Time: A Brief Essay without Maths

The idea of this essay is to cut through the historical material typically given in the books, and concentrate on what is generally agreed. Every book I've read on time tends to gather these ideas toward the end of the book, having explored a wealth of interesting but redundant theories that were frankly blown away by the advent of relativity on the one hand, and quantum mechanics on the other.

I'm out to cut through the waffle, and give my impression of where the state of the art is at the time of writing. Because of this, and very contrary to my usual practice:

A. I've given no running references, just a brief bibliography at the end. This is rather a mixed bag, ranging from the accessible to the academic- I want to make it clear that any point I haven't labelled as just "my opinion" has some authority behind it.

B. Although I think my division of the material seems fairly natural, and that my opinion of this state is a reasonable and well-informed one, it is still my opinion, and you can feel free to believe me or not.

C. I've left out ALL the maths. I'm a mathematician myself, so attempting to convey the points here made without reference to the formulae has been an interesting intellectual exercise. Any statement I make, however, can be backed up by rigorous mathematics, in which I am entirely conversant… so there!

Following which, I intend to exceed the usual brief and consider what time means from the human perspective, and from the astrological.

My sincere thanks to Admin, in her persona of a slightly dippy 20-year old blonde actress named "Penny", who raised some very important points for clarification or inclusion.

The Four Schools of Time

I'll look at these in turn in some detail, but in summary we have:

1. Time according to Relativity. This treats time as a dimension of space, and works with a combination of the two called *spacetime*. Events are strung out along time in a *block universe*. This is one that can be pictured as an unmoving set of events, just waiting there, and never altered- a universe in which fate rules, and which is entirely deterministic. You can't have free will according to relativity.

2. Time according to Quantum Mechanics. This treats time as a physical quantity which allows the transmission, and the change of form, of energy. Events are probabilistic and their exact nature dependent on observation. It's often said that this doesn't of itself allow for free will- but it seems clear to me that for free will to exist, it needs some

non-deterministic system as a basis. Quantum mechanics provides free will the elbow room it needs to work in.

3. Time according to Thermodynamics. This more or less assumes that time happens anyway, and tries to explain some of its more puzzling features, especially the fact that it seems to move in only one direction.

4. Time according to the more creative psychologists, to mythology, and to astrology. This allows the existence of something greater than time, an eternal or archetypal realm to which space and time is subordinate. Quantum mechanical time is explicitly very amenable to this concept, and surprisingly, it is implicit in relativity also.

Relativity: The Gist without Maths

Relativity, broadly speaking, describes the universe on large scales. For astronomical distances and times, and lumps of matter big enough to cause NASA problems, reach for Relativity.

The world of Einstein's Relativity is a very simple world. It consists only of a universe populated by clocks. Each clock is also an observer- it can look at other clocks and read the times on their faces.

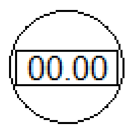

Figure 1. A clock, the only type of thing in Einstein’s universe.

The clocks exist in *spacetime*. Just as it sounds, this is a medium- a container, or arena- where the clocks exist and interact with other clocks. Spacetime gives each clock 3 dimensions of space to move in, and 1 dimension of time to use up as it moves. And, just as it sounds, the *space* part of spacetime and the *time* part of spacetime aren’t separate- they interact, changing together for reasons I will try to explain.

The motion of the clocks- the trajectories they follow, and their behaviour when they encounter gravitational fields- is determined by a quantity called *action*. If anything has a claim to be the primary substance of physics, it is this. Action can be split into many of the phenomena with which physics deals; depending on the experiment, action can be considered as position multiplied by momentum, or direction multiplied by angular momentum, or, as concerns us here, into time and energy. In fact, it is not unfair to say that action is the “real stuff”, and time and energy (and all the other things) are just perspectives on action. For the purposes of this essay, think of action as *the way energy distributes across time whenever things change*.

All the laws of motion- Newton’s and Einstein’s- are derived from a single specific behaviour of action; that when things change, *they change so as to minimize the action of the movement*. The universe is mean with its action; when Einstein's clocks move through Einstein's spacetime, they do so in such a way that they spend as little action as possible.

There are four important facts required to understand Relativity. The first is:

FACT I. If any clock- which is also an observer- is moving uniformly (without acceleration, so its speed doesn't change), then it can't tell that it's moving. It could be completely still, while everything else in the universe is moving past it.

In particular, if any two clocks-call them clocks A and B- are in relative motion, then there is no way to tell which is really moving just by comparing them. It will always be possible for clock A to claim to be still, while B and the rest of the universe moves past. Clock B could claim the same- and there is no physical test which could prove either clock wrong, for both are right.

The Special Theory of Relativity deals with clocks like this, in constant relative motion to each other. It says that two such clocks each appear to run slow to the other- the *time dilation effect*. It also says that the other clock will be flattened in the direction of motion- the *space contraction effect* (or *Lorentz effect*).

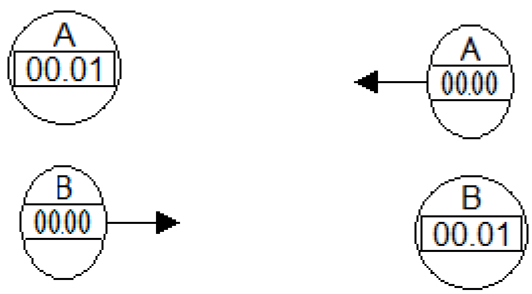

Figure 2. A sees that B is moving, running slow, and flattened. B sees that A is moving, running slow, and flattened.

These are not matters of appearance. Velocity is a real component of the universe- part of its structure. So, things in relative motion occupy parts of spacetime that are *structurally changed with respect to each other*. To all possible tests that B can perform, A is indeed narrower and ticking slower than B; and to all possible tests that A can perform, B is narrower and ticking slower than A.

Note that special relativity is *symmetrical*. What's true of clock A from clock B's point of view is true of clock B to clock A's point of view. This makes sense, because from A's point of view there is no way of telling which is moving and which is still, and the same is true of B.

The *reason* clocks run mutually slow, and flatten out with respect to each other, is because of both FACT I and the second important fact:

FACT II. From any clock's point of view, the speed of light must remain constant at "c", around 300,000 metres per second. Also, any clock must see the speed of light to be constant from the point of view of the other clock.

The geometry of the universe- its structure as measured by the three dimensions of space and the one of time- has this speed, *c*, and every clock's experience of it, *plumbed in to its very architecture*. In fact, space and time are what they are just so they can support this behavior of light. It's worth dwelling on this point. Space is the space we know, and time is the time we know, just so that light can travel at *c*. The special relativity effects of time dilation and space contraction are just such that this speed *c* remains constant when measured by any clock/observer.

