows you down in the other realm, you are sluggish and in the cold of Hell. Giving unselfishly to others, living for the benefit of others, decreases your energy, so you are free to fly far and wide in the warmth of Heaven

It remains an open question, however, if the spirit realm corresponds to the 70% of the cosmos that is dark energy. We do not even know if the wavefunction that organizes physical energy also organizes dark energy.

So there are three realms to the Cosmos—embracing everything—the Abstract realm where God, the Logos, the mind, wavefunction and mathematics reside; the Physical realm where we spend ~100 years becoming human, and the Spiritual realm where we spend eternity.

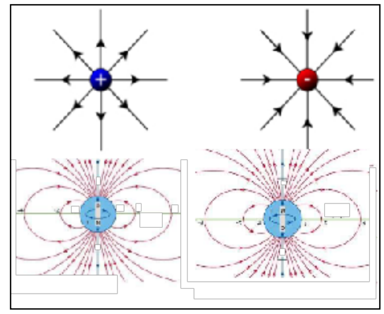
Math and Matter

In a famous address to scientists, Nobel Laureate Eugene Wigner discussed "The Unreasonable Effectiveness of Mathematics in the Natural Sciences." From the view of classical science, it would seem that concrete matter and abstract math have so little in common that their fervid embrace in the hard sciences—one using precise math-language not fuzzy natural language to describe its findings, the aspiration of all the sciences—is unreasonable. In the modern view where spacetime, matter and Natural Law are all mathematical entities, a common base for relationship is not at all unreasonable.

3. MIND & BODY

Fermions, bosons and wavefunctions are the basic stuff of which material entities are composed. We noted above that fermions are composite entities: a fermion swathed in a halo of virtual bosons.

The symmetrical wavefunction of bosons makes them, in anthropomorphic terms, extremely social. They have a strong tendency to join together in the same state, a phenomenon familiar in the laser where trillions of photon combine together in the same state—the more the merrier is the maxim of bosons. Virtual bosons do the same. The two different axes of the electron's twists shake off two sets of photons, the spin axis generates magnetic bosons and the other electric bosons. These unite into the magnetic field and the electric fields that surrounds the electron and, in reverse, the positron (anti-electron).



The asymmetrical wavefunction of fermions makes them monogamous: they are content to pair up with complementary spins, but the probability of a third intruding on this conjugal state is exactly zero. This *exclusion principle* underlies the pair-wise structure of the periodic table of the elements.

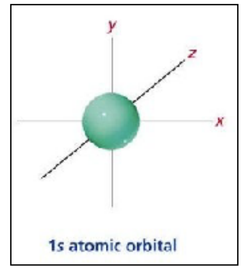
If the wavefunction says that a situation has a probability of exactly zero, it will never happen. If it is not zero, however, it has a possibility, no matter how small, of happening. This is what some have called the Totalitarian Principle of quantum mechanics: What is not forbidden is compulsory! The probability of a helium nucleus (alpha particle) escaping the energy barrier when it hits the boundary of an uranium atom is minuscule— $\sim 10^{-50}$ —but it hits the barrier a trillions of times a second. Over a time period of 4,500,000,000 years, however it has a 50-50 chance of escaping the nucleus.

System	Interacting subsystems	Coupling sub-subsystems	Natural Pattern	Emergent properties	Emergent interactions
H atom	1 electron, 1 proton	virtual photons	1s orbital	valence of 1	electron coupling

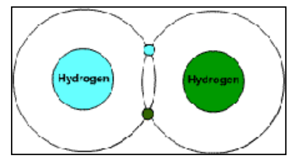
INTERACTION

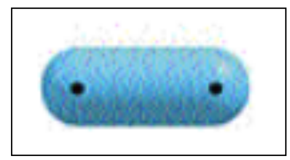
Interaction between composite systems involves sharing or exchange of some of their subsystems. While a proton has a complex internal structure, the quarks and gluons are firmly confined while the virtual wosons are too ponderous to get anywhere, so the only component of the composite nucleus that makes it out are the virtual photons. In this, the proton is like a positron that is ~1800 times more massive than an electron. Within a complex atomic nucleus the protons and neutrons couple with virtual pions (a quark/antiquark combination) that also never leave the nucleus. They only play a role in radioactivity and the thermonuclear transformation of elements deep inside stars, areas that we will not discuss here.

The complementary electric fields of virtual photons draw an electron and proton together (as would a positron, with mutual annihilation) and this alteration in both composites alters the wavefunction of both. These wavefunctions combine in the way a waves and generate a resultant wavefunction. This structure of interacting electron, and proton moving together in the resultant wavefunction is called a hydrogen atom. The proton, being so massive, barely quivers while the electron jumps about so rapidly in the wavefunction that it creates an electronic haze, a force field so to speak. It is this force field that gives atoms their apparent solidity.



This is the exemplar for systems more complex than the fundamental entities: The composite entity (hydrogen atom) is composed of interacting subsystems (electron and proton) coupling with their subsystems (virtual photons) that are sub-subsystems of the atom. In classical physics where natural law acts directly on matter, the laws are couched in linear terms and real numbers. In the quantum view, the natural laws are acting on the complex wavefunction; the result is not linear but a pattern. The resultant composite wavefunction of the hydrogen atom is a Natural Pattern and we shall henceforth use the term *Natural Pattern* rather than *natural law*. This pattern is called a 1s orbital. The pattern is a simple sphere filled with an electron cloud enshrouding the proton.

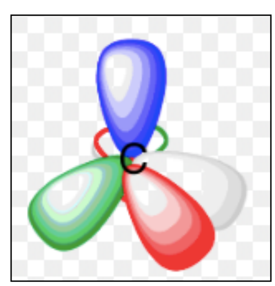




The Natural Pattern of the hydrogen atom is unbalanced with its single electron, and the atom has a strong tendency to balance it out by interacting with another atom, e.g. another H-atom, by sharing complementary paired electrons in a composite 1s molecular orbital. This is an oval cloud of the pair of electrons enshrouding both protons. This interaction sharing a pair of electrons is called a single covalent bond. This is a stable situation and, compared to a hydrogen atom, the molecule is relatively inert.

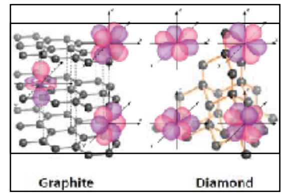
In chemical terms, the composite hydrogen atom has an emergent property called a valence of 1. The 1s molecular orbital is full, it will not accept another electron. Helium, with two protons in the nucleus, attracts a pair of electrons that also fill the 1s orbital and helium has no tendency to share its electrons and is absolutely chemically inert. The exemplar here is what happens when simple systems unite as the subsystems of a more sophisticated system:

1. The composite wavefunction has a Natural Pattern. The 1s orbital.
2. The composite has an emergent set of properties not exhibited by the subsystems. Chemical valence.
3. The composite system has the possibility of coupling with the subsystems and its subsystems. With electrons in the chemical bond, with virtual electrons in electrostatic interactions. While it is a realistic question: What is the source of the emergent properties? This is not within the real of science but the realm of theology.



While the Natural Pattern of the hydrogen atom is a simple sphere, for an atom with the six interacting protons and electrons of a carbon atom the Natural Pattern. Two of the electron fill a 1s orbital and do not participate further.

The 2s orbital and the 2p orbitals merge into four sp3 orbitals pointing at the vertexes of a tetrahedron. Each holds a single electron and the carbon atom has a strong tendency to pair these four giving it a valence of 4. For instance, a carbon atom will share electrons with 4 hydrogen atoms creating the methane molecule



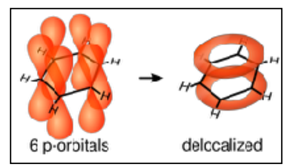
Carbon is so adept at forming compounds with itself and other elements that chemistry is divided into two: the molecules containing carbon (organic chemistry) and the molecules of everything else (inorganic chemistry. All the complex molecules in living systems contain carbon—hence the moniker—and hydrogen along with oxygen, nitrogen and others.

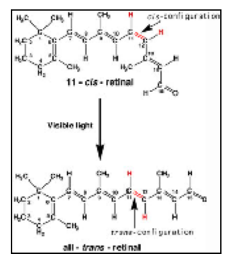
The orbitals of atoms with many electrons and protons have a Natural Pattern that can be quite unusual and give the elements their wide variety of chemical properties.

