Quantum mechanics is life

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Abstract

We claim that everything is alive, and that quantum mechanics of $U(N)$ unifies physics and biology.

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An economic system of workers

We start by considering an economic system composed of workers located at some point in space. The workers earn a money salary when they work. The money is controlled by a central bank and is a fiat money system with an arbitrary money unit. The workers do not have the exact same salary, but there is a typical salary, which we call the base salary. Individual salaries are distributed around the base salary. If the workers are somewhat similar and the market is competitive, the variance of the distribution of salaries is small. The base salary, $b(t) > 0$, is a function of time. We can now define the accumulated money income in a time period as

$$\tau = \int_0^T b(t)dt$$

τ is an increasing function of physical time. The workers can use τ as a measure of time. If they had no clocks, they could still use their accumulated money income as a measure of time. The central bank could have used a different fiat money unit in which the base salary would have been different, $b'(t)$. This change of unit would have led to another measure of time. Any reparameterization of time is of this form including standard physical time where $b(t) = 1$. Redefinitions of the money unit do not change real economic activities. There must be some measure of accumulated income that is independent of the choice of money unit. We call it accumulated real income. It is an increasing function of time and we can represent it as an integral

$$\text{Accumulated real income } = \int_0^T \sqrt{g_{00}(t)}dt$$

where $g_{00}(t)$ is a positive function and t is any of the money variables. In order to make the accumulated real income invariant under change of money unit, g_{00} must transform as

$$g'_{00}(t') = \frac{dt}{dt'} g_{00}(t) \frac{dt}{dt'}$$

Now, let us introduce several economic systems located at different points in space. At each point x, we introduce a money system with arbitrary units and real incomes $g_{00}(t,x)$. For a worker staying at a particular point in space, the accumulated real income has the same form as above. However, a worker can also travel and work at different locations. There is a cost of traveling which is an expense for a worker. The accumulated real income for a traveling worker must be expressible by some generalization of the formula for a worker at rest. The trajectory of a worker is given by $x^\mu(t), \mu = 0,1,...,D$ where t is any parameter along the trajectory, x^0 is the money time mentioned above, and $x^i, i = 1,..,D$ is a parameterization of the space. The money times can be reparameterized in a space dependent way, as described above. Furthermore, the space coordinates can obviously be reparameterized. But we can also mix the space coordinates and the money times. The central banks above indicate a preferred split of space and time, but they are not really necessary. The central banks could be drifting or simply removed. The central banks are like clocks and physical clocks obviously come with a preferred split of space and time. Only the workers are needed. The upshot is that the x^μ behave like the coordinates of a manifold. Now, there is only one way of extending the formula for accumulated real income above to the case of a traveling worker.

$$\text{Accumulated real income } = \int_0^T \sqrt{\sum_{\mu\nu} \frac{dx^\mu}{dt} g_{\mu\nu}(t) \frac{dx^\nu}{dt}} dt$$

where $g_{\mu\nu}$ is the real income tensor and mathematically it behaves like a metric on a manifold. We need an interpretation of the real income tensor. $g_{00}(t,x)$ is the square of the real income of a worker as described above. The space components $g_{ij}(t,x)$ can be thought of as the real cost of travel between the space points. In other words, the distance between points is defined as the cost of traveling between them. We will refine this definition shortly. The real income tensor has signature $(1, -1, ..., -1)$, because the cost of traveling subtracts from the salary. There is a maximum speed in the system which is attained when a worker spends all its income on traveling. We can now refine the definition of the space components of the income tensor. The distance between two close points is given by letting a worker start at one point, travel with the maximum speed to the other point and return. The distance between the points is defined to be half the accumulated real income at the starting point during the time the traveling worker was away. This definition requires that there is a subgroup of workers capable of traveling with the maximum speed, and that these workers are similar, or symmetric, in a certain sense. We could also say that the definition requires that the real income tensor is the same for all workers. This would only be the case if there are many workers and almost economic equilibrium.

The case of many workers and complete economic equilibrium must be described by a constant real income tensor which can be reparameterized to the Minkowski metric

$$g = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ 0 & -1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & -1 \end{pmatrix}$$

Consider two workers, A and B. B stays at rest in the Minkowski system, and A travels away, turns around and comes back to B. A and B both make the same income from working, but A has spent money on traveling, so when they meet again B has more money. A had to accelerate to get back to B. If we view this example from another parameterization where A stays at rest, and B travels away, we must still get the result that B has more money than A. The reason that B still has more money is that B travels to locations with higher salaries than the place where A works. Even though B must pay for travel expenses, B still comes back with more money. There is an equivalence between working at a high salary and paying for travel expenses versus getting a lower salary but free travel.

The workers will try to follow paths of maximum income, i.e. geodesics in the metric. Suppose the income tensor is Minkowskian at infinity and has curvature in the middle. The curved regions are regions where the income is low and the cost of traveling away is high. Workers are attracted to poor regions and can only escape them by working hard.

Let us look at this system conceptually. The dynamics comes from the workers themselves. The real income tensor is an emergent property which, for each worker, summarizes the effects of all the the other workers. The only way of defining real income is to say that real income is set by the workers' subjective preferences. If there is a large number of workers and market equilibrium, we can forget about the details of the workers, and there must be some equations that govern the income tensor. Since the system is reparameterization invariant, these equations must involve curvature tensors and be similar to the Einstein equations. The exact equation depends on the details of the workers.

This system resembles gravity. We will use the principle that when two systems are identical up to the use of words, then those systems are exactly identical and the words must be synonyms. Firstly, we learn that money is time. Secondly, we learn that particles are workers. But worker is just a word. The essential properties of a worker are that it makes subjective decisions and has a goal it pursues. A typical goal for a worker would be to find food, shelter and to replicate. Basically, the essential property of a worker is that it is alive. Before we go on, we note that it is unclear whether the system of workers is a quantum system. We will return to this question.

Everything is alive

If particles are alive, the only natural interpretation is that everything is alive. We claim that everything is alive including particles, cells, human beings, the earth, the moon, the solar system, stars, galaxies, the universe and much more. The world is not separable into dead and living things. This point of view automatically provides a solution to several problems.

How and when did life start? By continuity, there must have been some point in time where life started. What kind of event could have possibly taken place at such a time? The standard view is that life started when certain organic molecules were formed. However, if those molecules were formed from earlier molecules, then those earlier molecules should be alive as well.

It is hard even to define what life is. This problem is also conveniently solved by the claim that everything is alive.

It is known that natural constants, such as quark masses, seem to be fine-tuned for life on our planet. If the natural constants were slightly different, carbon-based life could not exist. The orbits of the earth and the moon also seem fine-tuned for our existence. Such fine-tuning is completely natural in a living organism. Indeed, the body temperature and the glucose and oxygen concentrations in the blood seem fine-tuned from an individual cell's point of view.

The free will theorem by Conway and Kochen [1] proves that quantum mechanics implies that humans and particles either both have or do not have free will. This theorem is a problem for the standard view that particles are dead and humans are alive. The free will theorem supports the claim that everything is alive. Here, we assume that free will is a property of living organisms.

There are two big questions of creation. How was the entire system, the universe, created, and how was life created? The claim that everything is alive reduces two hard questions to one.

The miracles of the past

Many events of the past are hard to explain quantitatively. As an example take the formation of the solar system. The theory is that the solar system was formed by random aggregation of dust under the influence of gravity. However, the solar system has so much structure that it is hard to explain from models of randomness. Another example is the formation of cells with DNA, RNA, and proteins. Such cells are also supposed to have formed by random events guided by natural selection. It is hard to form cells with DNA and proteins stepwise, because they only make sense when they work together. Other examples are large scale structures of the universe, formation of galaxies, stars, and planets, and the creation of multicellular organisms and mammals including human beings. This is not the place to go into detail with all these problems. We will just make the general comment that all of these examples share the properties that their formation was incredibly improbable, happened very fast, and the end result is highly structured. The combined development from interstellar dust to human beings is, of course, even more startling. The usual explanations of these events make sense qualitatively, but in our opinion not quantitatively. Our claim, that everything is alive, provides a nice way out: All of these systems were made by a mother of some sort and went through the equivalent of embryonic development. Living organisms also experience sudden changes induced from outside like a phase transition. When a human being enters puberty, hormonal signals are circulated in the body which leads to dramatic cellular and physiological changes.

Monkey to human transition

Let us for a moment forget about the claim that everything is alive and look at the development of the human species. Suppose that humans developed from an ancestor monkey. For our purpose, it is not terribly important whether this actually happened or not, but it is a well known example. The monkeys had a certain physiology and genome. At each generation of monkeys, some random mutations took place. The fittest mutations got fixed in the population because all monkeys without this mutation lost out. This process was repeated a number of times, say one million, and in the end the human species was reached. This picture makes qualitatively sense, but the numbers do not really add up. Firstly, almost all mutations are deleterious. If one just changes the genome randomly, it will in almost all cases lead to a weaker, or even dead, monkey. Secondly, small beneficial changes do not change survival rates enough to matter. In many cases, the beneficial mutation will die out due to chance events such as accidents. It is also highly unlikely that there exists a route from monkey to human with increasing fitness along the way. Humans might be fitter than the ancestor monkey, but there is almost certainly a barrier (of dead monkeys) between the two species. What is needed is a mechanism that can scan the entire space of animal fitness, compare fitness with each other and jump through the barrier to the fittest solution. This is exactly what quantum mechanics can do. But for quantum mechanics to be able to transition from one species to another, there must be a relationship between the fitness of a species and the Hamiltonian of quantum mechanics.