Suppose that clock A is seen to be moving by clock B at a speed *v*. As B watches, A emits a light beam in A's direction of motion (Einstein's clocks are capable of lots of tricks like this). B measures the speed of this particular light, and finds it to be *c*. B doesn't see the two velocities adding to $c + v$, but why should it? Light isn't a massive thing that can be "pushed" by clock A as it moves- it isn't like a cricket-ball thrown ahead of it by clock A. Rather, it is a disturbance in spacetime that can stretch out at the rate *c* only. (B *will* see an effect on the colour of the light beam- but I won't go into that.)

But now consider the beam from A's point of view. A will be constantly catching up with the light beam, so if A measures the speed of its light, wouldn't it find this light to be travelling at $c - v$?

No! A will also find the light to be travelling at *c*. If it didn't, this would directly contradict FACT II- *from any clock's point of view, the speed of light must remain constant at "c"*.

Here's where time dilation comes in; A's *clock rate slows down*, so that light takes less time to travel the same distance. And here's where space contraction comes in; A's *measure of distance shrinks*, so that light can cross more distance in the same time. Between them, the two effects work to cancel out the velocity *v*. A is of course unaware of these effects- A only knows that the speed of light is *c*, and that A itself is at rest.

We should expect this, because A must be at rest from its own point of view. If this weren't so, it would contradict FACT I, *if any clock is moving uniformly, then it can't tell that it's moving*- because if A measured the speed $c - v$ for light, it would have proved itself to be travelling at *v*.

General Relativity deals with clocks that aren't moving at a constant speed- they are allowed to accelerate, decelerate or change direction (all of which are just different forms of acceleration), and they are allowed to move into areas of higher or lower gravity. This brings us to the third important fact:

FACT III. Clocks which have been accelerated run slow compared to clocks which have not been accelerated, and clocks in strong gravitational fields run slower than clocks in weak gravitational fields.

In fact, a gravitational field has an effect exactly equivalent to acceleration. If clock A shuts its eyes, it can't tell whether it's accelerating due to an applied force, or if it's standing still in a gravitational field. Acceleration feels like weight to it- as it does to us in a lift. In fact, the universe itself can't tell the difference between the two- the force that accelerates mass and the mass that exerts a gravitational force are two sides of the same cosmic coin.

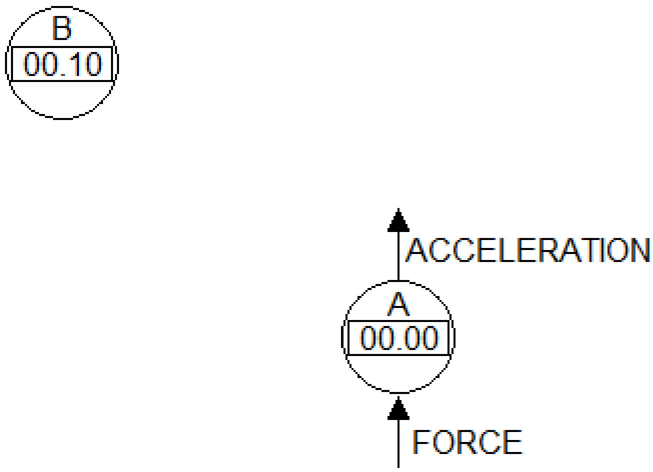

Figure 3. If clock A is accelerating compared to clock B, then clock A will run slow from B's point of view, but clock B will run fast from A's point of view.

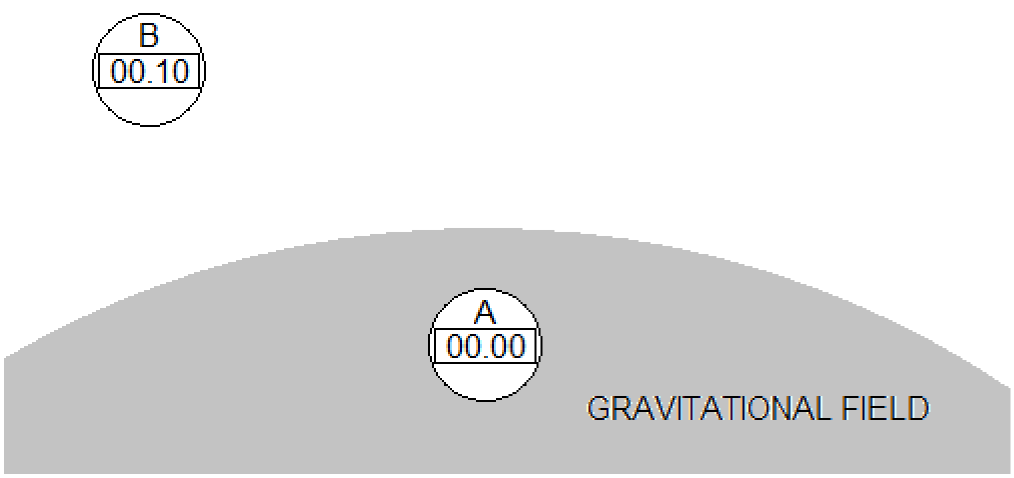

Figure 4. Equivalently, if clock A is in a stronger gravitational field than clock B, then clock A will run slow from B's point of view, and clock B will run fast from A's point of view.

So the General Theory of Relativity is *asymmetrical*. This also makes sense, because if A is accelerating it is subject to an ongoing force, which is something that isn't true of B. Equivalently, if A is in a stronger gravitational field, this is another measurable thing that isn't true of clock B.

Paradoxes only occur when we fail to take both theories into account. First consider special relativity's paradox of mutual slowness. Suppose clock A passes B at a constant speed. According to Special Relativity they are mutually slow. So what if you stopped A dead when it reaches B? How would the two clocks compare? They can't each be earlier than the other!

This is resolved by taking general relativity into account. When you stop clock A dead you must apply a force, causing a negative acceleration- which is still an acceleration. So you break the symmetry: A runs slow from B's perspective, while B suddenly runs fast (for a short while, very fast indeed) from A's perspective. Clock B's time overtakes that of clock A. Bring the two together again, and clock A will be seen to have an earlier time on its face than clock B.

This is also the gist of the more famous Twins Paradox. One twin remains on Earth, the other is sent on a long space journey at something close to the speed of light. When the travelling twin returns, the home-loving twin has aged much more than the traveller. The traveller has accelerated twice; once on leaving Earth, and once when at the destination the rocket had to slow, turn around and speed up again. It is during these periods of acceleration that the twin's lifetimes get so out of step, and the traveller's clocks move much slower than those back on Earth.

We can get a similar effect by placing the travelling twin in a high gravitational field, then reuniting the two. Gravity is equivalent to acceleration, so the travelling twin is again the younger of the two.