The molecular Natural Patterns govern the arrangement of the interacting atoms. Even molecules composed of just carbon can be very different as graphite and diamond. Quite a few of the elements have such, *allotropes* with a different Natural Pattern governing the arrangement of atoms.

System	Interacting subsystems	Coupling sub-subsystems	Natural Pattern	Emergent properties	Emergent interactions
Diamond	C atoms	electrons	tetrahedral sp3 orbitals	ultra hard crystal	transparent RI = 2.42
Graphite	C atoms	electrons	aromatic rings	very soft lubricant	black. opaque

From this we learn that it is not the external particles that determine the emergent properties, but that it is the Natural Pattern of the resultant wavefunction is preeminent. Another example of the significance of the wavefunction is observed in benzene , C_6H_6.. In this molecule are three double bonds—where 4 electron, not 2—are in the covalent bond. The benzene molecules has 3 *conjugated* double bond separated by 3 single bonds. Yet the molecule was remarkable stable compared to other *unsaturated* molecules. At first it was thought that the molecule resonated between two forms; 1-2-1-2-1-2 and 2-1-2-1-2-1. It was only later that it was understood that the conjugated bonds had electrons in a delocalized wavefunction that embraced the entire molecule.

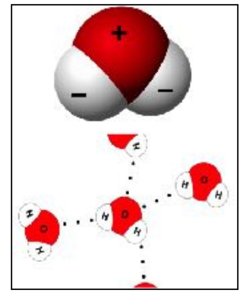




The delocalization of these conjugated bonds are essential to the functions of such key molecules in living systems as hemoglobin (oxygen transport), chlorophyll (capture of light energy), cytochromes (capture of metabolic energy), ret rhodopsin (detection of light in the retina), etc. A similar sequence supports almost all life on earth where conjugated bonds are used to capture light energy in photosynthesis that is eventually used to combine carbon dioxide and hydrogen (stripped from water) into carbohydrates.

BIOCHEMISTRY

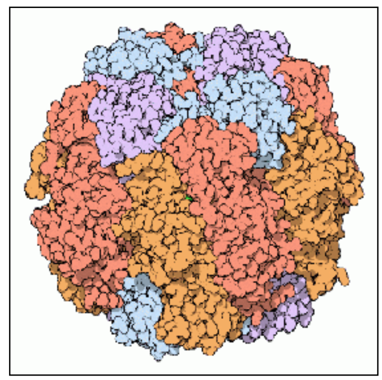
By far the most significant molecule in living systems is the simple water molecule of two hydrogens and one oxygen. It outnumbers all the other molecules—being ~70%of the adult body and ~95% of a developing embryo—and it is intimately involved in almost every biochemical interaction. Books have been written on the anomalous properties of water that make it such a great base for life on Earth, and most of these are based on the ability to couple with hydrogen atoms, the H-bond. The water molecule is polar: the oxygen pulls the shared electrons close—it is electrically relatively negative—leaving the two hydrogens relatively positive. The charges attract, and in the liquid state, the water molecules are 'sticky' to each other and to polar entities such as hydroxyl groups and amino groups. The wavefunctions of the oxygen and two hydrogens blend together into the Natural Pattern that makes it an ideal foundation for life.



As our goal is to describe the most sophisticated of living systems, we shall now leave the realm of basic chemistry and enter the realm of biochemistry, where simple molecules are combined into macromolecules.

Simplifying matters for simplicity's sake, there are two main classes of macromolecules each with mastery in quite different fields:

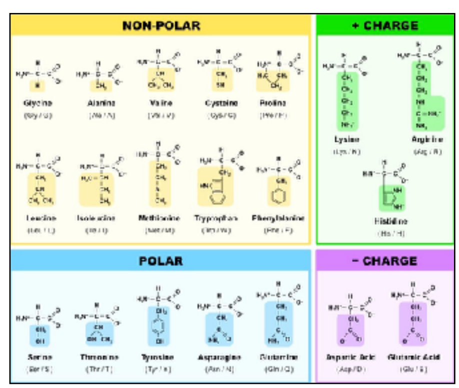
1. *Proteins:* These are masters of analog form manipulation. They are the constructors of living systems; they are the master chemists that convert carbon dioxide and water into carbohydrates, and carbohydrates into the plethora of other molecules that play a role in living systems.
2. *Nucleic acids*; RNA and DNA: These are masters of digital information manipulation. These are the molecules that carry digital information—some of which is used to generate the proteins—down a lineage for deep time to the present day.



Proteins & Analog Form

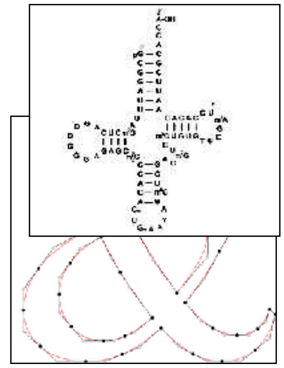
By far the most common protein on the planet earth, and probably the most important, is RuBisCO. This is the protein enzyme that absorbs carbon dioxide from the atmosphere and attaches it to a 5-C molecule that it splits it into two 3-C molecules. Other enzymes, using the energy and activated hydrogen generated by photons absorbed by chlorophyll, convert these into carbohydrates, the fuel of all life. Rubisco is a multi-polymer macromolecule of thousands of atoms. In spite of its central role, Rubisco is remarkably inefficient dealing with the almost inert carbon dioxide). As enzymes go, it is painfully slow. Typical enzymes can process a thousand molecules per second, but Rubisco fixes only about three carbon dioxide molecules per second. Plant cells compensate for this slow rate by building lots of the enzyme. Chloroplasts are filled with Rubisco, which comprises half of its proteins. This makes Rubisco the most plentiful single enzyme on the Earth.

Getting carbon dioxide, which is very stable and with little tendency to change (which is why it is used in fire extinguishers) is a very difficult chemical task. The wavefunction of all the atoms in RuBisCo blend into a Natural Pattern that is capable of such a feat.

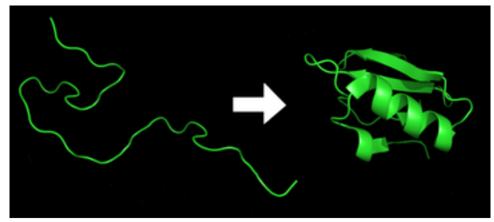


All proteins used by living systems on Earth are linear chains of linked monomers, the universal set of 20 L-amino acids (one off which is technically an imino acid). This set is universal as it is used by viruses, bacteria, pond scum. plants, fungi, animals and humans.

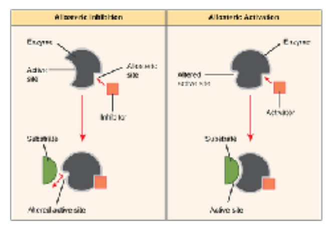
All twenty monomers have a N-atom at one end with an attached H-atom, and a C-atom at the other attached to an-OH group. Elimination of H-OH (water) between these two links the two in a peptide bond. The differences between the set of 20 is what is in-between these link-up ends, the wide variety of *side chains*.



While the role of the side chains in the eventual structure and function of the final protein is still a matter of debate, a useful analogy is the role of Bezier points in computer graphics. Simply put, any curved shape, such as the hollow ampersand illustrated, is composed of a set of control points: some for straight lines—start here, end here—some for curves—this length, this amount of curve, this thickness, this color, etc. The alphabet in a modern computer, for instance, is stored as a set of Bezier points which easily allows switching from 6 point *Times Roman* to 300 point *Academy Engraved*.



The linear chain of amino acids with their various chemical proclivities is akin to a linear set of Bezier points, they tell the chain where to bend, where to curl, where to pleat, where to exclude or embrace the surrounding water molecules, etc. The result is a precisely-folded chain with an analog shape that performs a specific task.



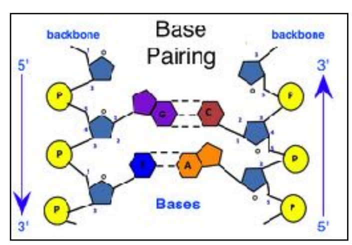
All enzymes have an *active site* where binding to the substrate occurs along with other sites that bind control molecules. These additions/subtractions cause an *allosteric* alteration in the folded form. The shape and activity of a folded protein can be altered by many factors. It might be generated in an inactive form and later activated by cutting off a section or adding on a phosphate, binding an ion such as calcium, etc.