Natural selection

Let us discuss the hypothetical question of how to construct a world of living organisms based on the principles of evolution, natural selection and survival of the fittest. The organisms can come in different species. The word evolution is hard to define in any other way than simply change or flow of time. Besides time, we need a fitness function, and we need to be able to compare the species for any past history of the world. At a given point in time, the fitness of the species in the future must be a function of the state of the world at that time. The fitness should only depend on the past history of the world through the current state. At any time point, there is a set of possibilities for going forward. Natural selection is the problem of finding the best one. At the next time point we have a new set of choices. We can not know the fitness of a certain choice without looking ahead and trying all future choices, and we need to do the same for all the other choices at that time point. Basically, we need to list all paths of configurations as functions of time and assign a number, the amplitude, to each of these paths. A path becomes a full world history. The amplitude of a path can be thought of as the importance of a path. For each path, we could ask whether a given species existed in that path. We then define the fitness of a species as

$$\text{Fitness of species } S \; = \sum_{\{\text{path}|S\in\text{path}\}} \text{Amplitude(path)}$$

It is somewhat subjective whether a certain species exists in a path but that is acceptable. We could also condition the path integral on an initial state and a final state, in which case we would get the fitness of a species in terms of reaching a certain goal in the future starting from a certain point. This definition of fitness is applicable for all objects including an individual animal, a species of animals, a quark, a planet, the atmosphere, etc. The contribution of a species to the outcome of observations is proportional to the fitness of that species. Species can be correlated. A symbiotic relationship is an example where two species exist together. This definition is impractical because it seems impossible to perform the sum over all paths. But nature does in fact perform such a sum. Quantum mechanics sums over all paths simultaneously in some massively parallel way. The system described here is exactly quantum mechanics. The amplitudes in quantum mechanics are complex numbers. It is not clear from this discussion what type of number the amplitudes should be, but complex amplitudes provide the nice possibility of interference patterns. We will return to this point later. Conclusively, we claim that quantum mechanics is the natural implementation of evolution and natural selection.

The moon as a scientist

Suppose the moon is a scientist observing the earth. The moon discovers humans and notices that humans come in discrete recognizable units. The moon counts the number of humans at two nearby time points and observes that the number of humans is conserved. The moon knows that a conserved integer number corresponds to a $U(1)$ symmetry. Therefore, the moon models the humans by a single global $U(1)$. The moon notes that population number is not just globally conserved but even approximately locally conserved. Hence, it is too simplistic to use a single global $U(1)$. The moon models the situation by dividing the earth into regions or points. The symmetry group is augmented to $U(1)^P$, where P is the number of points. The original $U(1)$ is the diagonal subgroup of the $U(1)^P$. The moon observes that the population number at a point can decrease, but that there is always a corresponding increase at another point. The individual $U(1)$s must be broken and coupled to each other. The moon determines the pairwise couplings between all $U(1)$s. The couplings have dimension time^{-1}. The coupling between two points is given by the typical amount of time before the population number decreases at one point and increases at the other point. Strong coupling corresponds to a short time scale and weak coupling to a long time scale. The couplings give the moon a sense of how close the various $U(1)$s are to each other. This distance measure corresponds more or less to the geographical view the moon has of the earth, but not exactly. Certain islands seem to be more weakly coupled than expected from geographic distance and certain airport $U(1)$s seem more strongly coupled than naively expected.

Now, the moon looks more closely and discovers that the humans often move in pairs. This pattern is inexplicable in the $U(1)$ theory. The moon discovers that there are two types of humans, males and females, that look almost identical. The moon could extend the $U(1)$ at each point to $U(1) \times U(1)$ and find the couplings between the points. However, the male travel couplings would be so similar to the female couplings, that it seems more reasonable to use a broken $U(2)$ in each point. The slight asymmetry in travel patterns between males and females are encoded in some $U(2)$ breaking parameters. If we write $U(2) = \frac{U(1) \times SU(2)}{\mathbf{Z}_2}$, the $U(1)$ denotes the original population number and the $U(1) \subset SU(2)$ counts the difference between the number of males and females. The moon notices that a male and a female, which have opposite charges under the male-female $U(1)$ inside the male-female $SU(2)$, can pair up for a while. It looks like the original male and female disappear and a new type of particle, the pair particle, shows up in their place. After a while, the pair particle decays into the male and the female again. The moon keeps track of the situation by drawing Feynman diagrams. The event, where a male and a female combine into a pair particle, is drawn as a triple vertex. The coupling constant of this triple vertex denotes how much time the male and the female spend in the pair state. The coupling constant of the vertex quantifies the degree of symmetry breaking of the $SU(2)$. If the $SU(2)$ is unbroken, the male and the female only occur in the pair state. When the $SU(2)$ is broken to $U(1)$, the male and the female have opposite charges under the $U(1)$. The coupling constant of the vertex of the $U(1)$ quantifies the amount of attraction between the male and the female. A high $U(1)$ coupling constant means that the male and the female are mostly together and that the $SU(2)$ is almost unbroken. The moon might say that the pair particle is an exchange particle for the attractive force.

The moon keeps track of all these interactions by drawing a giant Feynman diagram. There are events where a male and a female pair up, split again, stay separated for a while, and then pair up again. These events are drawn as loop diagrams. The moon has observed all the coupling constants for how the males and the females move around from place to place and how they pair up. It is all encoded in a broken $U(2)^P$ theory. Now, the moon discovers that the global population count is not constant. The outer $U(1)$ is broken. The moon models this situation with two new types of diagrams. The first type is the vertex of death and looks like a human just ending. The second type is the diagram of birth. The diagram of birth is a female splitting into a similar female and a new human. The moon incorporates birth and death rates into its theory.

The moon soon realizes that the diagram of birth was too simplified. It had to be replaced with a diagram of a male and a female combining into a pair particle, followed by the pair particle splitting into a male and a new type of particle, a pregnant female, followed by the vertex of birth where the pregnant female splits into an ordinary female and another human. The pregnant female has a sharply defined characteristic decay time, the time of pregnancy.

The moon does not like the new symmetry breaking diagrams. Especially, the vertex of death is ugly. The moon devotes more time to studying the system. It finds that each human is composed of four almost equal limbs: a left arm, a right arm, a left leg, and a right leg. The limbs are almost identical, so they are modeled as a slightly broken $U(4)$. Each human is now seen as a bound state of four limps. The diagonal $U(1)$ of the $U(4)$ is the original human $U(1)$. The $SU(4)$ is unbroken at each point, which means that every time there is a left arm, the three other limbs are also present. A human is a strongly bound state of four confined limps. The male-female distinction is still there, so there must be two types of limbs. The moon models the system as a $U(4) \times U(2)$. And the 8 types of limbs look so similar that they must have originated from a broken U(8). The diagrams of human death now looks like a human disintegrating into four freely floating limbs. And the pregnant female takes up four limbs before she splits. The male and female numbers are now broken $U(1)$s inside the $U(8)$, and the slight difference between the limbs come from the symmetry breaking. Now, the moon discovers chimpanzees, gorillas, and orangutans. Their dynamics look similar to humans and can be modeled in a similar way. The moon represents this by embedding the human $U(8)$ as a block inside a $U(32)$ matrix. Each type of ape gets its own $U(8)$ block. The $U(32)$ symmetry is broken to approximately

$$U(4)_{\text{ape}} \times U(2)_{\text{gender}} \times U(4)_{\text{limb}}$$

For instance, a chimpanzee male-female couple pair up in a somewhat similar way to a human couple, a gorilla right arm looks similar to an orangutan right arm, etc. The moon models all of this by a giant gauge theory with lots of couplings. The couplings respect the approximate $U(32)$ symmetry. For instance, the characteristic pregnancy time of a gorilla female is similar to the pregnancy time of a chimpanzee female. The amplitude for a gorilla limb to transform into a human limb is non zero. The moon picks up speed and it manages to find more animals and plants and even individual cells. It constructs a giant $U(N)$ local gauge theory of cells. This gauge theory extends the original $U(1)$ theory, and the original vertices have now been completely smoothed out.

The matrix of life

The tree of life is the idea that all biological species originated from the same common ancestor. The ancestor species splits into two new species which themselves split again later. This principle leads to a tree of life, where each living species is a branch of the tree. In terms of symmetry groups, we can think of the n species seen today as transforming in the fundamental representation of $U(n)$. The first split of the tree corresponds to the symmetry breaking

$$U(n) \to U(n_1) \times U(n_2)$$

where $n = n_1 + n_2$. This splits the n species into n_1 species in one branch of the tree and n_2 species in the other main branch. The species always transform in the fundamental representation. Continuing all the way down, we get a hierarchy of $U(k)$s. The similarity of two species is given by the size of their smallest common $U(k)$.