The most extreme case of this would be seen at the event horizon of a black hole. A black hole is a point of infinite gravity, the *singularity*, surrounded by a gravitational field that drops off in strength with distance. At a particular distance from the singularity, gravity is just strong enough to prevent light from escaping. This is the *event horizon* of the black hole, and it's where the extreme conditions of time and space occur.

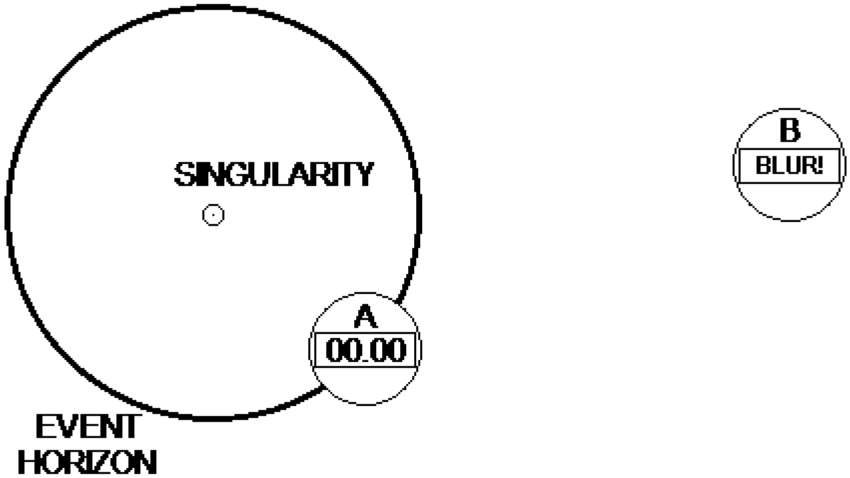

Figure 5. Around a Black Hole

If clock A approaches a black hole, while clock B remains at a safe distance, clock B will see clock A's rate slow down more and more- until, at the event horizon, A's rate of tick would stop altogether. Clock A will see B's rate speed up, until, when A just touches the event horizon, B's rate will blur into infinite speed. To B, A will forever remain frozen at the event horizon. To A, the whole infinite lifetime of the universe will condense to a moment.

When A crosses the event horizon, it will find itself living in a "time" that has swapped its place entirely with a dimension of space- along the Black Hole's radius. That is, outside the Black Hole time has its own special dimension, but inside, time is identical with the spacial dimension that runs from the singularity to the event horizon. Inside a Black Hole, you can't go forward in time unless you go deeper into the Black Hole.

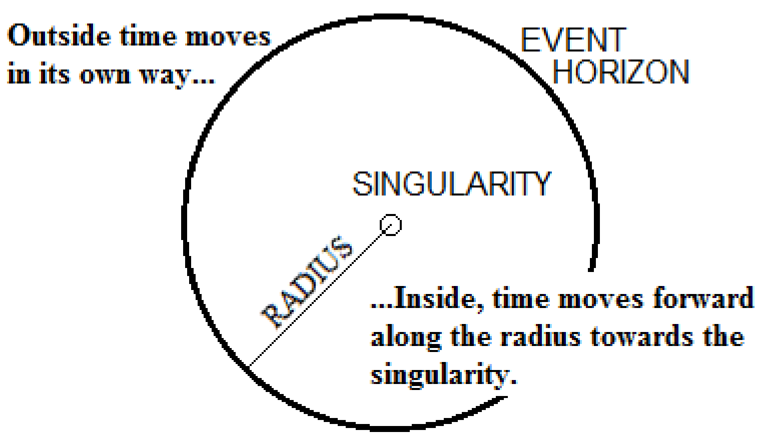

Figure 6. Time inside a Black Hole

Spacetime Intervals and Proper Time

So in Relativity, space contracts and time slows.

Take two events, X and Y. Two different clocks A and B may disagree on the time that passes between X and Y, and they may disagree about the distance between X and Y. Is there anything that clocks A and B *will* agree on?

There is, and it's called the *spacetime interval* between the two events. The spacetime interval is a kind of sum of the time and the distance between X and Y. For A, X and Y might be years apart with only metres between them; for B, X and Y might be seconds apart with billions of miles between them. But the spacetime interval, the measure that takes both space and time into account, will be the same for both clocks A and B.

FACT IV. *Any two clocks will measure the same spacetime interval between the same two events.*

Related to the spacetime interval is the *proper time* between the two events.

Suppose events X and event Y happen to a particular clock, clock C. Perhaps event X is clock C flashing red at 00:00, and event Y is the same clock C flashing blue at 00:10. Then since the events both happen to clock C, and clock C shows 10 minutes difference between the two events, that 10 minutes is the proper time between the two events.

Now consider all the other clocks looking on. They may disagree on the *distance* that clock C travelled between the two events. They may themselves tick out *different times* between the two events. But they will agree on the spacetime interval between the two events. They must also agree that clock C experienced 10 minutes between X and Y, and since the events happened *at that clock*, this time interval is special- it is the proper time between the events X and Y. These other clocks can also find the proper time from the spacetime interval- they just have to divide it by the speed of light.

(The technical phrase is that the *events*- which aren't just the flashes, but also the places and times that the flashes were emitted- are on the clock's "world line". Think of the world line as the unique history and itinerary of Clock C- all that's happened to it, and everywhere it's been.)

This proper time is given the symbol τ (the Greek letter *tau*), and is very important. It is the nearest thing relativity theory has to Newton's absolute time. It is the time the universe as a whole recognizes, the reference time to which all the other times are compared. It is the experience of physical time that all individuals have in and of themselves- the time our bodies keep (though not necessarily the time our minds keep).

Let's look at proper time from a slightly different perspective. Relativity tells us that if clocks A and B are moving relative to each other, uniformly or under acceleration, they fall out of step. In fact, the situation is a little more profound. Each clock A and B has its own personal "now"- some things which are past for A are future for B, and vice versa. That particular slice of space and time that is A's present is tilted with respect to B's- again, a geometrical feature of the Universe. Not that this is noticeable except for very great differences in speed, or over enormous expanses of space. But it does allow proponents of relativity to state that events are predestined, since, as they argue, if A has observed an event which is in B's future, B can do nothing to avoid it. (Quantum mechanics, however, has more to say on this matter.)

