G.K. Chesterton remarked that "the simplification of anything is always sensational". We currently model our world using two quite disparate field theories. An exemplar field in this context is that traced by iron filings scattered around a bar magnet. One of these field theories is an analogue theory ('classical' or 'continuous'), and applicable out to the largest lineal dimensions of the universe. The other theory is digital ('quantum' or 'discrete'), and only applicable to the very smallest of lineal dimensions. Both theories fall into the philosophical category of instrumentalism, for while they are spectacularly successful at predicting how the natural world will behave, they offer scant insight into the underlying reality, despite a century replete with heroic attempts to do so. The gravitational field, for example, is described as a 'curvature in space-time', and physicists' cats can 'simultaneously be both dead and alive'. These clichéd examples only scratch the surface of the deep storytelling tradition in the physics of the past century. As in life more generally, if you keep saying abnormal things often enough, they eventually become the new normal, a process that encourages even more distant excursions from common sense.

The ideal scientist will conduct an experiment to discover how the world behaves, and proceed to develop a testable hypothesis to explain why. A century ago, Michelson and Morley discovered that the speed of light could not be increased by adding on to it the existing speed of the earth around the sun. Michelson was awarded the Nobel Prize in 1907 for his work. Einstein was then awarded the Nobel Prize twenty years later for explaining this mystery (and a few others along the way). Today's comparable mystery is the accelerating expansion of the universe, the discovery of which has already earned Perlmutter, Riess and Schmitt the Nobel Prize in 2011. And of course a Nobel Prize awaits anyone who can successfully explain this newfound mystery of 'dark energy'.

The sound of a live musical performance, which arrives at our eardrums as a smooth analogue waveform, can be captured digitally by segmenting that smooth waveform into discrete recordable values. The audiophile is forever seeking recordings where the waveform has been broken up into the shortest possible segments, and the position of each of those segments has been determined with the highest possible precision.

If an audiophile were to continue this pursuit to its conclusion, seeking to reproduce the absolute sound of the original source, the specification would declare units at the Planck scale, named after the winner of the Nobel Prize in 1918. These are the smallest possible units of length and time, and were first established by merging the equations of Relativity and the Quantum. The Planck length is to a grain of sand, as a grain of sand is to the *width* of the universe, and the Planck time is to a second, as a second is to the *age* of the universe. So these units are very small indeed. By definition, light travels one Planck length during the period of one Planck time.

Life often takes us wandering far and wide, only to return us to the place we started, older but wiser. Our journey of discovery in physics is no exception. An apocryphal suggestion is that Descartes was lying in

his sick bed, when a fly crawling across the ceiling prompted him to contemplate and develop the coordinate system that bears his name. We can hypothetically segment the universe into cubes, each with sides of one Planck length. X, Y & Z coordinates, each a mere 256 bits wide, are sufficient to uniquely address each one of these boxes relative to an absolute origin. As we look inside each box, we find the 'reality' at that absolute address, and point in time. Because the world is in constant flux, at the next instant of Planck time, we will find a different 'reality' inside the boxes we investigated one Planck time earlier.

Instead of thinking of the 'reality' we encounter inside each box as an ordinary physical entity, like a 'field' or a 'particle' (or some part thereof), we can simply think of the contents as a 'mathematical relationship', or more fundamentally, as a 'computation'.

The theories of Relativity and the Quantum are built with complex mathematics that is in the most part beautiful (Quantum theory has a few inelegant renormalizations). At the time this mathematics was being discovered, it was also discovered that all mathematics (whether known to us yet or not), could be constructed (albeit not necessarily proven), not just through mystical reve-

lation (as formalized by Plato and vividly witnessed by Hamilton), but through methodical, algorithmic, computation. Computation has thus emerged as an even more foundational science than mathematics.

Because the universe is so accurately described by mathematics, it has been argued since ancient times that the universe is actually *composed* of mathematics. Now it is routinely argued that the universe is ultimately composed of computation, or information, following the lead of Wheeler. Mathematics describes the universe so effectively, because each element of the universe is a computation.

Indeed, this year's FQXi essay collection addresses the question "IT from BIT, or BIT from IT?" In this context, 'IT' refers to the material world, the physical stuff of which we and computers are made, and 'BIT' (Binary digIT) refers to the information that we and those computers process. As it happens, it is not a question of choosing one precursor over the other, but of choosing both.

Hawking tells the anecdote of a somewhat forthright woman who interrupts a physicist's lecture, declaring that he is in fact quite mistaken, for the world is a round disc resting on the back of a giant tortoise.

When he asks her what the tortoise is standing on, she retorts "You are very clever young man, but it's tortoises all the way down!"

The definition of a universal computer is that it can simulate *any* computer, including itself. This reality is now commonplace in computing infrastructure, where 'virtual' computers are hosted on more powerful 'real' (physical) computers. When this functionality first emerged, one was naturally tempted to test the fidelity of the simulation by building a virtual computer on a computer that was itself already virtualized. While possible, the cumulative processing overhead would push the host machine to its limits, just as successive tortoises would be crushed by the weight of those above them.

While physical reality (IT) is thus subject to the laws of physics (thermodynamics in particular), abstract information (BIT) is not. So one virtual computer (which is purely BIT) can simulate another virtual computer (which is also purely BIT), and this *contingent* simulated computer can be twisted, like a Möbius strip, so that it becomes the host of the initial virtual computer, as in the ancient conundrum of self-reference (Paul cites the then already ancient Epimenides paradox in a letter to Titus:

"One of Crete's own prophets has declared that Cretans are always liars.")