The wavefunction of the individual amino acids blend together into the wavefunction of the protein. This gives it an analog form that determines the role that the protein contributes to the living system. The protein enzymes control all the steps in metabolism, the structural proteins are construction materials, railways for transport, transducers of signals, etc.

All these activities can be summed up as:

Proteins are master manipulators of analog form.

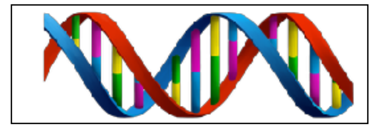
Nucleic Acids & Digital Information



The primary nucleic acid is a macromolecular polymer composed of a backbone of alternating phosphate and ribose, a 5-C sugar. Attached to the ribose is one of four ringed nitrogenous bases, symbolized by double-ring A and G, and single ring U and C.

The preeminent characteristic of these polymers is that the bases on two opposing backbones, can link up the backbones by coupling with H-atoms. As seen in the diagram, the pairing is such that the link is always 3 rings across and that A-U link with 2 bonds while G-C link with 3 bonds. Ribonucleic acid (RNA) is a single chain that can fold in water into an analog shape by pairing along its own length. It is somewhat stable in water.

A more famous cousin of RNA has reduced its affinity for water by replacing a ribose hydroxyl with a H-atom (deoxyribose) and adding a drop of oil (a methyl group) to all the Us, now called Ts. This DNA does not H-bond with water as well as RNA, and its preferred form is two separate, opposing backbones coiling around each other in the famous double helix.



Unlike previous generations, we are familiar with the remarkable uses of digital information. While the world we inhabit is filled with analog forms, when converted to compact digital information it can be duplicated, manipulated and transported with ease before being converted back to analog form. There are a few steps common to digital devices:

1. Convert analog form to digital information (AF –> DI)
2. Transport DI
3. Store DI in short-term memory
4. Manipulate DI in short term memory
5. Write DI to long term memory for storage
6. Preserve and duplicate long-term memory
7. Read DI from memory for step 4
8. Convert DI to analog form (DI –> AF)

All electronic devices—computers, DVD movies, CD music, smart phones, etc.—perform these functions with a variety of devices, silicon chips, copper wires, radio waves, etc.. Living systems also perform all these functions: RNA being responsible for all such functions except step 6 which is performed by DNA. DNA can store digital information in deep time and along innumerable lineages—human DNA shows signs of inheriting digital information stored billions of years ago in the earliest forms of bacterial life.

While step 1—turning analog form into digital information is well-understood in the electronic realm—cameras, keyboards, microphones etc.—it is a contentious issue in living systems. Darwinism assets that digital information is altered and accumulated by chance-accident, then sifted for its usefulness by natural selection. (Apple Computer aficionados sometimes accused Microsoft of using this method of software development.) Modern Creationist views assert that Natural Patterns being captured by yet-to-be established mechanisms (probably involving RNA) makes more sense based on what computer science has taught us.

Step 8 is probably the best characterized in living systems. Just as a computer translates bytes (8 bits) in letters and numbers in word processing using the universal ASCII code; all living systems translate triplets (3 bases) into amino amino acids in protein synthesis using the universal triplet code. The universality of this code is one of the facts that support the concept of a single origin of all living systems, and their divergent lineages since an origin event.

ACU = thr	AAU = asn
ACC = thr	AAC = asn
ACA = thr	AAA = lys
ACG = thr	AAG = lys
GCU = ala	GAU = asp
GCC = ala	GAC = asp
GCA = ala	GAA = glu
GCG = ala	GAG = glu

Universal Triplet code in Life for amino acids

C	0100 0011	a	0110 0001
D	0100 0100	b	0110 0010
E	0100 0101	c	0110 0011
F	0100 0110	d	0110 0100
G	0100 0111	e	0110 0101
H	0100 1000	f	0110 0110
I	0100 1001	g	0110 0111

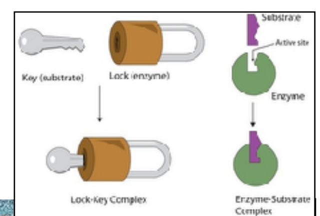
Universal ASCII computer code for letters

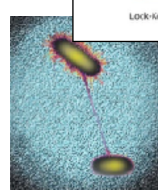
In the early days of genetics it was thought that all the digital information in DNA was used to code for proteins, and that RNA was only involved in the translation: tRNA, mRNA and rRNA. This is the case in simple bacteria.

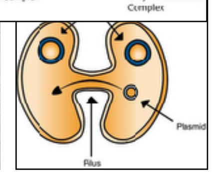
When it came, however, to eukaryotes—all the rest of life—this was not the case at all. Only ~5% of the DI stored in DNA was directly involved in protein synthesis; so the rest was considered parasitic junk. This has proved a false assumption: There are dozens and dozens of types of RNA—these day, a new variety seems to emerge every month—all transcribed (copied) from DNA that slice, dice, splice, interact, and otherwise interact with the RNA cloud that pervades the nucleus. The nucleolus, an area within the nucleus, is a particularly frenetic center of RNA activity. In this sense, it seems to act as the CPU of a computer that manipulates DI and generates an output that controls what is going on.

Based on early work with bacteria, the basic dogma of genetics was formulated: the flow of information was DNA —> RNA —> protein. This supported the prevailing concept of natural selection of random variation. The reverse process, however, was discovered in viral infections: an enzyme that could reverse the flow; copy DI from RNA to DNA. This *reverse transcription* enzyme was, at first, a novelty until further research uncovered ~600 types of reverse transcriptase in the human genome. This finding was dismissed as they were all considered inactive remnants of ancestral infections.

The problem was that current techniques were relatively insensitive to low levels of DI recall from DNA. A spectacular example of this is the SDR region on the male Y chromosome. This is utterly inactive throughout a lifetime except for about ~1 hour when an embryo is just weeks old. During this hour, it determines a protein that starts processes that cause a fetus to develop male gonads (testes) and prevent the development of female reproductive structures (uterus and fallopian tubes). If there is no SDR activity during this crucial hour, the embryo develops into the default form of a female. Such low level or sporadic recall of information from DNA is difficult to detect.

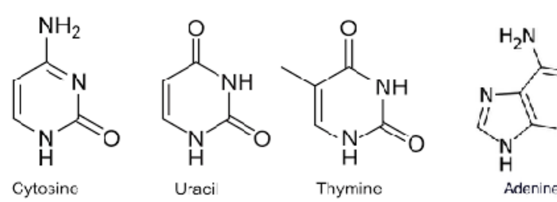






Until recently, it was assumed that cells communicated with analog signals, such as varying concentrations of Ca^{++} ions, cyclic AMP, epinephrine, acetylcholine, etc. Bacteria, however, use narrow tubes, called pili, to exchange DI with each other, so it is not really a shock that such tubes have been found to link eukaryote cells together in tissues. It is probably just a matter of time before the exchange of RNA-encoded information is detected between eukaryote cells.

All computer science is founded on binary logic, on manipulating sets—almost invariably multiples of 8—of the binary bits, 0 and 1. A simple example is the NOT logic, or 1s-complement (1-n), symbolized by ¬: where ¬1=0, ¬0=1. The actual analog form of these symbols is endlessly variable: charge on silicon, magnetic



orientation, pits in aluminum, sound tones, radio frequency, etc.

The current symbolism used in recording the digital information of living systems is rooted in the analog chemicals, the pairs A and T/U, G and C. Separating the digital logic from its analog roots would enhance the use of logical manipulations, such as 3s complement (3-n) version of NOT (which is used when nucleic acids duplicate themselves or generate RNA).

While step 1 of the analog-digital realm is still controversial, step 2 is not; digital information is carried from place to place by RNA 'wires'. Step 3 is also becoming clarified, the digital information in bacteria is not held for processing but immediately translated into analog form. Step 4 is minimal in bacterial but extensive in eukaryotes.

Step 8 is by far the best understood, at least in terms of proteins and their analog forms, where a subset of the linear digital information is translated into a linear array of amino acids—this folds into an analog form which contributes its form to the composite form of living system.