There are other ways of breaking $U(n)$. The group could be broken as

$$U(n) \to U(n_1) \times U(n_2)$$

where $n = n_1 \cdot n_2$, and the species transform in the (n_1, n_2) representation. The species would be organized in a matrix of life instead. The $U(k)$s are broken down further to $U(1)$s. The symmetry breaking from top to bottom could also be a mixture of the two types. A given species would share some similarity with its siblings in the $U(n_1)$ and other similarities with its siblings in $U(n_2)$. For example, the 4 apes might be organized as a representation of $U(1) \times U(1)$.

	+	-
+	Human	Gorilla
-	Chimpanzee	Orangutan

A matrix of life.

This example is only illustrative and especially the orangutan might be misplaced. The closest ape to humans is the chimpanzee. However, a recent assembly and analysis of the gorilla genome shows that in 30% of the genome, the gorilla is closer to the humans or the chimpanzee than the latter are to each other [2]. Convergent evolution is the term used to describe the property that species from distinct lineages develop very similar traits and genetic patterns. Convergent evolution does not fit into a tree of life but is predicted by $U(n)$ representations. We propose that biological species should be organized into representations of broken unitary groups instead of in a tree.

The gravitational system of the workers

Let us go back to the economic, or gravitational, system of workers. The workers were moving in response to the metric, the value of which was given by the workers' own choices. From the moon's observations, we saw that when we explicitly include male and female workers, the system must be described by a $U(2)$ local gauge theory broken to $U(1) \times U(1)$. A male worker will move based on the positions of females, other males, and of the real income levels. We can say that the force on the male is a combination of an electromagnetic and a gravitational force. We could think of the motion of the male in either a passive sense, where he is pulled by forces, or in an active sense, where he is using his free will to make moves. We could model more aspects of the system explicitly such as introducing more animals, food and vehicles. Then the force on a worker, or anything else for that matter, would be determined by a larger $U(N)$ gauge theory and gravity. The moon is really watching gravity coupled to gauge theory along the surface of the earth. The real income tensor included all contributions to real income such as food and transportation. If we explicitly account for food and transportation, the real income tensor should be reduced accordingly. We should not double count. As we make the gauge group larger, the metric becomes less and less important. It is reasonable to assume that gravity disappears completely in the limit where $N \to \infty$. Gravity is an average of all the implicit gauge forces that are not explicitly accounted for by gauge theory. An equivalence between gravity and $U(N)$ gauge theory has been shown by Maldacena with the Ads-CFT correspondence [3].

Maximal symmetry

The $U(N)$ gauge theory existed along the space where the workers, the animals, the particles, or whatever we call them, live. However, there was no need for distances in space. Only the couplings between the particles mattered. There is a more symmetric state where all the particles are on top of each other. This state has the largest possible $U(N)$ symmetry. The $U(N)$ symmetry is broken in the states where the particles have spread out. All symmetries, including spacetime symmetries, should be subgroups of the $U(N)$. For instance, the $U(N)$ could be broken to

$$\prod_x (SU(2) \times U(n))$$

where each $SU(2)$ is the covering group of the local rotation group and $U(n)$ is a local gauge group. A translation group could also be present.

We believe that two requirements of a theory of nature are quantum mechanics and a large $U(N)$ symmetry group. We choose the term quantum mechanics of $U(N)$ to denote this class of theories. We do not propose a precise formulation of quantum mechanics of $U(N)$. Conceptually, one can think of the theory as given by a path integral over a configuration space

$$Z = \int dg(t) e^{iS(g(t))}$$

where the action has $U(N)$ symmetry. The configuration space might be $U(N)$ itself.

Quantum mechanics of $U(N)$ can also be called a matrix model. A supersymmetric matrix model was found by Banks, Fischler, Shenker and Susskind to describe M-theory [4]. The $D0$-branes of string theory give a nice picture for certain aspects of a $U(N)$ theory. The properties of D-branes that led to the connection with $U(N)$ theory was found by Polchinski [5] and Witten [6]. A review of matrix theory is given by Taylor in [7].

We think the exact form of the theory is a metaphysical question. In the limit $N \to \infty$, all these rich $U(N)$ theories are equivalent. The choice of vacuum depends on the way the limit $N \to \infty$ is taken. But the vacuum is just a mathematical notion. Inside each of these rich theories, bubbles of arbitrary sizes can exist, and inside these bubbles, any of the other theories can live for an arbitrarily long time. What matters is what an observer will see and observations will always be described by an effective theory. We will now describe some properties of quantum mechanics of $U(N)$.

Discreteness in the $U(N)$ world

We view the real world as described by a $U(N)$ quantum theory for an infinite, or extremely large, N. In any configuration of broken symmetries there are some $U(1)$s. A $U(1)$ corresponds to a conserved number which we can think of as particle number or charge. It is the $U(1)$s that divide the world into discrete particles. At every scale of nature such as atoms, humans, and galaxies, we see discrete objects. The world does not look like a homogeneous soup at any scale. The fundamental unit is a particle. Particles are characterized by their charges. Charges include momentum and angular momentum since all symmetry groups have the same $U(N)$ origin.

Any $U(1)$ can be resolved meaning that we can replace it with a $U(n) = U(1) \times SU(n)/Z_n$, and let the diagonal $U(1)$ represent the original unresolved $U(1)$. This corresponds to letting the particle be composed of n smaller constituents. Each of these constituents are themselves a particle with a corresponding $U(1)$. If the $SU(n)$ is unbroken, the n constituents are confined. Similarly, any $U(1)$ is also embedded in a larger $U(n)$, which means that every particle is part of a bigger particle. The particles are fuzzy because the symmetry is not necessarily broken in a simple hierarchy. The system is similar at all scales.

Time scales

The system is dynamic at all time scales. Nothing is stable forever. The slow time scales become an effective background for faster time scales. And fast time scales can be integrated out seen from the point of view of the slow time scales. Every observer is sitting in the middle. Suppose we have a configuration $g = e^{iX}$, where

$$X = \begin{pmatrix} a & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & c \end{pmatrix}$$

If a, b and c are very distinct, it is a world of three weakly interacting particles. If $a \approx b$, it looks like two particles, where one particle is a bound state of two smaller particles. The dynamics inside the bound state takes place at a faster time scale than the motion of the particles relative to each other.

Multiple memberships

Consider $m \cdot n$ particles transforming in the (m, n) of $U(m) \times U(n)$. If the $U(n)$ is more broken than the $U(m)$, it looks like n weakly interacting particles, each of which have m constituents. Likewise, if the $U(m)$ is more broken than the $U(n)$, it looks like m weakly interacting particles, each of which have n constituents. Each small particle is a member of two composite particles. The system can transition between these two states. There are intermediate states without a hierarchical representation of the system. A simple example is humans with family members and work colleagues. For each human, there are times where the family members are confined in a family particle, and other times where the work particle is strongly bound. There are strong correlations across society for these two phases. During working hours, work particles are strongly bound, and during evening and night, the family particles are strongly bound. The system oscillates back and forth every day. Weekends and holidays represent longer periodicities in the system. This principle of dual memberships generalizes to multiple memberships. A person is a member of a club, say. The principle of multiple memberships is very important for information transfer in the matrix. The principle of multiple memberships is a property of groups. It could never be understood from a hierarchy of particles inside particles in a geometric configuration.

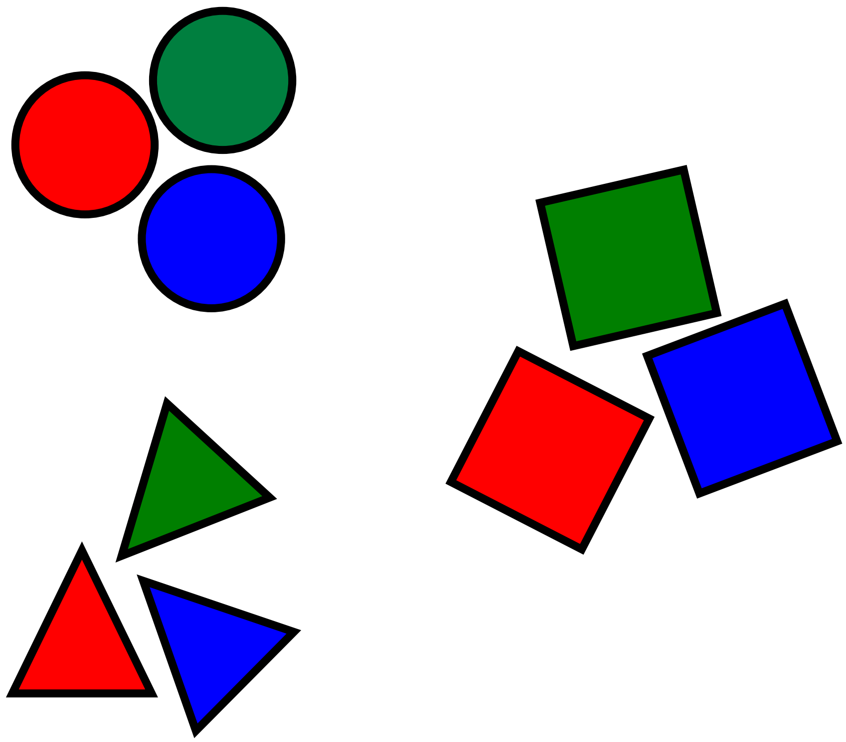

Figure 1: Nine particles with dual memberships. The system can transition between two phases.