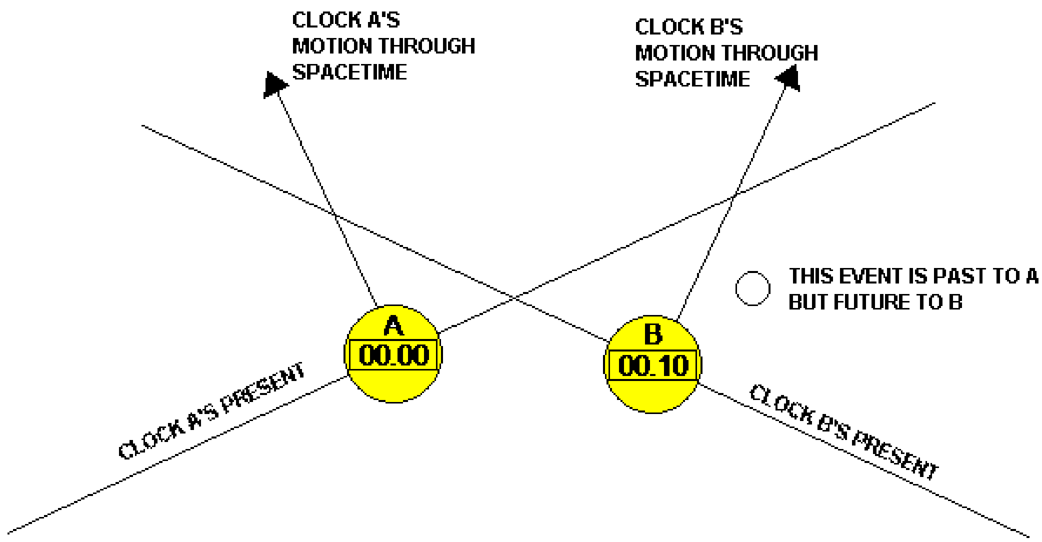

Figure 7. If the event circled is future from B's point of view, but has already happened from A's point of view, how can it fail to happen for B?

Only clocks which are not moving with respect to each other- that is, clocks which are both still or both moving at the same speed in the same direction- agree on what events comprise the present. And since every clock is naturally moving at the same speed as itself, every clock's personal time remains consistent. Accelerate clock A and it will see the universe slow around it, but its own experience of personal time- its own tick, its own personal rate- remains unchanged from its own point of view.

There is, then, *an irreducible personal experience of physical time*. This must be identical to the proper time discussed above, but this is all that relativity has to say on the matter.

It's often said that time in relativity is "reversible". This is true, in that the equations work just as well if you reverse the direction in which time is counting. That is, given the position of a rocket, plus the equations of its motion, I can work out not only where it will be a month from now but also where it was a month ago. However, there are two things that mark out a privileged direction of time.

Firstly, relativity allows the expansion of space, making “the future” that direction in which the universe is getting bigger. Secondly, relativity allows gravity to be an attractive force only; the future is that direction in which masses attract, not repel, each other.

Quantum Mechanics

Quantum mechanics, broadly speaking (again), describes the universe on small scales. For atomic and subatomic distances, and times so short they can barely be said to have existed, and particles of matter so small that the gravity between them is negligible, quantum mechanics is your man. QM is notoriously difficult to picture, so I’m not going to try to illustrate any of its points- all the descriptions will be verbal.

FACT V *While not being observed (i.e. not interacting with the environment) a system evolves deterministically with time in such a way that possible states of the system proliferate. The equation that describes this evolution is called the wavefunction.*

For our purposes, a state can be considered a distribution of energy across the system- how active each part is, and what it’s doing to the other parts. A complex enough system will have many such states. FACT V tells us that while the system is not observed, all these states exist at the same time, superposed one on the other. It also tells us that the superposition, the set of possible states, is *predictable*.- something that often surprises people. However, I give you Fact VI.

FACT VI *When observed (i.e. at the moment of interacting with the environment) a system alters so that only one of its possible states can be observed. Which state, out of all those possible, is determined entirely by probability- there is no way of telling, before the observation, which of the many possible states will be found. So all the possible states allowed, and really coexisting, in the superposition, “collapse” to a single state. This is the collapse of the wavefunction.*

This is the majority view of QM, based on the work of Niels Bohr The wavefunction can both evolve and, as it were, devolve- it can be calculated the same way whether time counts up or down. The collapse of the wavefunction, however, is irreversible- the original superposition of states can’t be spun out from the single, collapsed state that remains. This again allows for an arrow of time.

Facts V and VI together are the basis of the famous “Schrodinger’s cat” thought experiment. The cat’s health represents the state to be measured- until the box is opened, the cat is in *every* possible state, including both “alive” and “dead”. When the box is opened, the state collapses to one or the other.

Action is particularly important in quantum mechanics. The quantities into which action can be split – time & energy, or position & momentum, or direction & angular momentum- are *complementary*. On the atomic scale, when any quantity is measured, the degree of accuracy taken is robbed from the complementary quantity. That is, the more certain you are about quantity A, the less certain you can be about quantity B. Bear in mind that when you measure a quantity, the wavefunction collapses to a single distinct value of that quantity. The complementary quantity, however, remains in its superposed state. We can approach this through an analogy.

Consider an ordinary car, being driven at some unknown speed by an unknown driver. Pretend that all the information about the car comes from a single photograph, a snap of the car at some point on the road. A blurry photograph would show that the car is moving, and the worse the blur (for a given shutter speed) the faster the car. *Blurriness gives you information about speed.*

But a blurry photo is no good if you want to know who's driving the car. To get a useful snap of the driver, you need a fast shutter speed, giving a sharp photo. The faster the shutter, the clearer the driver's face. *Sharpness gives you information about the driver.*

But the faster the shutter speed, the less it's clear that the car is moving at all- you're cutting down the tell-tale blur. In the extreme case, you'd have a crystal-clear photo of the car if you had an infinitely fast shutter speed, but it would look like the car was still. The two pieces of information- driver and speed- are *complementary*; the more you know about one, the less you know about the other.

The above isn't a terrific analogy. For the car, we could take different pictures at different speeds and narrow down speed and driver as accurately as we want. For the quantum world, this isn't possible. To measure, say, position with any accuracy is more than just to give up accuracy on momentum- it's to put the particle into a state in which it has *no well-defined momentum at all*. Similarly, if you know the momentum with any accuracy, you displace the particle so that it *could be anywhere*. It's as though, if we knew what the speed of the car was, *every possible driver in the world would suddenly be sitting, superposed, at the wheel*- and this would be true even if we knew that just a second ago, it had been Emerson Fittipaldi.

There is a smallest possible unit of action- the *quantum of action*- and the uncertainties in the two measurements must multiply to make this.

Pin a particle down to a single position, collapsing its wavefunction so that the particle is found in a given state, and you make its momentum completely unknowable- the momentum remains in the superposed wavefunction of possible states. If you measure the momentum, however, the position blurs out into the wavefunction- and the particle is no longer in any one place.

Consider what this means from the point of view of time. If you determine that an event occurred within a certain period of time, you put its energy into the wavefunction state- the event has no distinct energy. This means that an event which takes place on a short enough scale can have wild excesses of energy- momentarily, even, to the exclusion of the conservation of energy (see below under “Thermodynamics”), although the universe will demand that this energy be “paid back” elsewhere. If, on the other hand, you measure the energy of an atomic event, you do so by putting the time into its wavefunction- so there is no longer a distinct time at which the event happened. You can of course know when you made the measurement- but the time of the measurement needn’t relate to that of the event, *which need not yet have even happened*. For instance, the measurement of the energy of a particle called a positron depends on the future emission of an electron- the positron is considered to be the electron travelling “backwards in time”.