The wavefunction of the individual nucleotides blend together to generate the wavefunction of the macromolecules. For some RNA, like a protein, this creates an analog form that can manipulate other molecules (mainly nucleic acids). These are the ribozymes. By far the main activity of the nucleic acids is the emergent property for the reading and writing, the storage and manipulation, of digital information.

All these activities can be summed up as:

Nucleic acids are master manipulators of digital information.

Lock & Key or Wavefunction?

It would seem that prokaryote-size is the most efficient for such coordination and control of water structure because the sophisticated, and much larger eukaryotes are all divided internally by lipid membranes and meshes of microfilaments into thousands of ~prokaryote-sized volumes that are coordinated and unified at a higher level.

Much of the basic theory of biochemistry is based on the *lock-and-key* concept where molecules fit together because their external forms complement each other. In this view, the molecules zip around with kinetic energy (temperature) and constantly bump into each other until they collide with a matching surface and stick together. This is classical local view, that ignores the non-local wave aspect of matter. While waves blend together, they do not loses their individuality.

A perfect example of this is a choral symphony. The sound waves of the voices and instruments do blend into a pleasing whole, yet the trained ear of the conductor can pick out each source and tell how well each is performing—an incorrect play can elicit a reprimand even during a crescendo when every instrument and voice is pumping out the maximal sound waves.

The waves in a bacteria are obviously not sound waves of pressure but waves of water structure. The wavefunction of the substrate is moved by probability towards the enzyme, and so for all *lock-and-key complement*. An example of the rapidity of pairing is the PCR technology that doubles DNA every cycle. Each cycle of PCR includes steps for template denaturation, primer annealing and primer extension by DNA polymerase to generate twice as much DNA each cycle.

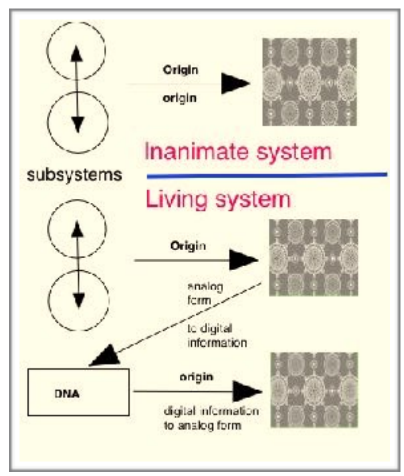
After the heat separates the two DNA strands, a primer has to find its complementary place to enable the DNA polymerase to copy the naked strand. This step tales less than a minute. In that time the pattern on the primer—a stretch of 40–70 bases, average 55—has to find and bind with the exactly complementary stretch on the DNA. As there are 4 choices for each base the number of combination is $4^{55}=10^{33}$, a billion, trillion trillion. The chance of kinetic motion bringing together one successful pair by random is infinitesimal. The complementary wavefunctions, however, can reduce this improbable happening to certainty in less than 60 seconds. This is what wavefunctions do—they alter probabilities.

A *diffusion limited* enzyme is one which catalyses a reaction so efficiently that the rate limiting step is that of substrate diffusion into the active site. A simple calculation using the size of the enzyme and substrate, and the speed at which they are moving, gives the probability that they will bump into each other in ultra dilute situations, an estimation of the kinetic limit. This is similar to the concept of *cross section* in nuclear physics. In many situations, the enzymatic activity is greater that the calculated kinetic limit due to the cross section including the wavefunction is much greater than the physical size. This is also seen in nuclear physics were a slow neutron can have a larger cross section for interaction than an entire uranium nucleus of 238 nucleons.

Inanimate and Living Systems

The fissure between inanimate and living systems—while obvious to observers—has been difficult to define. Our perspective will involve the origins of systems.

The origin of the first hydrogen atom in the universe—the paradigm of a non-living system—is essentially no different from the origin of all the other quintillion of H-atoms that followed: the wavefunction of a proton and electron merged resulting in the H-atom Natural Pattern wavefunction. This is the defining characteristic of non-living systems: the Origin event of the first in the universe—and there was a first H-atom—is no different from the origin of all the others to appear in the universe.



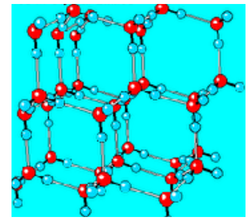
Living systems, however, are different. The Origin event of the first Natural Pattern is just like that of the inanimate realm. One of the emergent properties of life is the facility of capturing the analog form of a Natural Pattern and storing it as digital information. The Natural Pattern can be recalled by converting the digital information back into a form that resonates with the Natural Pattern.

The defining characteristic, in this view, between inanimate and living systems is that Origin (of the very first) and origin (of all the rest) are different. A magnificent example of this is that the analog forms needed to convert glucose into carbon dioxide, water and stored chemical energy were discovered billions of years ago; and the digital information to recreate these patterns has been the digital patrimony of all living systems ever since. The way we humans use glucose is identical to how bacteria use it!

Prokaryotes

The great divide in living organisms is between prokaryotes and eukaryotes—prokaryotes are like the very first simple computers in the digital-analog realm, while eukaryotes are akin to a sophisticated 2020 computer that can handle sound, videos, email, word processing, photos all at the same time.

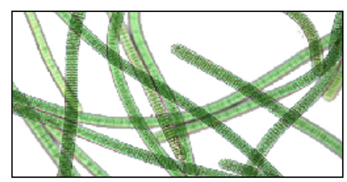
While there are two distinct types of prokaryotes—the eubacteria and the archaebacteria—their commonality is that they are a small single lipid-bilayer container with no distinct sub-containers (organelles)—especially a nucleus—dividing up the interior.



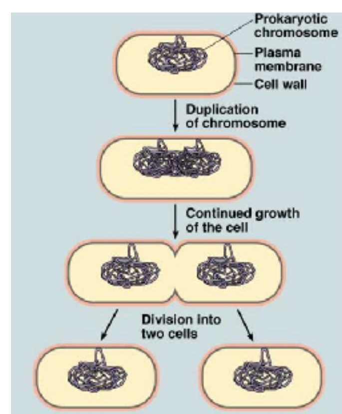
Like all living systems, bacteria are 70% water in a gel embracing all the other constituents. The water is structured and controlled by the proteins. Water molecules are most stable when all the charge dipoles are aligned in the ice structure of an open lattice. For pure water, this structure is only stable below 0 °C when the kinetic energy is incapable of disrupting it. The presence of just a few proteins can dramatically alter this.

A familiar example is Jello when just a few grams of gelatin protein can solidify a liter of water into a wobbly solid at 20 °C. Proteins can also do the opposite: during the extreme winter months, the budworm resists freezing at temperatures approaching -30 °C with only a low concentration of antifreeze proteins (AFPs) proving the protection.

The proteins in a bacteria are quite capable of controlling the water structure, and water molecules participate in the precise folding of amino acid chains into an active protein. The wavefunctions of the water, proteins, nucleic acids, metabolites, et al, combine into the Natural Pattern we recognize as life, albeit in its most simple, basic form. Life is an emergent property of this Natural Pattern to water, macromolecules and molecules.



Under ideal conditions, individual E. coli cells can double every 20 minutes. At that rate, it would be possible to produce a million E. coli cells from one parent cell within about 7 hours, in another 7 hours, a trillion, in another 7 hours a trillion trillion, etc. Clearly, such fecundity will overwhelm the resources of any environment and halt the exponential multiplication.

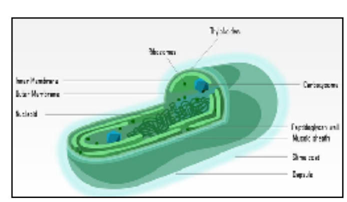


In hostile conditions, most bacteria can expel water and enter a semi-crystalline state called a spore. The spores are inactive and capable of surviving time and space until beneficence is reencountered when the spore springs into activity and recommences exponential multiplication.

The asexual reproduction of bacteria creates identical clones, and is relatively simple. The (usually) single DNA molecule storing all the digital information is attached to the cell wall. It is duplicated and the two are separated by protein activity enlarging the wall.

Cell growth continues as protein activity then puckers in the wall until it cuts the organism into two and DNA duplication starts up and the cycle continues.