Forces are attractive

Forces originate from the $U(n)$ confinement. The strongest attractive force is for two particles that always live on top of each other. In this case, the particles have a $U(2)$ symmetry. Consider a $U(2)$ broken to $U(1) \times U(1)$. The particles have charge $+$ and $-$, respectively, under the $U(1) \subset SU(2) \subset U(2)$. The attractive $U(1)$ force between them is a remnant of the $SU(2)$ symmetry. The more broken the $SU(2)$ is, the smaller the $U(1)$ coupling is. A typical reaction is that the two particles combine into an exchange particle which is a bound state of the two particles. The reverse reaction is that the exchange particle splits into the two particles. The larger the coupling is, the more time the particles will spend in the bound state, the stronger the attractive force is, and the less unbroken the $SU(2)$ symmetry is.

The various $U(n)$s inside $U(N)$ compete with each other and this can make forces repulsive. A typical example is the pair of pairs which consist of four particles in a $U(4)$ with a symmetry breaking pattern of

$$U(4) \to U(2) \times U(2) \to U(1) \times U(1) \times U(1) \times U(1)$$

One can think of the hydrogen molecule of two protons and two electrons, or four humans composed of two couples, each containing a man and a woman. The $U(2)$ of electric charge is the most unbroken, so a proton and an electron will pair up first, and then the pairs will form a molecule. The force is generally attractive. The protons only repel each other to find an electron. From far away, it is a confined bound state represented by a single $U(1)$, the diagonal $U(1)$ of the $U(4)$.

Species

A species is a collection of individuals, or particles, that look similar. They can only look similar because of a symmetry, so the n individuals of a species transform in the n of $U(n)$. A collection of particles in the n of $U(n)$ is the same as a bound state. Hence, a species is the same as a bound state, which itself is a new particle one level higher. Species, particle, organism, and bound state are synonyms. Species, like particles, are fuzzy because of the principle of multiple memberships.

Distances

The distance between two particles must be a measure of their coupling. Two decoupled systems must be infinitely far from each other. The coupling between two particles originates from the smallest common $U(n)$ under which they are both charged. This $U(n)$ corresponds to a certain time scale, and it controls the degree of similarity of the internal structure of the particles. Particles at large distances from each other interact on a long time scale and are different on the inside. Distance is only well defined for large distances because of the fuzziness of the particles themselves. Distance has dimension of time and there is a maximum speed by definition. If two distant particles could interact on a short time scale, they were not distant to start with.

The collection of distances between a set of particles can take different shapes. In biology, the distances originate from a tree. The evolutionary distance between two species is the shortest path between the species in the tree. The distance has dimension of time and is a measure of the time since last common exchange of genetic information. In physics, the distances between particles originate from a space time manifold. The distance between particles is given by the last time in the past where they could share information.

Symmetry breaking patterns of $U(N)$ contain both of these notions of space. The tree comes from a hierarchical symmetry breaking pattern. First $U(N) \to U(n_1) \times U(n_2)$, then $U(n_1) \to U(n_{11}) \times U(n_{12})$, etc. The manifold notion of space comes from a pattern of symmetry breaking similar to the placement of $D0-$branes along a manifold. There are symmetry breaking patterns that combine these two notions of space. There are also more complicated patterns.

Time in quantum mechanics

Consider a particle of mass m in a $1+1$ dimensional spacetime with a metric

$$ds^2 = (1 + 2\phi(x))dt^2 - dx^2$$

Suppose $\phi(x)$ is centered around $x = 0$, e.g. $\phi(x) = \frac{1}{2}\omega^2 x^2$. The particle will remain around $x = 0$. A world line of the particle can be parameterized by t itself. The time along a world line from t_0 to t_1, with boundary conditions $x(t_0) = x(t_1) = 0$ say, is given by

$$T = \int_{t_0}^{t_1} \sqrt{1 + 2\phi(x) - \dot{x}^2}dt$$

In the limit of parameters where the particle stays close to $x = 0$, the square root can be expanded and we get

$$T = (t_1 - t_0) - \int_{t_0}^{t_1} (\frac{1}{2}\dot{x}^2 - \phi(x))dt$$

Multiplying with the mass m, we get

$$mT = \text{constant} - \int_{t_0}^{t_1} (\frac{1}{2}m\dot{x}^2 - m\phi(x))dt = \text{constant} - S$$

where S is the action. This calculation illustrates some important points. The action of quantum mechanics, S, is proportional to the world line time itself. The path integral is

$$\int d\{\text{path}\}\; e^{-imT(\text{path})}$$

where $T(\text{path})$ is the time along the world line of the particle.

The particle is attracted to points where the potential, $\phi(x)$, is low. Here time goes slower and g_{00} is smaller. All forces of nature are time dilation forces. Particles are attracted to points where their own time goes slower. Time goes slower for an electron when it is close to a proton. Time goes slower for humans closer to the opposite sex. People in good company live longer and age slower. Time goes slower for a planet close to its star. A clock built out of positively charged particles of standard electromagnetism would show time dilation depending on its position in an electric field.

The invariant quantity is the product mT which appears in the path integral:

$$e^{-imT} = e^{-im'T'}$$

For a particle in an attractive field, we can either say that the particle has lower mass, or that time goes slower for the particle. Usually, we use the former terminology for an electron bound to a proton, and the latter for a planet close to a star.

Negatively and positively charged particles experience distinct metrics, g^+ and g^- because of their coupling to the gauge field. Schematically,

$$g^+ = g + A$$
$$g^- = g - A$$

The ordinary metric is an average of the individual metrics seen by the particles. The ordinary metric is the approximation where we forget about all the small gauge charges of the particles.

We also see from e^{-imT} that time in quantum mechanics is periodic with period $\frac{2\pi}{m}$. We will discuss the interpretation of periodic time later.

The egg

An egg is a configuration of high symmetry, a highly symmetric $U(n)$ state. This can be seen both from the way it is formed and the way it develops.

The egg is formed when the male and the female $U(n)$ form a bound state and restore a $U(2n)$ symmetry.

An egg develops into an embryo by repeated cell divisions. The egg divides into daughter stem cells that have less power than the egg itself. The major symmetry axis of the body is laid out and the stem cells for various types of tissues are produced. The development of the organism progresses through rounds of symmetry breaking differentiation events. The daughter cells are differentiated and do not have enough information to generate the whole organism. The distance between the cells as defined here, namely the degree of symmetry breaking, increases at each round of cell division. The original egg has the most symmetry. The egg can even make a copy of itself with almost the same amount of symmetry. The beginning of embryogenesis is a time of exponential expansion, symmetry breaking and distance enhancement.

The meaning of time and black holes

Time is an internal property of the particle or the organism. No reference frame is needed. Time is an increasing function for the particle along its world line. Time represents the amount of internal change inside the particle, the amount of evolution, or the number of mutations. A clock follows the time of its constituents. If a clock is made of atoms that all mutate slowly, the clock will progress slowly as well. The quantum mechanical system inside the particle has the state $\sum_k e^{-iE_k t} v_k$. The internal rate of change is set by the energies. Energy is mutation rate.

When two particles split up and meet again later, they have lived in different environments, and the total amount of accumulated mutations could be different. In regions around a heavy object, such as close to a star, time goes slower. A black hole is the most extreme. Time almost stands still in a black hole. A black hole has higher degree of symmetry than other places. It is built from a more unbroken $U(n)$. We saw above that the highly symmetric $U(n)$ structures were eggs. A black hole must be an egg. A black hole is the place where condensed information is stored, it contains the (generalized) DNA of the system. That is why time stands still in the black hole: the DNA must be preserved; the mutation rate must be low. When the egg develops, by absorbing matter from the outside, a well-defined structure results. The properties of the emerging structure were encoded by the DNA. The information in the black hole is a recipe. Alternatively, black holes could be described as places where all masses and energies are close to zero. The time evolution $\sum_k e^{-iE_k t} v_k$ is slow. The DNA is encoded in the quantum state which has almost unbroken $U(N)$ symmetry.

Black holes are not qualitatively special. Every cell is an egg. Every particle is a black hole. Black holes just have more symmetry and more time dilation than other particles. The term black hole emphasizes the absorption of matter and ignores the purpose of the black hole.

Quasars

Galaxies are organisms and they make baby galaxies. A male and a female galaxy meet, their black holes mix, and later baby galaxies are born. The baby galaxies are probably what we call quasars. The merged black holes divide and form the egg of a new quasar. The egg of the quasar grows by attracting matter. The light coming from the quasar escapes from a place close to the black hole and hence it is highly red shifted. The mother galaxy gives birth to a litter of quasars. The quasars move away from the mother galaxy. There is an approximate characteristic time period between consecutive births. Seen from the outside, it looks like a group of quasars around a mother galaxy with the highest red shift quasars located closest to the mother galaxy. The red shifts of the quasars of a given galaxy would come in discrete values correlated to the time of birth. The exact patterns would usually be more complicated as always in life. This exact pattern of highly red shifted quasars around a galaxy has been argued by Halton Arp et al.[8].

The quasars are young but they look like something from the distant past.

They are from the distant past in a certain sense, because they came from black holes where time stood still. The age of a system is an extremely tricky question in a quantum world. The creation of the quasar was a quantum event, outside the regime of validity of general relativity.