This has extraordinary implications for time on the atomic level. On the “macroscopic” level, however, where human beings live, we don’t observe such effects- the probable states of things tend to conspire so as cancel out such extreme events. In particular, no quantum wavefunction is seen to extend to the human scale (except under very exceptional experimental circumstances). Although the outcome of a single collapse is unpredictable, given many such collapses the tendency will be for the most likely outcomes to dominate. This happens long before such systems are large enough to be directly perceived by we human beings.

However, biological cells (like neurons) and molecular carriers (like those in the brain) are on a small enough scale for quantum effects to be significant. Although many commentators pooh-pooh the idea that this gives scope for free will- because, they claim, random behaviour isn’t the same as willed behaviour- it seems likely that this lack of determinism is just the kind of thing that genuine free will could exploit. But then, why shouldn’t the random behaviour itself *be* free will? When we look at free will from the outside, it often looks random, capricious. Perhaps randomness is free will seen from the outside, and free will is randomness seen from the inside!

There is a minority school of quantum mechanics, based on the work of Hugh Everett III, that suggests that the wave function does *not* collapse. If you reread Fact VI, it could be interpreted as saying that the observed state is just that particular one that happens to be observed by us- but that this doesn’t necessarily destroy the other states. If this school is correct, then all possible outcomes of an experiment (or observation) do, in fact happen. The outcome we observe- the collapsed outcome- is just one of many that exist side-by-side in a complex mathematical space called *Hilbert Space*. This space, loosely speaking, is the home of the “parallel universes” of science-fiction. (Hilbert Space is also used in the majority school, as a calculation device.)

(A deterministic wave form that, when observed, collapses to a unique instance? The planets move in predictable cycles and communicate with harmonic waveforms. Then an event, a birth occurs which collapses them to an individual fate- or at least, an individual set of possible fates. What quantum physicists do prosaically may be more than an analogy for what astrologers do poetically!)

Thermodynamic Time

Thermodynamics, still broadly speaking because that's how this essay rolls, describes the universe on human scales. For distances between those you can see with an optical microscope, up to those for which you need an aeroplane; and for times from the blurry numbers of a digital stopwatch up to the calendar; for the machines that we make and the people that make them, we need thermodynamics.

The "laws of thermodynamics" come from the Newtonian physics on which the science is based. These aren't actually the FACTS that I'm concerned with, but I do have to mention two of them. The First Law is the conservation of energy- you can't just create energy out of nothing. In particular, for a machine to do work, you must reduce the machine's energy. If you could break the First Law, your engines would never need refueling, and you'd have a *perpetual motion machine of the first kind*.

There's a misconception that perpetual motion is impossible. In fact, the motions of (say) the planets already constitute perpetual motion. What *is* impossible is getting work out of such motion without also reducing the motion. For instance, when Voyagers I and II gained velocity by their "slingshot gravity assist" maneuvers around Jupiter, they actually slowed Jupiter- by a nearly infinitesimal amount. A machine is something that does work, so it's the" machine" bit which makes a "perpetual motion machine" impossible on the grounds of the First Law.

The second law is the tendency of *entropy* to increase. For thermodynamics, action plays very little explicit part in the phenomena- the big player is this entropy.

Thermodynamics is especially concerned with the way that energy spreads out with time. So it concerns itself with quantities such as temperature, pressure, volume, physical state and chemical composition. For example, hot things cool because their internal energy leaves them for the surroundings (heat energy spreading out); pistons expand because high pressure pushes outward (the physical energy of a gas spreading out). All these entail the increase of entropy.

Take a system on a human scale- a working engine of any kind, or a manufacturing process, or the weather. Then the entropy of that system, whatever it is, is a measure of the number of different possible states that the system can have. "Different" in this case requires some qualification. If any two states have the same value of a relevant thermodynamic quantity- especially the temperature, the pressure, and the volume- then those states are the same state in thermodynamic terms, even if, examined on a small enough scale, there are distinguishing features. We say that the same *macrostate* can have many different *microstates*. The proportions of the number of microstates of one macrostate to the total number of microstates can also be considered as a probability- the probability of finding the system in that macrostate.

As an analogy, think of a macrostate as a horse race, and the microstates as the possible finishing orders. Every result in which a particular horse wins is a microstate of the race. The order of the other horses will be different between any two microstates, but the winner makes the macrostate. There are more microstates in which the favourite wins, so the macrostate with the favourite ahead is the most probable one, and has the highest entropy. The microstates in which the outsider wins are the fewest, so the macrostate with the outsider leading is the least probable, and has the lowest entropy.

There is, however, a connection between entropy and action. The action of the change in a system depends on the difference between the kinetic and potential energy of that system, and this is also a measure of how energy tends to spread out (over what physicists call “degrees of freedom”- the ways in which the system can possibly change). We can take these degrees of freedom to be those complications that give rise to microstates. Returning to our race meeting, and stretching the analogy horribly so I apologize, the favourite will win with less effort than any other horse, so the most likely outcome (the one with the greatest entropy) entails the minimum action (sort of). The favourite will also benefit from a well-run, orderly race, one in which the fewest surprising things happen, such as falls, sprains, handicapping errors, and suffragettes. The outsider will win only after tremendous effort on the part of horse and rider, and will most benefit from surprising events (especially another horse falling), so the least likely outcome (the one with the least entropy) entails the greatest action (in a manner of speaking).

The connection with time is that, in the universe as a whole, as time goes on *entropy increases*. This is the second, law, after all. When high pressure gasses expand, they have more configurations of molecules with the same pressure- more microstates for a given pressure, higher entropy.

A hot thing has many molecules, each moving energetically. When it cools, the same heat energy is spread among many more molecules, so there are more possible configurations with the same temperature- more microstates per temperature, higher entropy.

In particular, our engines work either due to a pressure differential, or due to a difference in heat, and in doing work their pistons expand and their combustion chambers cool. If it were possible to break the second law, we could gather heat from cooler surroundings, or build up pressure in our pistons just by opening them up to the atmosphere. This would create *type two perpetual motion engines*- another impossibility, of course.

From relativity, we had time given a direction from the expansion of the universe, and the behaviour of gravity. From quantum mechanics, the irreversibility of the collapse of the wavefunction distinguished future from past. But both these conclusions rather begged the question of time’s arrow. That is, they answered what the difference is between past and future- but why is one “past” and the other “future”? What is it about the times when the universe was smaller, or masses were further apart, or wavefunctions were not yet collapsed, that puts these in the past?