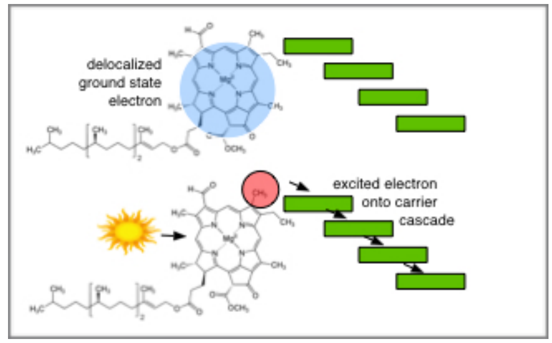
The emergent properties of the Natural Pattern of the bacterial



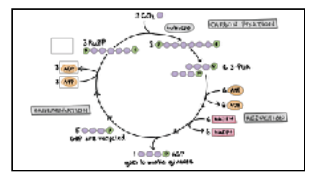
wavefunction are basically growth and multiplication.

One class of larger bacteria are the cyanobacteria. Unlike most bacteria which are heterotrophs—relying on other organisms or their products for nutriments—the cyanobacteria use sunlight, water, carbon dioxide and nitrate to generate all their needs. They have internal membranes to support photosynthesis; also they have a tendency to remain attached forming long filaments of clonal cells.

The cyanobacteria are immensely significant in the history of life; the cyanobacteria were responsible for converting the early anoxic atmosphere of the Earth into an oxygenated one, and one lineage was adopted and became the precursor of the plant chloroplast that provides nourishment for all animal life.



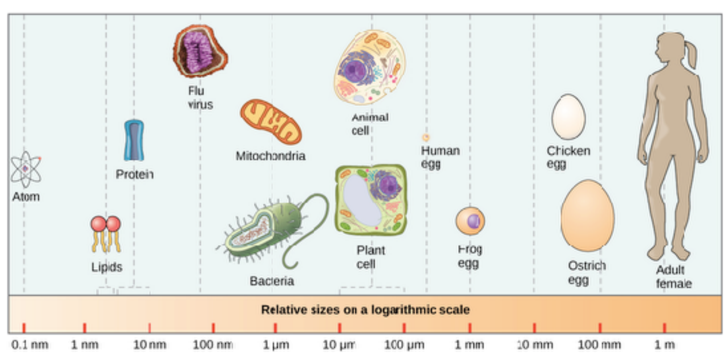
Photosynthesis, itself, is strictly dependent on the wavefunction aspect of the chlorophyl molecule, a multi-ring molecule with a magnesium ion at the very center. This has lost its two electrons now in an orbital that spans the molecule. Absorption of a photon of light, however, localizes the electron in a very small excited orbital close to the first of a chain of electrons carriers, down which the electrons flow generating ATP and activated hydrogen (NADPH). These, along with the CO_2 absorbed by Rubisco, come together to generates carbohydrate, the foundation of all metabolism.



With oxygen in the atmosphere, bacteria learnt, in essence, how to reverse photosynthesis; how to strip hydrogen from carbohydrates and combine it with oxygen and use the liberated chemical energy to assemble ATP to power metabolism. This process of oxidative phosphorylation is ~30 times more efficient than anaerobic fermentation, and it was adopted by many lineages. The mitochondria that are the energy generating organelles of animals, fungi and plants are descended from specialized bacteria (probably purple non-sulfur bacteria) that were adopted early in the evolutionary emergence of the eukaryotes.

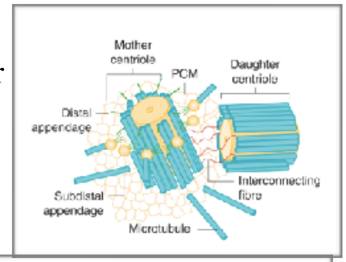
EUKARYOTES

The bacterial prokaryotes are all basically a small, single, well-organized bi-lipid pouches of water where all the various activities of DNA, RNA, proteins and metabolism all happen together. The limits of sophistication possible for this Natural Pattern have long been reached and modern-day bacteria are similar to those found in fossils created billions-of-years ago.

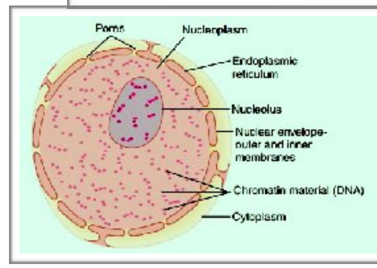


All sophisticated lifeforms—animals, fungi and plants—are based on the eukaryote cell Natural Pattern. In terms of linear size from atom to human, on a logarithmic scale the eukaryote cell fall roughy in the middle

Lengthwise, prokaryotes are ~1μm while eukaryotes are ~50μm; the volume difference is thus 1:100,000 and the eukaryote can contain a large number of prokaryote sized compartments.

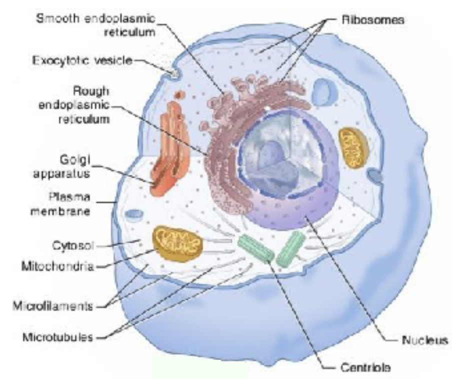


The eukaryote Natural Pattern exploits the great advantages of division of labor—the assignment of different parts of a complex task to different entities in order to improve efficiency. While eukaryotes discovered its advantages a billion years or so ago, it is now used in computers, industry, and international commerce.

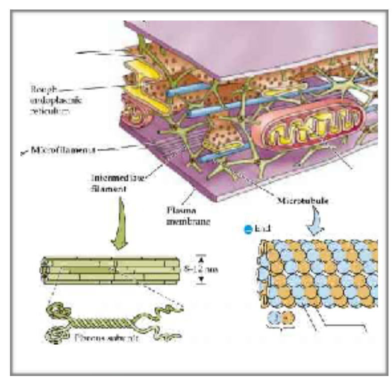


Nucleus

Just as the management offices of steel plant are isolated from the noise, heat and danger of the heavy industry, so the defining feature of an eukaryote cell is the segregation of digital information storage (DNA) and manipulation (RNA) in the nucleus away from the analog general metabolism run by proteins in the rest of the cell (cytoplasm). In a typical cell, the nucleus takes up ~10% of the total volume.



The nucleus has its own subcompartments, the main one being the nucleolus taking up ~25% of the nucleus. This is where RNA synthesis and activity is centralized. It is best known as the site of ribosome biogenesis, but the nucleolus has numerous other functions including assembly of signal recognition particles, modification of transfer RNAs and sensing cellular stress. In computer terms, the nucleolus is akin to the CPU while the rest of the nucleus is akin to the hard drive storage.



Cytoplasm

The rest of the eukaryote cell apart from the nucleus is called the cytoplasm This is divided into small compartments by bi-lipid membranes or proteins and includes smaller organelles including vesicles, rough—studded with ribosomes— and smooth endoplasmic reticulum, the Golgi apparatus, an extensive cytoskeleton of micro filaments, intermediate filaments and microtubules, mitochondria (and chloroplasts in plants), vacuoles, lysosomes, peroxisomes, and a centrosome containing two centrioles.

All the ribosomes that synthesize protein are either studded in the rough endoplasmic reticulum or cached in small groups at microfilament junctions. The nucleus exports RNA to program these ribosomes.

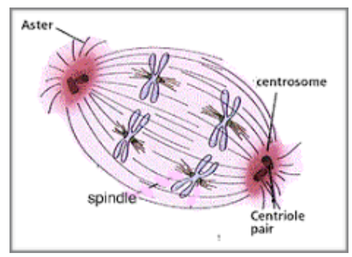
It is only recently noted that there is a type of exported RNA that programs the centrioles in the centrosomes. Five different novel RNAs were detected in the centrosomes of a mollusk egg in 2006. This RNA was named centrosomal RNA (cnRNA). Then it was found that centrioles contain RNA which was required for initiation of aster formation. Indeed RNA may really represent the informational molecule that turns the sophisticated architecture of these organelles into highly directional organizing centers.

The control of the cytoskeleton controls the shape and movement of the entire cell, and moves the organelles and packages of molecules to where they are needed. The closet analogy would be a computer controlling the raising of poles and tensioning the ropes of a complex canvas tent.

