Quantum Realism Part I. The Observed Reality

Chapter 1. The Physical World as a Virtual Reality

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"Not only is the universe stranger than we imagine, it is stranger than we can imagine."

Sir Arthur Eddington

We take our world to be an objective reality but is it? Those assuming that the physical world exists in and of itself have struggled to assimilate the findings of modern physics for some time now. An objective space and time should just "be" but in our world space contracts and time dilates. Objective things should inherently exist but in our world, electrons are probability of existence smears that spread, tunnel, superpose and entangle in physically impossible ways. Cosmology now adds that our universe just popped out of nothing about 14 billion years ago. *This is not how an objective reality should behave!*

1.1. A STRANGE WORLD

This book explores a possibility normally dismissed out of hand, that the physical world is the virtual result of quantum processing. The reader is asked to keep an open mind, as what will be proposed is neither illogical, unscientific nor incompatible with physics. Nor is it a modern concept, as the idea that the physical world is not all it seems has roots that go back thousands of years. It applies today because modern physics has re-discovered that *we live in a very strange world*.

1.1.1. Strange physics

Strange theories abound in modern physics, e.g. in *many-worlds theory* each quantum choice divides reality so everything that can happen does happen in an inconceivable multiverse of parallel worlds (Everett, 1957). In the *inflationary model*, our universe is just one of many bubble universes (Guth, 1998) and according to *string theory* it has six extra curled-up dimensions hidden from view. In *M-theory*, our universe floats on a fifth dimension "brane" we can't see (Gribbin, 2000) p177-180 and in *ekpyrotic theory* we are one of two universes that collide and retreat in an eternal cycle (J. Khoury, 2001). The days when physics just described the physical world we see are long gone.

Such explanations arise from the equally strange findings of physics, like Einstein's discovery that the sun bends light by curving the space around it, that the earth's gravity slows down time and that clocks tick faster on tall buildings than on the ground. Movement also dilates time, so an atomic clock on a plane ticks slower than a synchronized one on the ground (Hafele & Keating, 1972). In our world, reality basics like space, time and mass vary with speed, while the speed of light is strangely constant.

If relativity is strange then quantum theory is more so, as in Young's experiment *one* electron goes through *two* slits at once to interfere with itself, entangled photons ignore speed of light limits on causality, the vacuum of space exerts pressure, and gamma radiation is random with no physical cause. Einstein, who was as open to new ideas as anyone, thought quantum theory made no sense and that is because it doesn't. Physics has polled our reality and the results are in:

"... the weirdness of the quantum world is real, whether we like it or not."

(Tegmark & Wheeler, 2001) p4.

The conclusion is that physics theory is strange because our world is strange.

1.1.2. A hollow science

Quantum mechanics and relativity theory are the crown jewels of physics because they have quite simply never been proved wrong. Modern physics began with Maxwell's wave equations in the 1860s, then Planck's constant in 1900, Einstein's special relativity in 1905, general relativity in 1915 and Schrödinger's wave equation in 1925. Despite initial skepticism, these theories met every logical and experimental test their critics could devise and amazed even their advocates, as Fermi predicted the neutrino in 1933 before it was found in 1953 and Dirac predicted anti-matter before it too was confirmed. Yet over a century later, *quantum theory still doesn't make any sense.* As Ford says:

> *"Its just that the theory lacks a rationale. 'How come the quantum' John Wheeler likes to ask. 'If your head doesn't swim when you think about the quantum,' Niels Bohr reportedly said, 'you haven't understood it.' And Richard Feynman … who understood quantum mechanics as deeply as anyone, wrote: 'My physics students don't understand it either. That is because I don't understand it.'"* (Ford, 2004) p98

For the first time in history, the scholars of a discipline don't actually believe what their reigning theories say! They accept the calculations are correct but deny that they represent reality. This is, to say the least, an unusual state of affairs. The problem isn't inexperience, as these theories underlie a host of technologies that define life today, from cell phones to space exploration, yet:

> "*… physicists who work with the theory every day don't really know quite what to make of it. They fill blackboards with quantum calculations and acknowledge that it is probably the most powerful, accurate, and predictive scientific theory ever developed. But … the very suggestion that it may be literally true as a description of nature is still greeted with cynicism, incomprehension, and even anger*." (Vacca, 2005) p116

The equations, tests and applications work but the theory makes no physical sense, e.g. in Feynman's sum over histories an electron travels *all* possible paths between two points at once - but how can *one* electron do that? Theory usually increases understanding but physics theory seems to take it away, as wave-particle duality lets waves morph into particles which denies what waves and particles *are*. Given a choice between meaning and mathematics, physics long ago chose the latter and the results are seen today, as quantum theory still isn't taught in high schools because who can teach what makes no sense? Modern physics is a mathematical feast whose core is empty of meaning. It is a *hollow science* built on impressive equations about quantum states that everyone agrees don't exist! And this *way of no meaning* is a deliberate strategy:

> "*… we have locked up quantum physics in "black boxes", which we can handle and operate without knowing what is going on inside*. (Audretsch, 2004) (Preface, p x).