The answer comes from thermodynamics, and it ties in with the operation of the brain- or with the operation of any information processing devices, which is why a computer is typically used to illustrate. It is the big FACT VII for thermodynamics (in respect of time, at least):

FACT VII When a computer stores a memory, it makes or breaks a connection that wasn't there before. Both actions generate heat, increasing the entropy of the universe. Therefore memories increase only in the direction of increasing entropy.

The physics underlying thermodynamics is quite old, indeed Newtonian, and so is taken to be deterministic. In particular, the second law is taken to be unbreakable- if it weren't, we could make our type 2 perpetual motion engines as noted.

However, it *is* in fact possible for violations of the second law to occur on the smaller end of the scales involved- that is, given a small enough space, and for a very little time, it is possible for order to increase, and for heat energy to pass from the cooler to the hotter material. Possibly, free will can again ride these violations, which have been measured to take place over scales greater than the cellular level in the human brain.

Linked to the thermodynamic concept of entropy is that of information. Layzer's (non-standard) definition of this is the difference between the maximum and the actual entropy of a system. That is, the information content of a system is the difference between how disordered it is and how disordered it could be. If entropy is increasing with time, information must be decreasing- but it may not be that simple, as Layzer explains in his book Cosmogenesis.

If every possible state of a system has some significance, we can take a more standard definition of information as the "logarithm to the base 2" of the number of possible states. By this measure, the human brain has something like 7 followed by 100 zeroes of information. Recently, however, there has been discussion as to how much of this is really important for consciousness, and the consensus- incredible though it may seem- is that *only 37 bits are valid*. Of course, this still amounts to something like 170 billion states.

Admin, in an early review of this essay, raised the interesting question as to the information held by a horoscope. As a rough guess, if we take the luminaries, the major planets, the ASC and MC points, and the North Node, we have 12 factors to consider. These can be arranged in $12\times11\times\ldots\times2$ = 479,001,600 ways, and in each of these ways can occupy one of 360 degrees, so $\times360$ = around 172 billion states. Taking log to the base 2… haha, that's 37 bits. Don't read too much into that! My calculation is very rough indeed.

Psychological Time

So both relativity and quantum physics allow of an irreducible physical time, the time of the body, and thermodynamics distinguishes the past from the future from the point of view of any information-processing mechanism, such as the human brain.

We humans are however aware of a different time, *psychological time*, the time of the mind, and therefore of human activity. To a large extent this psychological time is linked to the *tau* time. We age, and our metabolisms slow down, and our sense of time passing speeds up- so our metabolisms are an imperfect clock for *tau* time, and our minds seem to reflect this. Interesting things are associated with time moving quickly (but we look back on them and feel we accomplished more, that they generated more memories); dull things are associated with time dragging (but we look back on them and they blur into one another, so they generate fewer memories). So our sense of time is also linked to our capacity to process information- how much our internal clocks have changed, so to speak.

But there is clearly more to psychological time than this. When we dream, our awareness transcends the *tau* time, and when we awaken from a dream, we have not only recalled the past, we have also brought something of the future into the present. Only a fool or a physicist fails to see that dreams are part memory, part fantasy, and part precognition, as J.W. Dunne demonstrated. We experience *de ja vu*, we have intuitions. Even the prosaic fact that we remember is a creative act, not just the playing of a recording.

It seems that our minds- why not our souls, our spirits?- exist at a boundary, or overlap, between *tau* time, which is physical, and something else, which is eternal. Possibly psychological time, the *now*, is an intrusion from this other realm- when we are aware, when we observe, and especially when we make the decision to investigate, we open up time to this timelessness.

This eternal “thing”- call it Plato’s Ideal World, or the Australian Dreamtime, or the Collective Unconscious, or Tolkien’s Faerie, or the Welsh Annwyfn, or the Classical Golden Age, or the Anglo-Saxon Wyrd, or any of a hundred names from philosophy and myth and legend- exists outside of time, and holds time, past, present and future, within it. It may be impossible to understand intellectually, but it is not ineffable. It has its own Laws, and these are poetic, the laws of correspondence and right expression. It has its own inhabitants, which are these same Laws as our stories express them, the *Archetypes*. These are the primary figures of psychic activity that at the same time comprise and shepherd our awareness. No perception is uncoloured by the activity of an archetype, which we perceive- or fail to perceive- as an emotion, a bias, an apparently unfounded opinion, an intuitive insight, a precognition, or any of those things that make the perception a perception, rather than just a reading on a dial. *Because we are not Einstein’s clocks.*

And we can’t claim that this relationship between time and the eternal is unique to us. It was C.G. Jung who first made the concept a matter of scientific conjecture, under the name *synchronicity*, and it was he who introduced the term “archetype”. In Jung’s terms, synchronicity is experienced- the eternal thing intrudes- when two objective events, or an objective event and a subjective experience have the same meaning, but the one is not caused by the other (Jung does put this a little differently). To have the same meaning is to belong to the same archetype- to be ruled by the same god- or as an astrologer would say, to belong to the rulership of the same planet. For instance, the lighting of a flock of whippoorwills on a house, and a death in that house show synchronicity because both have the same meaning; they are ruled by the same god (Hermes, the psychpomp), or the same planet (Mercury, the messenger and bringer of omens). Similarly, a precognitive dream and the event it anticipates show synchronicity because they must have the same meaning, the same archetypal content. So there exist synchronistic phenomena than demonstrate the activity of the Archetypes *in the material universe*. We observe coincidences that are meaningful to us, or to others.

But relativity says that events are deterministic. Quantum mechanics says they are probabilistic. The universe is the minimization of action, and action is a continuous quantity- it doesn't take breaks that allow an archetype to slip in. In all this purely material activity, how do the archetypes make themselves known?

But in quantum theory, there are breaks in the continuity of action- they occur when an observation is made. The result of an observation isn't necessarily the option with the highest probability (the least action) attached.

In the larger world of relativity, something analogous happens when a measurement is taken. The equations of motion that action enforces aren't enough, of themselves, for us to predict what happens. We must take measurements of how things are *now*, at the start of a process, and feed these measurements into the equations. These measurements are called *initial conditions*, and they are quite different from the equations themselves. Every physical theory presents an equation, but not one can specify initial conditions in advance. The universe itself hands us the initial conditions- they at least are incidental, or accidental, a matter of chance. The laboratory is something of a cheat in this respect, in that there, the initial conditions are arranged artificially at the start of an experiment- every step is taken to exclude chance. It is when we have occasion to take the initial conditions of a process that synchronicity has its opportunity. Something has made us interested in the process- we have become involved in the process, as observer or participant- and now, at this time and place, the state of that process has some meaning to us.