Information

The whole system seems very similar to a system of pure information. Suppose we try to write a book by assembling words into sentences, sentences into paragraphs, paragraphs into chapters, and chapters into books. Free sentences can be mutated at a shorter time scale than the book itself. It is very difficult to mutate the book without breaking it. The book is not just a hierarchical assembly of words. If we change a word in one sentence, corresponding changes are needed in remote parts of the book. The book is very non-abelian in nature. The relationships are neither hierarchical nor described by a smooth manifold.

Chromosomes

The human chromosomes are divided into the 22 autosomes and the sex chromosomes, X and Y. The 22 autosomes are always together indicating a strong $U(22)$ symmetry. The X and Y chromosome come from a weaker $U(2)$ symmetry. Each of the X and Y chromosomes can pair up with the bound state of the 22 autosomes. A pair of the 23 particle states can pair up themselves, but only $X - X$ or $X - Y$ never $Y - Y$. All of this could be described by a broken $U(n)$ theory. The theory could be enlarged to encode individual nucleotides. And it could be enlarged to include the whole universes sitting below. The better the system is built, the lower the mutation rate is. $U(N)$ symmetry, confinement, low mutation rate and time dilation all coincide.

The biology, physics, bottom-up, top-down dualities

The whole system can be seen either from a biology or a physics point of view, and from a bottom-up or top-down view. Take the example of the development of cities. People formed cities and moved to them from the countryside. The usual explanation would be the bottom-up biological explanation of humans with free will deciding to build cities. The top-down biological explanation would be that the larger organism, say the earth, had reached a certain developmental stage and distributed some signals, an environmental change, that unconsciously told the humans to behave differently. The physics explanation would be to describe the system as a gauge theory. The bottom-up explanation would claim that the particles were attracted to each by gauge forces and got assembled into bound states. The physics top-down explanation would be that a phase transition had taken place.

These dual points of view are equivalent, but certain views are more suited for certain situations. Take the example of the appearance of a new animal species like humans. We claim that the top-down biological explanation is the most suitable. The top-down biological explanation is that the larger organism had reached a certain point in its development and that the new species were created in a process comparable to cellular differentiation.

Everything is quantized

All objects in nature are quantized. They come in discrete countable units and relationships between objects are governed by integers. From the physics point of view, it is a consequence of quantum mechanics and the $U(1)$ and $U(N)$ groups. From the biological point of view, it is because organisms belong to species. Stars and planets should come in quantized types. Solar systems should resemble atoms and molecules. The number and type of planets correspond to the type of the star. Orbital quantization in exoplanetary systems have been found by Rubcic and Rubcic [9], Nottale et al.[10], Poveda and Lara [11], Chang[12], and Zoghbi [13]. Solar systems can be ionized and governed by laws similar to chemistry. The stability of a multi star system should be dependent on the planets. The galaxies should also group into multiplets of $U(n)$s, collide with each other, split up, and create new galaxies. The night sky is a snapshot of a giant Feynman diagram seen from below. The periodic table of elements could be reinterpreted as multiplets of some $U(n)$s. Geological structures likewise.

Magical symmetries

The $U(N)$ symmetries imply that the world should have amazing symmetries and numerical coincidences at all levels. The symmetry breakings at a high level should have traces all the way down such as large scale structures in the universe, and the cosmic background radiation aligning with galaxies, with solar systems, with planets, with animals, and with cells in magical ways.

Rest mass

Consider a particle with rest mass M in Minkowski spacetime with world line $x^\mu(\tau)$. The internal time t of the particle is given by

$$(\frac{dt}{d\tau})^2 = (\frac{dx^0}{d\tau})^2 - \sum_i (\frac{dx^i}{d\tau})$$

If we choose $\tau = t$, multiply the equation with M^2, and choose a constant velocity, the equation becomes

$$M^2 = E^2 - \sum_i (P^i)^2$$

If the particle is charged, the interaction with an external $U(1)$ gauge field,

$$Q \int A_\mu(x(\tau)) \frac{dx^\mu}{d\tau} d\tau$$

leads to extra terms

$$M^2 = E^2 - \sum_i (P^i)^2 + QA_0E - Q \sum_i A_i P^i$$

A natural generalization of this formula is

$$M^2 = \sum_{\mu,\nu} Q^\mu A_{\mu\nu} Q^\nu$$

where $Q^0 = E$, and Q^i include momenta and gauge charges. The $A_{\mu\nu}$ are background fields including the metric and the gauge fields. The rest mass, which sets the amount of time dilation inside the particle, is given by the charges of the particle, and the background fields. There is a large group of reparameterizations that generalizes spacetime reparameterizations and local gauge transformations. Energy, momenta, and charges can be mixed into each other. Time, space, and gauge fields can be mixed into each other. For any particle, there is a generalized rest frame where momenta and charges are zero, and $E = M$. On our planet, there would be no way of detecting long range cosmic gauge fields. These fields would only be needed to understand dynamics in the solar system or the galaxy.

This type of formula could be used to count the number of microstates for a given rest mass. These formulas are in no way exact. The point is that it is natural to assume that energy, momentum and gauge charges can be described in a unified way. The counting of microstates for a black hole should be the same as counting microstates for any particle.

Geometry or group theory

Consider for a moment the requirement of a common origin for all the properties of particles. Particles have mass M, momentum P, angular momentum

J, and gauge charges Q under some $U(n)$. P and J are geometric in origin. One approach is to explain M and Q in terms of P and J. This leads to the Kaluza-Klein theories, extra dimensions, and compactifications. Another approach is to explain M, P and J in terms of Q. This is the idea of replacing space with a $U(N)$ group. We claim that the latter option is more natural. The momenta P come from $U(1)^n$. The charges come from $U(n)$. It is easy to obtain $U(1)^n$ from $U(N)$, but it is difficult to obtain $U(n)$ from geometric constructions. The rotation group looks like $SO(3)$, but the presence of spin-$\frac{1}{2}$ particles tells us that the group is really $SU(2)$. That in itself is an argument for $U(N)$ rather than geometry. $U(N)$ comes with its own way of interpolating between different symmetry breakings. Geometry can not easily interpolate between distinct topologies. Also, $U(N)$ is $U(N)$ifying.

Spectral lines

Spectral lines come from transitions from one state to another, and the energy of the emitted photon is given by the difference of the energy levels. Shifts of spectral lines can have different origins. When an atom is placed in an electric field, the shift is called the Stark effect. The shift due to a magnetic field is called the Zeeman effect. These two effects lead to relative shifts of individual lines. When the atom is placed in a strong gravitational field, all lines are shifted collectively due to time dilation.

In the $U(N)$ language, these cases have the same underlying explanation. The atom is placed in background gauge fields, and the energy of the emitted photon is a function of the initial charge, the final charge, and of the background gauge fields. The gravitational field acts like an outer $U(1)$ field under which all states have the same charge. Changes of this $U(1)$ field leads to an overall shift of the spectrum. Other fields, such as an electric field, interacts with the internal $SU(n)$.

When a particle is moving relative to the observer all lines are shifted together. This is known as the Doppler effect. The Doppler effect corresponds to changing the charges of the system simultaneously such that the energy levels shift proportionally. The internal $SU(N)$ version of the Doppler effect is to change the charges in a more complicated way, e.g. by replacing a Hydrogen atom with a Helium atom.

Let us forget about the claims made so far in this paper and impose the requirement that all shifts of spectral lines have the same underlying cause. Such a requirement would force gravitational and gauge fields to have the same origin. Since gauge fields shift the lines individually and the gravitational field shifts them collectively, gauge theory must be the general principle and gravity the special case. Gauge fields touch the internal $SU(n)$ structure of the spectra, whereas gravity only touches the outer $U(1)$. It would also follow from the Doppler shift that momentum is a gauge charge. But if momentum is a gauge charge, there can be no predefined spacetime. The theory must be a simple quantum mechanical matrix model of $U(N)$. Since time and space can mix, time itself must also sit inside the $U(N)$.

Nuclear decay rates

The solar system is a $U(n)$ bound state. The are lots of $U(k)$ subgroups. The constituents are not distributed in a hierarchical way but mixed in a non-abelian way. The sun should be a source for various long range gauge fields, and particles on earth have different charges for these fields. We should hence expect that particles on earth experience differential time dilation depending on the distance to the sun and the activity of the sun. Such effects have indeed been seen in nuclear decay rates. In the papers [14, 15] by Jenkins et al., it is shown that ^{32}Si, ^{226}Ra and ^{36}Cl have decay rates that fluctuate with the seasons and the earth-sun distance. The communication channels between the sun and the planets are very advanced. Similar effects should be seen at all scales in the universe.