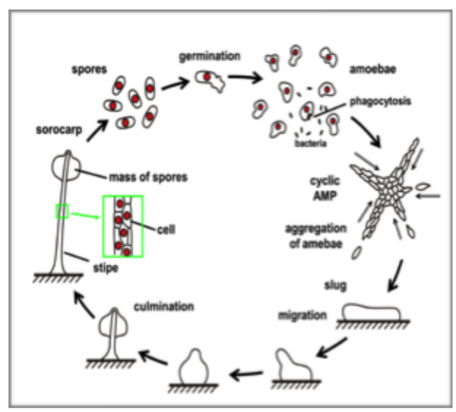
Cell Division

As described, the asexual division of one bacteria into two bacteria is relatively simple. The transformation of one multi-compartmentalized eukaryote into two is not so simple. Eukaryote cell existence can be divided into two quite different states: the everyday quotidian tasks of metabolism and response to other cells. This is the G_0 state of cells such as neurons and liver that perform their role without change. The centrosome runs the cell based on instructions received form the nucleus.

The other basic state is the fuss involved in cell duplication. When the nuclear CPU decides that preparations for cell division should commence, it duplicated the DNA chromosomes, sends out mRNA instructions to increase cell growth, and cnRNA to the centromere to prepare itself. In the resting cell there is a single centrosome enclosing two centrioles. The relation of these two is akin to the traditional relation in the orient between mother and daughter-in-law. The mother centriole literally hold all the strings that control the cell, while the daughter is in a totally subservient role.



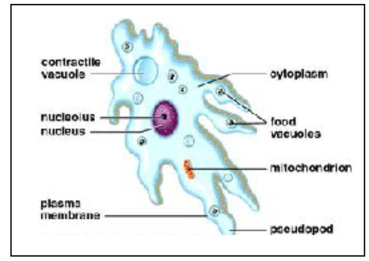
When the cnRNA instruction to prepare arrives from the nucleus, this starts to change. The centrosome takes a *kissing tour* of the cell where ~50% of the mother's control is passed to the daughter centriole. The two then separate somewhat, and the centrioles then start to duplicate themselves and assemble centromeres about themselves. The two centrosomes then start to separate and assemble a distinctive aster—anchoring it to the cytoskeleton—and a mitotic spindle that is responsible for the exact separation of the two sets of duplicated chromosomes.



Note that while the two resultant cells of mitosis are essentially identical, one now has the original mother centriole—with a new daughter attached—while the other has the daughter centriole—now in the mother position with a new daughter attached. This slight difference can determine a very different history, such as when a stem cell divides into two: one remaining a stem cell lineage, the other differentiating along a lineage into an appropriate specialization.

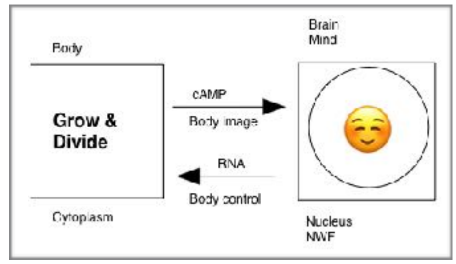
In the double cycle, the meiosis that results in haploid sex cells, the egg cell has a centrosome as normal while the sperm uses its centrosome to construct the flagellum that efficiently propels the sperm to the egg. The zygote ends up with a centrosome inherited from the mother; none from the father. In the future we might see a centrosomal Eve to join the mitochondrial Eve and the Y-chromosome Adam of current evolutionary studies.

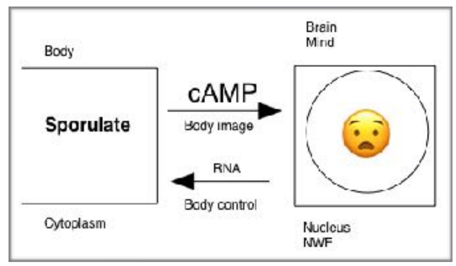
Single Cell Protists



The fossil record reveals that for over a billion years the eukaryotes were all protists, single independent cell, e.g. the ameba. This has all the components just discussed—nucleus, nucleolus, centrosome, mitotic spindle, mitochondria, etc. The flexible outer membrane allows food, such as bacteria, to be engulfed into a digestive vacuole where it is dismantled into useful components for ameba growth and asexual division.

The nucleus has a plethora of constituents—mainly water, RNA, DNA and proteins—whose individual wavefunctions merge into the wavefunction of the nucleus (NWF). There will be an influx of material through the nuclear pores that interacts with the nuclear constituents and thus alters the NWF. As it is probably of paramount importance, the concentration of ATP can stand for the state of metabolism. When food is abundant, ATP is high, and this level inhibits enzymes that convert it into cyclic AMP (cAMP, an important signaling molecule in all living systems). The small amount of cAMP entering the nucleus and its influence on the NWF can be thought of an image of what is happening in the cytoplasm impinging on the NWF. In a beneficent environment, this image will be a Natural Pattern and the NWF will be in its ground state. In anthropomorphic terms, the nucleus is like the brain, the NWF is the mind, the cytoplasm is the body, and the sense image is "all is well," and the mind is peaceful and content in the ground state of the Natural Pattern. As the ameba grows, the sense image becomes "I'm feeling fat" and the disturbed mind initiates cell division to get slim again. The "contented" housekeeping output of RNA to ribosomes and centrosomes switches to a "time to divide" output of RNAs and step-by-step, cell division ensues.





To an ameba, a beneficent environment is one where there are plenty of bacteria to ingest, digest and use the products for its own metabolism.

When the environment becomes hostile, when bacteria are too few to matter, ATP production falls, cAMP rises, and the image impinging on the NWF is not in the ground state but an exited state of the Natural Pattern. The mind is not at ease, it is in a state of dis-ease, of discomfort. The RNA output changes and the cell prepares to sporulate, creating inert, dry copies of itself that can disperse and come back to life when plenitude is chanced upon. An interesting variant of this response is seen in the slime mold amebas. The cAMP leaks out and influences surrounding amebas to excrete cAMP which induces the population to congregate into a slug and then a fruiting body that elevates and helps the spores disperse.

The entrance of external cAMP and its effect on the nucleus presages its key role in sophisticated systems as a *second messenger*. Information about the external world—the first message—impinging on cell membrane receptors is converted into a second message within the cell. Examples of second messenger molecules include cyclic AMP, cyclic GMP, and calcium ions. The output of the nucleus to keep the cell in a steady state or to flip it into a new state can be dependent on receiving information about what is going on outside the cell. This becomes of paramount importance in multicellular eukaryotes.

MULTICELLULAR ANIMALS

The bacteria-eating ameba is decidedly animal-like. Some single-cell eukaryotes, however, have both animal- and plant-like characteristics, photosynthesizing and eating bacteria as circumstances warrant. They also can act like the fungi, decomposing and recycling material.

I this discussion, we will focus on the animal kingdom, as much of plant and fungi systems are similar subsets of the animal kingdom.

The history of life on this planet has left traces in the fossil record. The Sun condensed ~4.5 billion years ago (Ga), with some of its leftovers forming the Earth. This Haden Eon of history was a molten planet constantly bombarded by solar debris, the greatest of which splashed off material that formed the Moon. This was an abiotic time with no possible lifeforms. At the end of this chaotic era, ~4 Ga, the situation had cooled enough for a stable ocean and atmosphere—mainly carbon dioxide and nitrogen—to envelop the planet.

The first unequivocal signs of life appear in the fossil record at 3.5 Ga while photosynthetic bacteria were active ~3.2 Ga. While photosynthetic bacteria are relatively simple forms of life, they are highly-complex systems, and must have descended from earlier simpler forms of life. From a chemical point of view, the classical probability of such a system emerging is essentially zero. The famous analogy is a tornado sweeping through a junk yard and assembling a functioning Jumbo Jet. Using the best modern technologies, scientists have yet to create even the simplest of living organisms.