"Now, at this time and place." In fact, time according to relativity, or quantum mechanics, or thermodynamics is missing this one important thing. None of these physical disciplines allow for a *now*, a present moment. Relativity says that clocks moving at different rates cannot share the same "now", but for that reason it can't allow a special "now", even from the perspective of a single observer. Quantum mechanics has a history made of evolving wave functions punctuated by collapses, but no point in this history is at all privileged. Thermodynamics tells us what is different between one time and another- the universal entropy will have changed- but again, it can't pick out a present moment.

The present moment, as experienced by a single observer, is a characteristic of *consciousness*. It is in the *now* that we exercise our free will, and by doing so create consequences all along our future world-lines. Surely, this *now* is some aspect of the meeting-point, the overlap of or interpenetration of time and eternity? When we choose, of our own free wills, to move a single pebble of matter, we alter all the future world line of the pebble- we have done the impossible, moving an infinite mass!

Time and Astrology

It is precisely the above synchronistic interruption in the ongoing processes of nature that are exploited in all mantic or "fortune telling" procedures.

The orbits of the planets (from whatever perspective, geocentric or heliocentric) are governed by Kepler's Laws and Newton's equations of planetary motion. The positions of the planets at a given time are precisely the initial conditions an astronomer would feed into the equations to determine the future positions. But the astronomer would only see a necessary (and unwelcome) compromise between the theory and the practice of astronomy. The idea that his observation- his willing intervention in the same process- opened up the world to the archetypes is anathema. *But this is what has happened*. The positions of the planets at a time and place encode, poetically, the possibilities of any action, or enterprise, or birth that occurs at that time and place.

(As a second example, the *I Ching* depends on whatever equations govern the generation of a nervous impulse to throw the coins, the release of chemical energy in the arm, and the impact and elastic rebound of the metal when the coins hit the floor. These equations are fantastically complex- after three or four tumbles in the air, the very gravity of the thrower's body makes a difference to the coins' trajectories, and the peculiar speeding up of the coins as they move from a spin to a flat-out vibration is governed by quantum mechanics, not classical. But the lie of the coins when they are still interrupt the equations, reset the initial conditions, and allow the pattern of heads and/or tails to take on a meaning.)

The birth chart, then, is a section through time. However, its meaning is much more than this. I recall a statement of Brian Bates, in his excellent novel *The Way of Wyrd*; "Each rune is a complete representation of wyrd. Just as one drop of water reflects a perfect image of all that is around it, so each rune reflects the totality of wyrd." The horoscope is likewise a representation not only of what is happening at the time and place for which it is cast, but of the history and future of what originates at that time and place. I mean this in a different sense from that in which transits and progressions are used -these would be a part of the evolution of the *equations* of the planets. I refer now to the way in which the early life can be found in the IC involvements, and the later in those of the MC; and how, for instance, the Jupiter disposition sheds light on the way the Native looks forward, and the Saturn in the way the Native looks back. These relate to the "initial condition" status of the horoscope.

So… What is time?

All the above. First and most usefully, it is a dimension, which gives the fourth set of coordinates in spacetime. Secondly, it is an irreducible experience of matter along its own world-line- it is what matter experiences, or gets out of, its own motion in the time dimension. Thirdly, it is the complement in action of energy, and so is self-referentially bound up with change- time changes because change happens, and change happens because of time. And fourthly, it is unidirectional because the information processing (like thought, which lets us know something has changed) always goes in the direction of increasing entropy.

It is also that particular dimension of spacetime at which, or along which, spacetime meets eternity. A symptom or aspect of this meeting is a single, privileged "now" that is different from times past and times future, and which changes because the point of meeting, or our relationship with this, itself changes. Here we have self-referentiality, time being considered in terms of change, which must need time to take place. Consciousness shares this self-referential nature. To be aware requires consciousness, which is the exercise of awareness.

This self-referentiality was considered by J.W. Dunne. Dunne assumed that since time is self-referential, it must be *infinitely* self-referential. That is, since time needed some other time to move in, that other must need a third time, and that a fourth, and so on and so on, making an *infinite-dimensional continuum* or *infinite regress* of times.

Consider a car moving along a road. The car has a speed. This means that the car's position changes, and it takes time for this to happen- Time 1, as Dunne called it. If time has been taken, then the car's position along the time-dimension has changed. But if the cars' position along the time dimension has changed, it *must have had a speed in time*. If so, it must have taken "time" of some other kind to change its position along Time 1, which brings in a whole new type of time, Time 2. But Dunne couldn't stop there, because motion along Time 2 would need a Time 3 to "happen in"- and motion along time 3, a Time 4- and so on forever.

Dunne was by no means necessarily wrong. Mathematicians use infinite sequences and infinite-dimensional spaces all the time (the Hilbert Space of QM is one). It remains as good an image as any- I'm rather fond of it. I like to think, however, that the infinite regress is what we mathematicians call a *convergent* one- that each time contributes less to the series as a whole, and that the whole infinite sequence adds to a finite value. To compound my folly, I like to imagine that this value is Euler's number, 2.718281828459… which has the special property that when used in differential equations, it is its own *rate of change*. Doesn't that sound time-like and self-referential?

However, to explain all the above phenomena of physics, psychology and synchronicity only requires three dimensions of time- as J.B. Priestley, building on the work of J.G. Bennett, set out in his book *Man and Time*. (We can still allow Dunne's infinite regress, and this may indeed lie behind reality- but if we only actually need the first three of its series of times, it does seem wasteful.)

Priestley's Model of Time

JB Priestley was neither a physicist nor a philosopher, but a playwright (and genius) concerned with the problem of precognition. He collected and analyzed many instances of these, and devised his model of time to explain what he found. The model also chimes in well with the above mentioned relativity, quantum mechanical and psychological times. I'm going to slightly expand on his idea.

Priestley gave time 3 dimensions, namely Time 1, Time 2 and Time 3.

Time 1 is physical time, the time of Einstein, the Tau time of our bodies and clocks. Our waking consciousness (Time 1 consciousness) is apparently tied to our brain and senses, and takes part in the physical events of the universe. In particular, T1 consciousness is subject to entropy and so perceives a unidirectional motion of time.

Time 2 is a second dimension of time. When we sleep, our waking consciousness defocusses, spreading forward and backward into Time 1 at some distance from the present. When we wake, our consciousness contracts to the Time 1 present, but can bring back perceptions that lie ahead of the present into which we wake.

Time 2 also extends left and right of Time 1. Time 2, in fact, consists of parallel lines, any of which can act as Time 1 lines, but only one of which we perceive as real. The rest comprises the realm of "fantasy" or "could-have-been" or "never-was" or "never-will-be".