The shadow universe, the template and the replicator

Suppose we have n particles, called electrons, in the quantum mechanics of $U(N)$ theory. The electrons are described by a $U(n)$ theory broken to $U(1)^n$. The electrons are located in a configuration described by the symmetry breaking of this $U(n)$. We can think of the electrons as embedded in a much larger broken $U(N)$ in which case the electrons are located in a bigger space. In any case, the electrons are structured in some time dependent configuration. Now, suppose there are n other particles, called muons, in their own $U(n)$, and that the $U(n)$s of the electrons and muons come from a broken $U(2n)$ with a $SU(2)$ symmetry relating the electrons and muons. If the $SU(2)$ is broken, the electrons and muons move independently of each other. It will look like two decoupled shadow universes, one consisting of electrons and one of muons. Now, suppose the $SU(2)$ symmetry is gradually restored. The attractive force between an electron and a muon partner will increase. In the limit of completely unbroken SU(2), each electron and its muon partner will be confined in an $SU(2)$ bound state. The two shadow universes of particles have aligned. If the muons are made of larger tighter block U(k)s than the electrons, the muons will dominate. The resulting structure will look more like the original muon structure. Now, suppose the $SU(2)$ breaks again. The muons and the electrons will decouple, but the electrons will be left in a configuration resembling the muon structure. The muon structure has made a copy of itself. The muon structure was the template. From the electrons' point of view, it will look like a magical force suddenly showing up and aligning the electrons into some new structure.

A simple example of this is a group of mothers and children, one child per mother. The mothers sit together in a group while the children play. Suddenly, the mother-child coupling is increased, and every child runs to its mother. The geometrical structure of the mothers have been copied to the children.

Black holes and eggs are especially good at acting as templates because they are the highly symmetric, high N, $U(N)$ states. The black hole is optimized for information storage, for information preservation, and to act as a template in a copying process.

Copies can not be made in quantum mechanics, so the template will be slightly modified, and there is an upper limit on the number of times the template can be used. It was the principle of multiple memberships that was used to transfer information. Quantum mechanics of $U(N)$ contains a replicator: Restore the SU(2), wait, break the $SU(2)$.

General relativity

General relativity is applicable at all scales of nature. Think of the world as a giant Feynman diagram. The diagram contains world lines and vertices. To define the diagram, a certain resolution is needed. The particles must be defined. There are always more microscopic formulations of the system. A choice of particles and vertices is made both when we make calculations and when we look at the world. Along the world lines, time is being calculated. A planet moving through space is an example of a very long world line. It is so long that a human does not see the vertices at all. Interaction vertices for the planet would be its birth, its death, or some major event like a collision. General relativity is the calculation of the world line time for a particle in between vertices. The calculation of the world line time is naturally done in an effective theory with a metric and the geodesic is the dominant semi-classical approximation to the path integral. General reparameterization invariance is automatic, since the choice of coordinates for the calculation of the world line time is arbitrary. A reparameterization is a change of basis in $U(N)$.

General relativity is contained in quantum mechanics. The general relativity description breaks down in the vicinity of interaction vertices. Quantum mechanics describes all aspects of life, whereas general relativity only describes the time between important events. General relativity can not be used to describe structure formation such as the creation of a galaxy or a solar system.

Expanding or steady state universe

Consider a particle of variable mass $m(t) = \lambda_1(t)m_0$ and a time dependent metric $ds^2 = g_{00}(t)dt^2 = \lambda_2^2 dt^2$. The contribution to the path integral from this particle is, as discussed above,

$$e^{-i\int m(t)\sqrt{g_{00}(t)}dt} = e^{-i\int m_0\lambda_1(t)\lambda_2(t)dt}$$

The quantum mechanical description of the system only depends on the product $\lambda_1(t)\lambda_2(t)$, so we can either include the time dependence in the metric or in the mass. Formulated correctly, a classical theory of an expanding universe and a steady state theory of increasing particle masses should be equivalent. A variable rest mass interpretation of cosmology was given by Hoyle and Narlikar in [17].

In the formula for the energy of a particle described above,

$$\sum_{\mu,\nu} Q^\mu A_{\mu\nu} Q^\nu = 0$$

there is a freedom to perform a scaling of the charges and the opposite scaling of the gauge fields. There are also more general changes of basis in $U(N)$. However, for small charges, the discreteness of the charges rules out continuous changes of a scale factor. In the regime where the discreteness of charges is important, the equivalence between an expanding universe and a variable mass theory would break down. The masses and the red shifts would be quantized.

Structure formation

Maybe the biggest difference between general relativity and the $U(N)$ world is the existence of charges. In general relativity, and in other theories of gravity, the only internal property possessed by a particle is its mass. We claim that mass alone is not enough to explain structure formation. In the $U(N)$ world, every particle is charged under various $U(n)$s. Moons, planets, stars, galaxies, clusters of galaxies, etc are charged. Stars within a galaxy are $U(n)$ confined to the galaxy. It will take more energy for a star to leave the galaxy than expected from standard gravity. The whole galaxy is color neutral under its own $U(n)$, but is part of a new $U(k)$ for a cluster. Galaxies of opposite charge under a dominant $U(1)$ can merge, split again, and create new galaxies of their own type. The stars and galaxies have multiple memberships as any other particle. A biological view might be simpler. All stars and galaxies belong to species. There are males and females, herds of animals, predators, food, etc. Stars in a galaxy are like animals in a herd. They move around rather freely but they are strongly bound to the herd. It is interesting to note that many ancient cultures grouped star constellations into animal species and sexes.

We claim that to understand the cosmos we must concretely find the charges for individual stars and galaxies.

A spiral arm galaxy

The distance between particles is the same as their evolutionary relatedness or the amount of symmetry between them. Consider a galaxy with a black hole in the center. All stars and solar systems in the galaxy were formed by repeated symmetry breaking or repeated cell division. The stars have less symmetry than the black hole and the symmetry breaking takes place in all directions. Hence, the black hole is in the center of the system. The first few cell divisions will lay out the major lineages of cells for the galaxy. Further cell divisions inside each lineage will lead to stars further away from the black hole. One can see how such a pattern can create a spiral arm structure.

Dimensionality of space time

If we view the world in geometric terms, it seems somewhat arbitrary that space is three dimensional. But in terms of $U(N)$ things are more natural. We live in a sea of $SU(2)$s. The rotation group of space is $SU(2)$. The Euclidean Lorentz group is $SU(2) \times SU(2)$. The most common symmetry breaking pattern of $U(N)$ is a product of approximately unbroken $U(1)$s and $SU(2)$s. We see many $U(1)$s, but $U(1)$s alone would not be enough. The interesting processes require non-abelian groups. $SU(2)$ is the smallest and the simplest non-abelian unitary group, and it has enough structure to consecutively build up the full $U(N)$ by block matrix embeddings. We live in the $SU(2)$ dimension.

Periodicity of time

Time evolution in quantum mechanics has the form

$$\sum_k e^{-iE_k t} v_k$$

in a diagonal basis where E_k is the energy of the state v_k. Each term has a periodicity of $\frac{2\pi}{E_k}$. The fast time scales reach their periodicity first. It is the periodicity of time that produces the interference patterns in quantum mechanics. Seen from a human point of view, the world looks more quantum mechanical at small scales because the period is reached faster for smaller particles. The presence of terms with different periods means that the world is not exactly periodic. When a period has been reached, the rest of the system has changed a bit. It is a system of fast cycles inside slow cycles. This phenomenon exactly parallels the generational cycles seen in living systems. A generation repeats the lives of their parents except for some mutations and changes in the outer world. On a longer time scale, the species themselves change. Life is a system of fast cycles inside slow cycles. The periodicity of time in quantum mechanics matches the mutated generational cycles in life.

Since time can mix with space and the gauge fields, time is represented by a $U(1)$ inside $U(N)$. The cycles inside cycles must be represented by some non-trivial twists such that the system returns to a transformed version of the group after a period. For reasons unknown to us, there are some interesting numerical relationships. We have

$$SU(2) = \mathbf{S}^3$$

and the Hopf fibration

$$SU(2) = \mathbf{S}^2 \times \mathbf{S}^1 (\text{locally})$$

These two views of $SU(2)$ lead to two different definitions of the volume of $SU(2)$.

$$\begin{aligned} &\text{Volume}(\mathbf{S}^3) = 2\pi^2 = 19.7 \\ &\text{Volume}(\mathbf{S}^2) \cdot \text{Volume}(\mathbf{S}^1) = 4\pi \cdot 2\pi = 8\pi^2 = 79.0 \end{aligned}$$

$8\pi^2$ is approximately a lifetime of a human measured in years, and $2\pi^2$ is the generational time. It is feasible that many important periods in nature come from properties of the unitary groups.

The age of a species

What is the age of a species or a particle? We saw that quasars are young but look like structures from the distant past. Imagine a 30 year old mother with a 10 year old child. From the grandmother's point of view, both the mother and the child have world lines that are 30 years old. The mother developed

30 years ago, and the egg of the child remained dormant for 20 years inside the mother. How old is the child? 10 years or 30 years? From the child's own world line, her age is 10 years. From the grandmother's global time, both mother and child are 30 years old.

A particle is represented by a world line in a Feynman diagram. The world line goes through vertices. Defining the particle across vertices is subjective. The birth of the particle must be defined. In order to quantify the age of a particle, it must be compared to another particle's world line. Quantum mechanics sums over all possible paths. Age is only meaningful when there is a single dominant semi-classical trajectory for the particle. The age of the earth or the universe might not even have a proper definition. The seasonal variation of nuclear decay rates illustrates the practical problems of even building a long term clock.