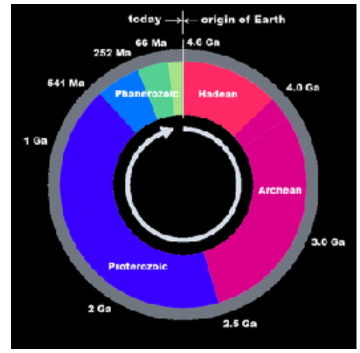
While life is improbable from a classical point-of-view, the introduction of the wavefunction into basic science—thought it has yet to make its impact in biology—has changed our concepts about what is probable and what is improbable. As noted, all matter and forces are made of fermions and bosons, neither of which obey classical probability considerations. Consider throwing two dice: the classical probability of throwing a double is ⅙ and a total of 7 is also ⅙. Including the wavefunction, for boson dice the probability of a double is 100%, and that of a 7 is 0%. For fermion dice the probability of a double is 0% while the probability of 7 is 100%.

As has been noted, there must have been a sequence of events that led to the assembly of the first living system, and that the probability of each step must have been high, because if even one step had a low probability then the sequence would never happen. It was the wavefunction and the high-probability of Natural Patterns that made a classically-improbable sequence so probable such that life emerged in just a few tens of million years after conditions on Earth became amenable.

Following the Hadean (4.5 - 4 Ga), came the Archean Eon (4 - 2.5 Ga) in which prokaryotes were the only form of life. At some point in this period, the Last Universal Common Ancestor (LUCA) of all life emerged, from which all subsequent life developed. This had all the things that all life has in common: the

20 amino acids, proton-motive force, RNA, the universal triplet code, glucose-phosphate metabolism, ATP, etc.

The emergence of eukaryotes and an oxygen atmosphere marked the Proterozoic Eon (2.5 - 0.5 Ga) during which simple plants emerged (along with a few multicellular animals that left no clear descendants).



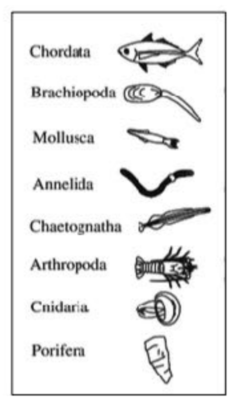
All this 3-eon-long period of life's development on Earth is called the Precambrian because it ended with what is called the Cambrian Explosion and the start of the Phanerozoic Eon (0.5 Ga - present). Complex life, including vertebrates, begin to dominate the Earth's ocean. Gradually, life expanded onto to land and all familiar forms of plants, animals and fungi begin appearing, including annelids, insects and reptiles. Illustrated on a clock, life started to bloom at 10 o'clock and the Age of Mammals at 11:30.

The Cambrian Explosion

The Cambrian Explosion of animal life forms started ~ 540 million years ago (Ma) and left its famous imprint in the the Burgess Shale which preserved the soft parts of organisms. This provided a wealth of data to aid in the classification of otherwise enigmatic fossils from less benign sites. In the subsequent ~20 million years most major animal phyla first appeared in the fossil record of ocean life—exploration of dry land came much later.

There have been many suggestions as to what caused such an acceleration in evolutionary change—rising oxygen levels with ozone layer formation, perfection of the basic eye, arms race between predator and prey, end of 'snowball earth,' increase in oceanic calcium ions, etc.—but none have risen to universal acceptance.

The creative aspect of the Darwinian theory of evolution—that random variation of the digital information generated all these different forms—is not in accord with the concept of Natural Patterns being expressed and then digitally-encoded and stored in DNA. This was a period of exploration and experimentation when basic subsystems were mixed, matched and tested in the real world.



However, the destructive aspect of Darwinism—that those forms that do not thrive and multiply will be eliminated—is a good explanation in accord with the facts: The fossil record of the Cambrian contains many basic patterns of lifeforms that did not thrive and eventually disappeared and left no descendants.

All the major animal phyla—the basic body forms—that survive to the present were established in the Cambrian. We are direct descendants of the early Chordata. The succinct history of animal life following the Cambrian is:

The chordates begat the vertebrates with a sturdy backbone;
The vertebrates begat the fishes who swarmed the oceans;
The fishes begat the amphibians who moved onto the land;

The amphibians begat the reptiles who dominated as dinosaurs;

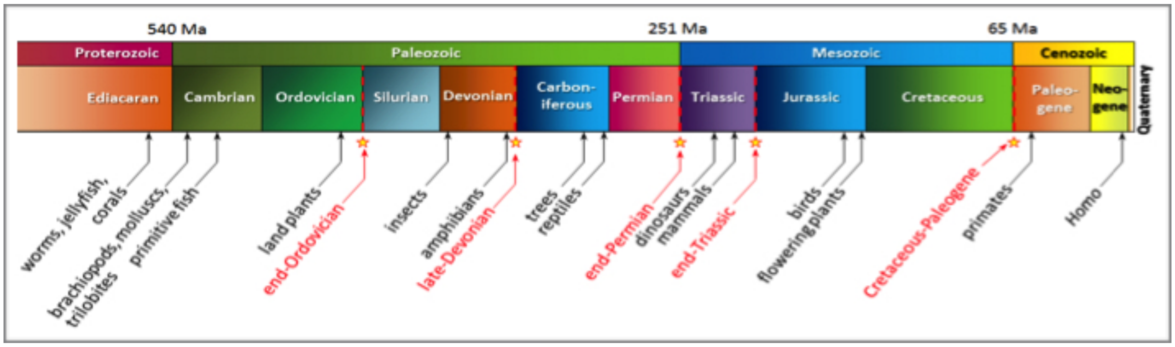
The reptiles begat the parental birds in the air and mammals on the ground;

The mammals begat the primates who swung in the trees;

The primates begat the hominids who walked on two legs;

The hominids begat us self-aware humans who attempt to understand everything.

Along the way, there were major extinctions as one environmental state gave way to another. These great changes in the fossil record mark the transitions between periods.



The central dogma of the Modern Synthesis that connects Darwinism and genetics is that the information flow is unidirectional: from DNA to RNA to protein to metabolism. The Lamarckian concept of learning from experience with the resultant wisdom being captured in DNA has long been ridiculed.

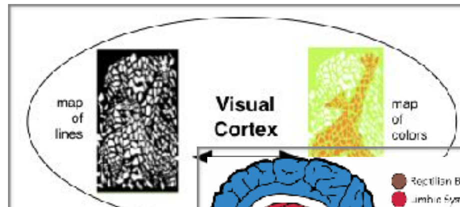
Confidence in this dogma has, however, been shaken by the emerging of a new aspect to genetics called *epigenetics*. While this new discipline is only in its early stages, the following points have already been established:

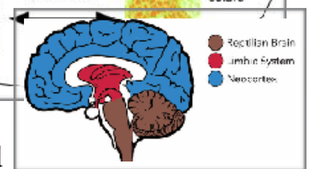
1. The molecular subunits of DNA are the substrate for recording the experience of ancestors that is passed onto descendants.
2. This epigenetic information has an influence on the genetic rearrangements that occur during the *tetraplex* stage of the formation of the sexual gametes, the sperm and eggs.
3. The wisdom and folly of ancestors has an effect on the subsequent lineage.
4. As DNA is relatively passive, it can be expected that learning will involve RNA. Contradicting the central dogma, there are proteins, called *reverse transcriptase,* copy digital information on the short-term memory of RNA onto the long-term memory of DNA. Intriguingly, the human genome contains over 600 reverse-transcription-like sequences, long considered *junk DNA* or remnants of ancient HIV-like infections. The fact that these sequences have not been observed to be active is not a sign that they are useless. There is a segment of the Y chromosome—called the Sex Determining Region—that is active for just one hour when the embryo is just weeks old, and never again. Yet this brief activity is sufficient to redirect embryonic development into the male pattern. Without this brief activation, the embryo develops into the default female pattern. Lack of observed activity is not evidence of inactivity.

This is currently all an area of research and rapid development that has yet to be fully incorporated into a post Modern Synthesis of Lamarckism and epigenetics in evolutionary theory.

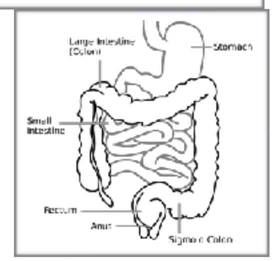
The Brain

The animal brain is the eukaryote nucleus writ large. The brain receives input that, interacting with the subsystems, alters the Natural Pattern of the collective wavefunction generating an image of the state of the body and the state of the environment. This view does not suffer from the binding problem as all is integrated into one wavefunction. The *binding problem* is most clearly illustrated in the process of vision. Our personal experience is that vision is like a projection on a screen —2D with one eye closed, 3D with both open.