Priestley needed this Time 2 for two reasons. *Firstly*, he found that some people can act on precognitive dreams to avoid what they dreamt of, apparently changing the future they have seen. For this to happen, the averted future must go somewhere- or rather the waking consciousness that would have encountered the event is diverted away from it, leaving the predicted Time 1 path. To do this it can't go forward or backward along the same time path- instead, the consciousness is shunted "sideways" in Time 2. What could have been has become what might have been, by an act of will- but it still exists, somewhere out there in Time 2.

Time 2 certainly resembles the "minority school" of quantum mechanics, the one that says all possible events do happen. It should be noted, however, that Priestley's Time 2 is a much simpler mathematical construct than Hilbert space.

Secondly, Priestley had also noticed that most precognitive dreams fall into two categories; they either predicted dramatic, disastrous events, or trivial, seemingly pointless ones. Dreams told dreamers about train crashes, volcanoes and wars, or about leaky fountain pens, broken shoelaces and practical jokes. "Useful" information- is the bus going to be late tomorrow? Will I win that contract? How will "Bebe's Brother" place in the 4:15 at Ascot?- never seems to feature. But these "middling" events- catching the bus instead of the train, courting the Smith contract instead of the Brown, or placing money on "Hunter's Moon" instead of "Bebe's Brother"- are just those kinds of things *that are most subject to our free will*. These events occupy only a very few Time 1 lines, side-by side with their alternatives, which we might easily have done instead. So they exist in a confused *pot pourri* of possible events, dependent on decisions we haven't yet made. Hence, the dreaming Time 2 consciousness can't possibly pick any one out.

Dramatic events, however, are things we have no control over and so can't easily avoid. They stand on many of the different Time 1 lines, and so are easy for the dreaming self to see and remember. Nothing we can do will stop the volcano from exploding, and we have very little control over the state of the train lines. But the same can be said of trivial events, the other type of event that dreamers reported. That fountain pen is going to leak on *that* day, because the flaw was in the nib from the day it was made; April 1st comes around every year; and that shoelace was always going to wear thin eventually.

Since a foreseen event can be averted, the alternative Time 1 paths can't be distinct from each other. They branch, so that a single Time 1 line can become two or more such lines. As our consciousness comes to a junction, our free will can act- within limits- to move along one branch rather than another. It's a simple as seating your child on the left of the car instead of the right, so that it's the shopping gets spilled, instead of the more dreadful thing you dreamt of last night.

But the consciousness that makes the decision can't, then, just be part of the structure of Time 1 or 2. It must exist in a more inclusive Time 3.

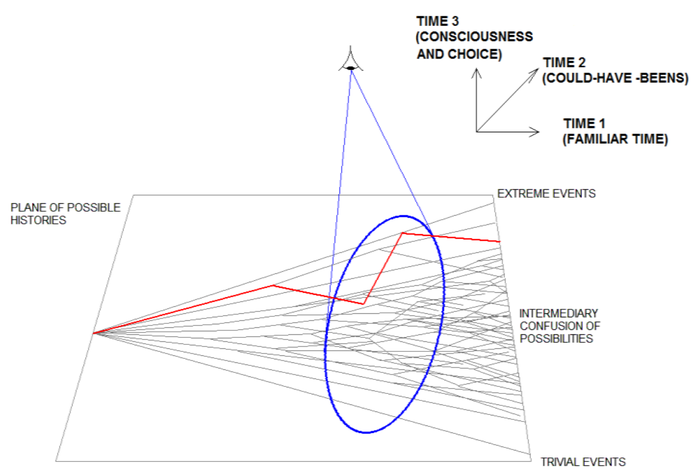

Figure 8 Priestley's model of time

Priestley doesn't use the analogy, but any fan of J.L. Borges will recognize the "Garden of Forking Paths". Each path is a "Time 1": the paths branch right and left into "Time 2"; and standing above in "Time 3" is the observer, happily walking in the garden.

Figure 9 The Garden of Forking Paths

This model has particular significance for astrology. I have written that energy is conserved in time- along physical time, Time 1in Priestley's terms. We might also ask ourselves, "is there any analogous phenomenon which is conserved in Time 2?" I suggest that there is, and this phenomenon is *meaning*.

Consider a hiker. In one memorable journey, the hiker remembers taking a right-hand road that led him to the little village where he met his future wife. According to Priestley (and no small number of quantum physicists) the same hiker *also* took the left-hand road, and came to a tumbledown farmhouse where Kathy Bates forced him to write a Gothic novel under threat of a chainsaw. After all, free will exists, and what can happen, must happen somewhere. In this light, astrology's claims to have significance, and especially to "predict the future" is clearly nonsense. The horoscope for the fictional hiker couldn't predict both events, let alone the other possible events *that must also have happened*- the ones in which the hiker turned back, or was taken too ill to travel, or was detained at the border for the suspect contents of his tobacco-pouch.

I suspect that this is not the case- that the alternatives are *not* infinite. Suppose that the hiker's chart had transitting Venus conjunct his natal Descendant in Capricorn at the time of coming to the fork in the road. This is certainly indicative of a forthcoming love-interest, so we shouldn't be surprised if he met a petite (Capricorn) woman (Venus) with whom he entered into a relationship (Descendant). However, I suggest that, had the hiker, exercising his free will, taken the left-hand path, he would have encountered not a Stephen King scenario but some other manifestation of the same transit. Perhaps he would come to that farmhouse and fallen in love with the older (Capricorn) but beautiful (Venus) farmer's wife (Capricorn) and stolen her away from him, thereby gaining a wife (Descendant) and making at least one bitter enemy (Capricorn, but also Descendant). That is, *the meaning of the transit would be conserved across the dimension of Time 2,* manifesting somehow whatever the decision of the hiker. Venus transits aren't even that rare, so perhaps it would manifest in a rather trivial way, but again conserving the same meaning- perhaps, being served pears (Venus) at an orchard (Venus) where the hiker worked (Capricorn) in a deal (Descendant) for a night's lodging (Venus).

Surely, this has to be so? The eruption of the volcano mentioned above is an event over which we have no control, and which therefore exists on very many Time 1 pathways. This is why it is amenable to precognition. *But the planetary configurations are the same over all these paths*. No person's individual choice can change the course of the planets- the same configurations, at the same instant of Time 1, occur all through Time 2.

In this way, the different Time 1's are knit together in a way unguessed by science. Energy, running along the Time 1 lines, forms the warp of the universe; meaning, running across the Time 1 lines in Time 2, forms the weft. These are also the terms in which Elwell explains synchronicity in *Cosmic Loom*.

How Seriously Should I Take This?

It's best to bear in mind that even relativity and quantum mechanics are just models, albeit very prestigious ones. As to any ideas I've put forward, a pinch of salt, please.

There are a few things that I haven't mentioned. Chief amongst these is *Noether's Theorem*, which explains all conserved quantities in terms of structural symmetries in spacetime, but for which an understanding of mathematics is required. Emmy Noether would be the only female authority I've quoted- an odd thing, don't you think?

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