Interference of times

Shortly after the discovery of the theories of special and general relativity, physicists could ask how the human species and societies would look if past humans had traveled away in spaceships and returned. Suppose the humans traveled in distinct colonies. Such colonies would have evolved and developed independently of each other. Some colonies traveled close to the speed of light. Others stayed close to heavy stars. At times, colonies would meet and mix with each other. Because of relativistic time dilation, some colonies would have had more technological and scientific progress than others. Some encounters would lead to collaboration. Others would lead to mutual destruction. Young and old colonies could interfere in both positive and negative ways. Colonies could merge and split in numerous ways. When two colonies met, they could be so far from each other in time that they would be unrecognizable to each other. Colonies could meet versions of themselves from the past and the future. How should these interactions be described? Should one sum over unknown events in the past? Is there an underlying theory for this?

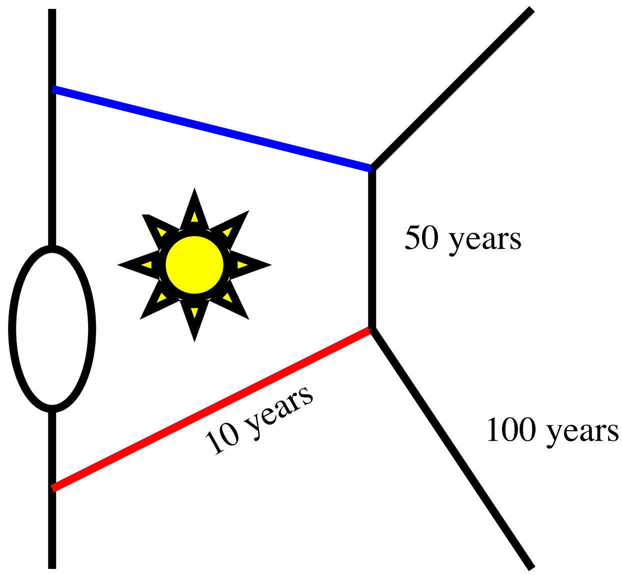

Figure 2: Colonies of space travelers. Colonies can merge and split. Each world line has an associated relativistic time. The colors represent different types of colonies.

Biologists could have asked a similar question. Eggs and cells can be dormant for long times. Some colonies of organisms could evolve for a long time. At the same time, there could be dormant eggs and cells. Eggs, and organisms of all ages would hatch, mate, form symbiotic relationships, eat each other, or become enemies. Organisms would co-exist with organisms of almost any evolutionary age. There would be both positive and negative interference. How should this system be described? Should one sum over unknown events in the past? Is there an underlying theory for this?

The theory needed by the physicists and the biologists is the same theory. It is quantum mechanics. Historically, quantum mechanics was discovered in atomic physics for different reasons. Quantum mechanics is the theory of the interference of a particle with itself from the past and the future. Quantum mechanics is the theory of interference of periodic, relative time

$$\sum_k e^{-it_k} v_k$$

where $t_k = E_k t$.

The super egg

The optimal egg must have certain properties. The information inside the egg must be completely preserved, which means that the internal time stands still. In a background metric, the egg's contribution to the path integral is given by $e^{-im_0\sqrt{g_{00}}t}$. The requirement that the internal time stands still gives $g_{00} = 0$ at the egg's location. If we consider g_{00} part of the mass, we get $m = m_0\sqrt{g_{00}} = 0$. The optimal egg must be massless seen from outside. The mass comes from the energy of the bound $SU(n)$ state inside the egg. The internal $SU(n)$ theory inside the egg must have a zero energy state, which requires that positive and negative contributions to the energy cancel out. A very natural reason for such cancellation would be supersymmetry. The optimal egg could be a super egg with a supersymmetric $SU(n)$ state on the inside.

The optimal egg must also have the property that it can travel with the maximum speed such that an organism can spread its genes as fast and far as possible.

An egg is made when the male and the female meet. The bound state of the male and the female was the mediator of the $U(1)$ force.

The photon exactly fits this description. It is massless, it travels with the maximum speed, and it is the mediator of the $U(1)$ force. The optimal egg must be a photon.

Thus, we obtain the picture that a photon is a carrier of information. A photon travels far away and tries to create a new structure similar to a seed in a field.

When the photon binds to matter, it becomes massive, and $g_{00} > 0$ in an external metric. If the photon can be seen as a supersymmetric black hole, the infall of matter breaks the internal supersymmetry. In an external view g_{00} acts as a supersymmetry breaking field. Seeing the photon as an egg, makes the connection between the distance measures of biology and physics more direct. The distance between two particles is a measure of the time since last common genetic information exchange.

The Milky Way

Many ancient cultures around the world had creation stories involving the Milky Way. Avid astronomers spent a lot of time watching the sky and finding patterns. The various creation stories have many similarities across the planet. Given the current world view, such stories can only be explained as superstition. The view presented here is more easily reconciled with traditional views. The existence of persistent, common creation stories is an observation that itself must be explained.

We postulate that the information to create all stars, planets, animals, and humans in the Milky way came from the black hole in the center of the Milky Way, Sagittarius $A*$. It is interesting that the distance between the solar system and Sagittarius $A*$ is estimated to $25000-28000$ light years and the period of the precession of the earth's axis is estimated to 25700 years. These numbers are close to a human lifetime in days.

The earth

We are almost certainly completely underestimating the information contained in the earth. Organic life and geologic structures could have come from a recipe inside the earth itself, similarly to what happens in a cell. It is known that biological species on the planet are getting older and accumulate more and more deleterious mutations on a species level as shown by Lynch [16] among others. This aging effect is similar to the cells in a human accumulating more and more mutations during the lifetime of the human. The solution is that the whole earth will be, or has been, reborn in a mutated form.

The theory of Darwinian evolution and the Big Bang theory of cosmology

The theory of Darwinian evolution, and the Big Bang theory of cosmology share a lot of properties. They are both theories that explain how the world came about. In combination, they explain why there are humans living on a planet. Both have an inexplicable root event. The theory of cosmology has Big Bang, and the theory of life has the creation of the first replicating biomolecule. The root event took place billions of years ago. The root event can not be reproduced in a laboratory, which is obvious for Big Bang, but a disappointment for the theory of evolution. After the root event, both systems spread out. Both theories have a fundamental principle for creation of new structures. In cosmology, structures form by aggregation of matter by the force of gravity. In the theory of evolution, new species appear by random mutations followed by survival of the fittest. This fundamental principle has never been experimentally verified in any of the theories. No object has ever been verified to have been formed by gravity. The fact that objects consist of matter does not mean that their creation is explained by gravity. A single human being also consists of matter. No species has ever been experimentally verified to have been formed by chance events and selection starting from a simpler species. The theories also share the property that observations have forced them to introduce periods of rapid development: inflation for the theory of cosmology and the Cambrian explosion for the theory of evolution. They also share the property that observations always indicate more fine structure than expected. The theories are always trying to catch up with observations. The theories also had to introduce ad hoc additions that made the theories less predictive, less natural, and harder to falsify. Cosmology had to introduce dark matter and dark energy. The theory of evolution had to introduce horizontal gene transfer and convergent evolution. The theories also lived side by side and became very popular during the 20^{th} century. They both had a major experimental discovery in the mid 20^{th} century: the DNA double helix by Watson and Crick and the Cosmic microwave background radiation by Penzias and Wilson. They both massively improved the methods for data collection towards the end of the 20^{th} century with high throughput genome sequencing and new telescopes. They also share a peculiar property that is rarely noticed. They are both bounded below by the scale of humans. Clusters of galaxies are formed from dust by the force of gravity, galaxies are formed from dust by the force of gravity, stars are formed from dust by the force of gravity, planets are formed from dust by the force of gravity, but humans, animals, and trees are not. Small biomolecules evolve and mutate. They form organelles, which evolve and mutate. The organelles form cells, which evolve and mutate. The cells form organs and tissues, and the organs form multicellular organisms including humans. But the biosphere, the planet, the solar system does not evolve and mutate. The theories have a mysterious creation event at the top and the human scale at the bottom. The two theories are so similar that they must share a symmetry. They transform in the 2 of a broken $SU(2)$ with each other.

Scientific theories

If the $U(N)$ theory is complete, it must describe everything including information. Scientific theories and abstract ideas must be encoded in the matrix. A scientific theory is itself a particle, a bound state of smaller particles. Any of these particles have multiple memberships. These other memberships could be humans, articles, or books. Everything is alive, even abstract ideas. Ideas transform in multiplets of $U(n)$, they are stored in eggs or black holes. They are born, they die, and they mutate from generation to generation. It also follows that ideas and scientific theories are not new discoveries. They are rediscoveries. They come out of eggs in due time. $U(N)$ is so rich that it contains and explains itself.

The theory of relativity follows the $8\pi^2$ generational life time

$$\begin{aligned}\text{Time of special relativity} + 8\pi^2 &= 1905 + 79 = 1984 \\ &= \text{Time of the first superstring revolution} \\ \text{Time of general relativity} + 8\pi^2 &= 1916 + 79 = 1995 \\ &= \text{Time of the second superstring revolution}\end{aligned}$$

The passage of a life time does not mean that the theory of relativity is eradicated from the matrix. It is incorporated into other theories. A similar principle must be valid for all particles.

Periodic time and dualism

World views and scientific theories can be categorized according to their view on time and dualism. Time can be either periodic or linear, in $U(1)$ or in $\mathbf{R}$. Theories can have or not have a notion of dualism. Dualism is the idea that the world can be understood in terms of opposite poles, of positive and negative charges.