Extending this idea to the universe, we can simulate the myriad Planck cubes of the universe, and whatever reality might happen to reside inside them, collectively labelled as 'IT', using pairs of extremely simple virtual computers that exist only by virtue of simulating each other (BIT from BIT). Each half only exists for that half of the time during which it is simulating the other half of the pair.

These 'cellular automata' have much in common with conventional computers. They have a clock, operating at the Planck frequency, they have firmware that implements the laws of physics, they can directly transfer data to and from their 26 neighbouring cells, and each has a unique address (as specified earlier). And like conventional computers, these automata do not behave capriciously, but process information, according to their firmware, in a dispassionate, precise and unerring manner. It is this behaviour that gives nature her consistency in which we have such confidence.

With a world built on BIT simulating BIT, we are no longer concerned about where the derivative reality of IT might have come from. At a funda-

mental level, the universe (including you and me) does not exist. There is no IT, except of course for that half of the time during which the reality we *perceive* as IT is simulated by one BIT of each cellular automaton, and the other half of the time when the *perceived* IT is simulated by the other BIT of each automaton.

One can picture a couple of tortoises sitting upright back-to-back, admiring their respective sides of the disc they are both supporting, while mutually supporting one another.

If we open the lid on a Planck box, we won't find the machinations of the virtual computers supporting the box, for the virtual computers are entirely abstract. Having no lineal dimensions, they have never left the singularity, the dimensionless origin of space.

Instead, the Planck box is the base component of the 'IT' reality that the virtual computers simulate. This minimum reality that the virtual computers engender is an empty volume of space (having three lineal dimensions) that persists in time. The box can then be filled with all manner of physical phenomena, from the quantum vacuum through to everyday baryonic matter. The contents, whatever they might be, are defined in the registers of the virtual computers. This defini-

tion includes the address of course, but also the vector of the contents - the direction they have come from, the direction they are heading, and their speed.

There is no content class that can move from one Planck box to the next any faster than light, which propagates at one Planck box per Planck time. This is a fundamental limit on the interface between the Planck boxes. Thus, while some box contents (other than light) might be accelerated close to jumping from one Planck box to the next every Planck time, they will never transcend the maximum transfer capacity of the Planck box interface.

Inertia results from the desultory processing performed by the virtual machines. Each cellular automaton accepts information from neighbouring boxes, processes that information according to the laws of physics held in its firmware, and passes the information forward to the next box in the direction of its destination, without question or exception. Of course in explaining inertia, we account for mass.

Entropy, the forward arrow of time, is encapsulated in that vector information being processed by each and every Planck box throughout the universe.

The universe did not always have the number of Planck boxes it has today. In fact it need only have started with one, for one pair of self-simulating virtual machines can replicate the information in which they consist, spawning another pair of virtual machines. Those two pairs can spawn four, those four eight, those eight sixteen and so on, resulting in a very rapid expansion in the number of Planck cubes (and the resultant size of the universe). As the number of boxes increases, so too does the width of their Cartesian address slowly increment to its current width, approaching 256 bits. Space may have begun at a singular location, but because *every* Planck cube is actively replicating, space is expanding at every cube (every point) in space, quite unlike an explosion, which expands from one central point. As the absolute number of Planck cubes increases, so does the rate at which the universe is expanding increase.

However, as mentioned earlier, the myriad pairs of virtual machines simulating these myriad Planck boxes are themselves dimensionless, and remain in a superposition at the origin of the universe. Furthermore, the interface between the Planck boxes is actually an interface between the virtual machines at the superposition. Thus any given Planck box anywhere in the universe can directly interface with each and every other Planck box in the universe. It is thus that Planck cubes can become entangled, such that they instantaneously respond to a change in the contents of the other. The vast expanse (and apparent inaccessibility) of the universe is merely an illusion, for its lineal dimensions, which have separated the realms of Relativity and the Quantum, are merely computed, never actual.

Where all this infrastructure has arisen from is a metaphysical enquiry, suffice to say that if you start with nothing (zero), and split it into (+1) and (-1), you have the distinction essential to binary (or indeed balanced ternary) data, of which this infrastructure consists in its entirety. Given an eternity, it is then a statistical certainty that these data will eventually align themselves as they did, quite self-evidently, a mere fourteen billion years ago.

Copernicus made the sun stand still and the earth move, where previously the earth had stood still while the sun moved. The picture just painted is just as momentous a transformation in the way we model reality. But it was Newton who had the technical skills to formalize the revolution promulgated by Copernicus, just as a Nobel Prize awaits a technician who can formalize our return, after such a long excursion, to the absolute space and time first introduced by Newton. Sitting beneath an apple tree in a bucolic setting, you are a world away from the frenetic activity upholding that reality – unless of course, you are Newton.

Englert and Higgs are worthy recipients of this years' Nobel Prize, but their elusive boson accounts for a mere 0.046% of the mass of the universe, and it cost us tens of billions of dollars over the course of almost fifty years to (probably) find it. Listening to the data inside a Planck cube could require little more than a very sensitive interferometer, or perhaps a condensate of trapped ions.