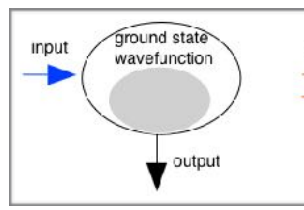


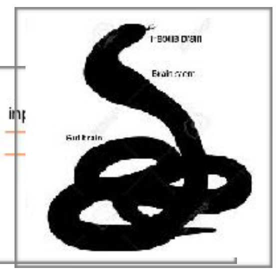


Rather counterintuitively, the retina does not send pixels of color (as in a computer screen) to the brain, instead there are subsystems that respond to lines and create a map of lines, and subsystems that respond to colors with a color map, etc. All these responsive brain subsystems and their maps are in quite different parts of the optic cortex. Just how all these maps come together so that they are bound into the unified perception of the world we observe is one of the unsolved mysteries in neuroscience. The global wavefunction view does not have this binding problem, it is not an issue.



Recall the discussion of the chlorophyl molecule: An excited subsystem (electron) is localized so that it is channeled into a new location (electron transport chain). Similarly, the excited brain wavefunction channels subsystems into new locations. This influences the output of the brain which directs the body into a new action. In everyday language, we call the wavefunction of the brain the *mind*, the intangible aspect that governs the body.



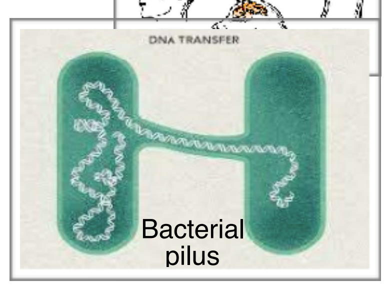


It is this intangible mind that responds to certain inputs as *red* while others are *green* or *blue*. Some as *delicious*, others as *nasty*, some as pleasant *harmony*, others as irritating *noise*. All of these intangible qualities experiences by the mind are called *qualia*.

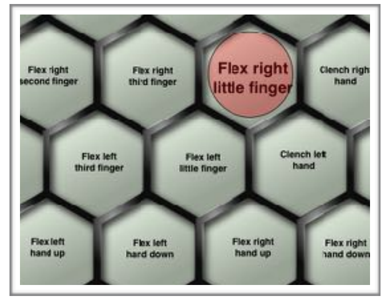
When the input image impinging on the brain wavefunction does not reflect a natural pattern, we feel discomfort, illness and pain, all being qualia in the mind. This natural response leads us to attempt to correct the situation. This usefulness is illustrated in leprosy patients who, lacking the pain response, cause great damage to their extremities without being aware of what is happening.

Brain Evolution

The developing sophistication of animal bodies since the Cambrian is mirrored in the increasing level of sophistication of the brain. The simple fish brain was sufficient for a watery existence, but it took the more sophisticated reptile brain to deal with the complexities of life on land.



The nervous system developed not only in the head, but also surrounding the digestive systems. Scientists call this little brain the enteric nervous system (ENS). And it's not so little. The ENS is two thin layers of more than 100 million nerve cells lining the gastrointestinal tract from esophagus to rectum.



The further development of the brain used this reptile system as a foundation, so in the human brain we find the innermost core to be a reptile brain; on this is constructed the mammalian brain; and on these levels the final sophisticated level of the human brain.

In literature, this reptile brain-gut foundation on which the human brain is constructed is often symbolized as a serpent: the head being the reptile brain while the serpent coils are the hollow tube brain that surrounds the gut.

When we talk of people as "being an animal," we consider them to be ruled by the reptile brain rather than the higher attributes, such as empathy and the conscience.

Attendant with the increasing sophistication of brain structure is an increase in the sophistication of the set of emergent properties bestowed by the Natural Patterns expressed. While scientists delight in discovering yet another higher qualia in non-humans—plants that respond positively to Beethoven but negatively to acid rock, crows that can count, apes that can understand simple nouns and verbs, hominids that mastered fire, etc.—by far the greatest suite of emergent properties emerged with the advent of humans. Probably the most significant of these is that we have a conscious mind that is self-aware

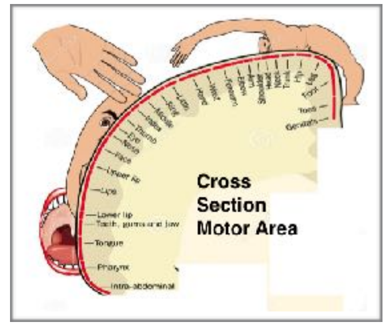
Conscious Control

It has to be admitted that the science of the brain is in its infancy, and the science of the mind more an art—as in psychiatry—or a bludgeon—chemical manipulation and suppression. There are two main classes of cells comprising the brain—neurons and glia.

For many years, it has been considered that the higher functions of the brain were generated by the active neurons and their multitudinous connections. The glia were considered as humble housekeepers, feeding and protecting the neurons. Recent research, however, seems to indicate a much more important for the glia. The analogy of the two roles is like two roles in a cell: the proteins that do all the work, and the nucleic acids that store and manipulate information and govern the protein activity. The neurons are akin to the proteins that do the work, and the glia that control their activity by manipulating information, a viewpoint explored by Andrew Koob in *The Root of Thought: Unlocking Glia*. This remains an active are of investigation.

For decades, it has been assumed that cells communicate by analog signals, even the neurons which convey signals in a digital fashion along their extensions, secrete chemical neurotransmitters across the synapse gap. Analog signals such as global hormones that effect the whole body and local chemicals that influence cell-cell interaction. This is somewhat surprising in our computerized digital world of the internet where the benefit of digital transmission is self-evident. It is only recently that it was discovered that there are "tunneling nanotubes" connecting cells through which RNA, proteins, even mitochondria, can be transported from one cell to another. While this is a recent discovery in eukaryote cells, it has long been observed in bacteria where bits of DNA can pass from one to another through a pilus.

An RNA signal passing between cells—such as from a glia to a neuron—through a tunneling nanotube has the potential to radically alter the recipient. This is readily seen in the action of a virus when a DNA or RNA enters a cell and converts it into a virus factory. The susceptibility of our cells to such an invasion is surely a sign that a natural process has been suborned. This digital method, complementing the well-characterized analog channels of communication, is also an active area of investigation.



Nevertheless, for all these unknowns, much has been learnt about the brain in the last century or so. For instance, the brain itself has no pain sensors, so open brain surgery can be performed on a conscious patient. Stimulation of the brain cortex (surface) with an fine electrode and a weak electrical current has allowed a mapping of the brain into input sensory areas and output motor areas. As can be seen in the illustration of the motor cortex, the size of the brain mapping does not correspond to the size of the body organ but to its capability—the tongue and hands are a small part of the body but occupy a large area of the motor cortex. Within each area are modules that control one of the many motor operations. For instance, flexing the little finger on the right hand. It takes just a thought, and the finger flexes.

It is not just input that can move the composite wavefunction that is the mind. The thought to flex that finger momentarily excites that aspect of the wavefunction, as described for the chlorophyl molecule. This creates an excitation that stimulates that module and a set of nerve impulses are output, the set muscles contracts, the little finger flexes.

Three Odd Couples in Classical Science 1

1. Mass & Spacetime 2

Classical View 2

Solid mass 2

Space and time 2

Contemporary View 3

Mass: unit of energy 3

Matter: mostly empty space 4

Spacetime: a physical entry that can twist and bend 4

2. Particle & Wave 7

Complex numbers 7

External Particle 8

Twisted spacetime 8

Bosons 8

Fermions 9

Mathematics 10

Internal Wavefunction 11

Particle and Wave 11

Conclusion 14

Interstellar Migration 14

Physical and Spiritual 14

Math and Matter 16

3. Mind & Body 17

Interaction 17

Biochemistry 19

Proteins & Analog form 20

Nucleic Acids & Digital information 21

Lock & Key or Wavefunction? 24

Inanimate and Living Systems 25

Prokaryotes 26

Eukaryotes 27

Nucleus 28

Cytoplasm 28

Cell Division 29

Single cell protists 30

Multicellular Animals 31

The Cambrian Explosion 32

The Brain 34

Brain Evolution 34

Conscious control 35