Quantum mechanics of $U(N)$ has periodic time and dualism. The periodicity of time comes from time evolution of the form

$$\sum_k e^{-iE_k t} v_k$$

There are fast cycles inside slow cycles. The dualism comes from the $SU(2)$s. Particles have charges. Two oppositely charged particles will combine into a pair particle, which after some time will split up into two oppositely charged particles. This chain of events represent a fundamental cycle in the system.

Life is in the same category as quantum mechanics. There are generational cycles. There is a dominant dualism of male and female. A fundamental cycle is the male and female coming together and splitting again. Organisms are grouped into species.

The world views of many cultures and religions belong to the same category as quantum mechanics and life. They have cyclical calendars with cycles inside cycles. They believe in a continuous cycle of birth, death, and rebirth. They also have a dualistic world view with opposing forces like Yin and Yang.

The theory of Big Bang cosmology has linear time. There was a beginning at time zero and maybe a heat death in the future. Astronomical objects are not attracted to each other because they have opposite charges. They just have masses.

The theory of Darwinian evolution also has linear time. There is a progression from simple organisms to more and more advanced organisms. There is no notion of opposite charges.

When a system of periodic time is observed on a time scale much shorter than the period, it is very easy to mistake it for a system of linear time. When a Feynman diagram is observed on a short time scale and only parallel world lines of propagating particles are seen, it is easy to believe that there are no vertices. And when there are no vertices, there is no obvious need for selection rules and charges.

The four theories

Consider the four theories

Quantum mechanics of $U(N)$ or the matrix model
The theory of life or biology
The Big Bang model of cosmology
The Darwinian theory of evolution

We saw above that the theory of cosmology and the theory of evolution transforms in a 2 of a broken $SU(2)$. There is also a broken $SU(2)$ symmetry between quantum mechanics of $U(N)$ and the theory of life as described in this paper. Up to the use of words, they both have species, Feynman diagrams with vertices, birth, death, bound states, organism inside organisms, eggs, black holes, replication, natural selection, twisted periodic time, mutated generational cycles, charges, and sexes.

We can represent these theories as a $(2, 2)$ of a broken $SU(2) \times SU(2)$

Quantum mechanics of $U(N)$	Big Bang model of cosmology
Theory of life	Theory of Darwinian evolution

We need to explain the symmetry between the left and the right part of the diagram. We claim the theories of the right are obtained by approximations of the theories on the left. General relativity is the approximation of quantum mechanics where time is linearized and charges are ignored. General relativity is then used to construct a theory of the universe. The theory of Darwinian evolution can be seen as an approximation to a full theory of life. The theory of evolution does not treat the appearance of a new species as a differentiation event in a larger organism.

We predict that the two theories on the left are in the process of capturing the theories on the right like protons capturing electrons. Quantum mechanics of $U(N)$ and the theory of life will become the major dual descriptions of our world. Dual theories can be defined as theories that transform under a 2 of an almost unbroken $SU(2)$. The duality implies that there will be parallel progress in our theoretical and experimental understanding of those theories.

Simplicity of the laws of nature

The current world view has three major parts. The microscopic world is governed by quantum mechanics, the macroscopic world by general relativity, and in the middle is biological life. It is a peculiar world view. Why are humans located in between quantum mechanics and general relativity? And why are only humans and very similar organisms alive? The most natural explanation is that we have put ourselves in the center, and that the division into a microscopic and a macroscopic world just reflects our own size. The simplest possible theory should employ the same principle at all scales. The view presented in this paper is a way of achieving that. Quantum mechanics of $U(N)$ describes the world at every scale with everything being alive. This world view is not centered around the human scale. Observations and time scales are, for obvious reasons, still centered around the human scale.

Inheritance

The world consists of particles of fast time scales inside particles of slow time scales. Of course, the $U(N)$ world is non-abelian and a hierarchical view is only an approximation. The higher we get in the hierarchy, the more immutable the particles are. Particles inherit information from above. The outer particles act as a background for all particles inside it. Quantum mechanics itself or mathematics could just be particles that surround us. Mathematics actually has a degree of subjectivity. We can not formalize why certain axioms, definitions or proofs are important. Mathematics could be a natural science and on long enough time scales, or in other parts of the matrix, the rules could be different. Our physics is describable in terms of mathematics because physics is located inside the mathematics particle.

History revisions

The world is quantum mechanical. In quantum mechanics, there is no classical past. The best understanding we can get of the past is to condition the path integral on current knowledge and calculate observables in the past. In the recent past, relative to the time scale of the particles under consideration, the path integral is dominated by a single dominant semi-classical trajectory. This dominant trajectory is what we usually call our past. But further back there will be contributions from more than one semi-classical trajectory and the past will be a superposition of states. The further we go back in time, the less meaningful the notion of a single past becomes. An even stranger aspect of quantum mechanics is that when we go forward in time, we can move to configurations whose semi-classical interpretation of the past is different from today's view of the past. A quantum world is a world of history revisions.

Reductionism

Suppose we were given an almost infinitely fast supercomputer and the standard model of particle physics. Would it be possible to understand macroscopic objects such as large molecules and even human beings? We claim that the answer is no. Think of a human body. It is composed of many different cells. A human can not be built from one or two different cell types. The individuality of the cells is needed. Small gauge group are sufficient for describing scattering experiments of limited resolution where one sums over many events, but not for structure formation. To explain composite structures of n constituents, the constituents must have at least n distinct quantum states. Position in space is not likely to be enough. The distinct quantum states must come from the gauge groups. A description of a large molecule in terms of small particles would require a $U(n)$ theory of the particles for a large n. Reductionism is the attempt to write

$$U(N) = \prod_i U(k_i)$$

which is not possible. The force that makes a human walk to a restaurant can not be deduced from electromagnetism, not even in principle.

The fundamental force and the purpose of life

The fundamental force must be the same as the purpose of life. The force is trying to restore symmetry, to recreate the original egg, or to stop time. Particles are trying to build immortal structures. The hardest problem is to write a book that survives forever, whose library never burns down, and whose language will always be understood. Every scale of nature is equally fundamental and must be described by effective theories.

An individual human life

Seen at a certain resolution, a human is a particle traversing a world line in a Feynman diagram. The flow of time experienced by the human is the time or action along the world line. The most important events in the life of the human are the birth and the death. The birth is represented by a triple vertex where the pregnant mother splits into the mother herself and the new human. Consciousness must be related to the world line of the human. Our consciousness begins around the time when we are born and disappears when we die. Death must be a triple vertex of pair creation. A human splits into two particles at death. Very interestingly, we lose consciousness during sleep as well. Sleep resembles death. Sleep should then be modeled as the human splitting into a pair of particles: the night time particles. When these two particles meet again, the human wakes up. Sleep is the insertion of a loop into the world line of a human. There are approximately 28,000 of these small loops before the death split occurs. The night time particles have multiple memberships and interact with other parts of the matrix during the night. In terms of Feynman diagrams, a night time particle meets one or more other particles, becomes bound to them, splits up again and comes back to the other night time particle, and recreates the consciousness. The night time particles collect information and come back with it. This picture explains why we sleep and why we often have new ideas when we wake up in the morning. Dreams represent the transition between memberships, a look into the non-abelian nature of $U(N)$. What are the night time particles? Observers can see a physical body of a sleeping person. One of the night time particles must be the physical body of the person. The other particle must be what many cultures and religions call a soul. The $U(N)$ world has a major $SU(2)$ division of the world into a physical and a spiritual part. It might be that from the spiritual world's point of view, the physical world is the spiritual world. The pair creation at death must be the soul and the body leaving each other for good. The body particle is split into smaller particles, which then become part of new bound states. Likewise, the soul particle is split up and incorporated into new bound states in the spiritual half of the matrix. Finally, the new spiritual particles bind to new physical particles. There is no information loss in quantum mechanics.

Conclusion

Quantum mechanics of $U(N)$ is the theory of life.

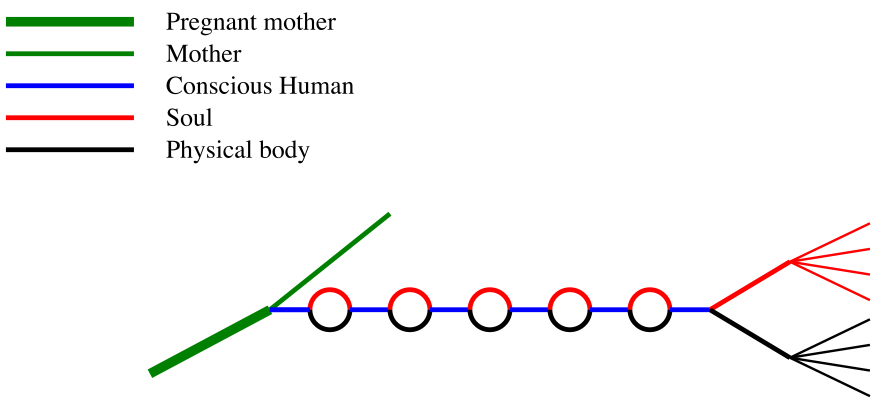

Figure 3: A Feynman diagram of a human life.

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