The result is what some now call *fairy tale physics* (Baggot, 2013), where virtual particles arise ex nihilo from invisible fields in empty space to fit equations that work for no good reason. And when physics stopped trying to make sense of its findings, the result was an evident lack of further progress:

> "*How unusual it is for three decades to pass without major progress in fundamental physics? Even if we look back more than two hundred years…it is unprecedented*." (Smolin, 2006) p viii

The issue is not a few anomalies in an otherwise perfect vision. Quantum theory rules the micro-cosmic world from which reality emerges and relativity rules the cosmic world around it. These theories are the bedrock of physics, and physics is fundamental to science, so for them to make no sense at all is unacceptable. This is confirmed by the fact that relativity and quantum mechanics contradict at their core. Each works in its domain, relativity for cosmic events and quantum theory for atomic events, but together they clash:

"*The problem … is that when the equations of general relativity commingle with those of quantum mechanics, the result is disastrous*." (Greene, 2004, p15)

That the two leading modern physics theories contradict each other confirms that something is wrong. The barren desert of particle physics today began with the Copenhagen "*shut up and calculate*" policy that effectively banned discussions of meaning, including the question physics chose to ignore decades ago:

"*… the main reason for the existence of myths in QM {quantum mechanics} is the fact that QM does not give a clear answer to the question of what, if anything, objective reality is.*" (Nikoli´, 2008) p43

It is time to return to the original "hard" question of physics - *What is Reality?*

1.2. WHAT IS REALITY?

For thousands of years people have wondered what reality is. Eastern philosophers concluded that the physical world is an illusion but the west split between *physical realism*, that physical matter is real, and *idealism,* that what we see reflects something else. Logically, one of these world views *must be wrong* and orthodox science and religion took opposite sides on the issue.

1.2.1. Idealism vs. physicalism

Western science began with Aristotle, who was a student of Plato who was a student of Socrates, an ancient Greek *philosopher* who lived when the word meant literally lover (*philo*) of wisdom (*sophia*). Plato argued that physical matter *forms* come from pre-existing *ideal forms* that exist apart from them, a position later called idealism. Aristotle didn't deny this but argued that if Plato's forms were abstracts of physical things, their causes were to be found not in the abstract world of forms but in other physical things. Western science then developed from Aristotle's view that the causes of the physical world were to be found in itself, while western religion sided with Plato, that a non-physical God caused all things. It's vivid depictions of a heaven and hell beyond this life dominated thought in the west for the next two thousand years until recently science rose to challenge this view.

In the West, some held to Plato's original idea, that the physical world is like shadows flickering on a wall[1], e.g. Gnostics saw the world as a *lie,* created by a demiurge ignorant of the original reality[2]. The same idea survived better in the East, as in Chan Buddhism a universal *essence of mind* creates the observed world like bubbles on a sea, and in Hinduism the physical world is *Maya,* an illusion created by God's "play" (*Lila)*. Yet at any time, whether in science or religion, only a tiny few ever truly believed that the physical world wasn't real in itself.

1.2.2. *Dualism*

In the west, the ideological war between science and religion grew until Descartes proposed the truce of *dualism* based on "*I think, therefore I am*". Why not have mind *and* body, the spirituality of religion *and* the physicality of science? This divided scientists into *atheists* who believed *only* in the physical world, *theists* who believed in a world beyond it as well, and *agnostics* who couldn't decide. This marriage of convenience worked for a while but today science and religion barely speak to each other.

The dualism problem is *how can two distinct realities co-exist?* If mind and body don't interact, they are irrelevant to each other, as what use is a mind that can't affect the body? Or if they interact, which

[1] In his analogy, people tied up in a dark cave with their backs to its exit see their shadows on the cave wall, created by sunlight from the outside, and take them to be reality.

[2] In this story, the original "fullness" (Pistis Sophia) tries to make something new from herself but accidently creates a monstrous *demiurge* (lesser god). Ashamed she quarantines him. He being alone and thinking only he existed, creates our world in his own image, entrapping Sophia's essence in a false physical world.

came first? A mind that *emerges* from a physical brain is like the whistle of a locomotive that is superfluous to the main action, while if a non-physical mind creates the world, why is it such a mess? Either way, if one is real then the other isn't, or at best irrelevant. And if the two realities conflict, why hasn't heaven purged earth already or earth corrupted heaven? If mind and body are two sides of the same coin, what is the coin?

Facing such challenges, *dualism* is currently in decline before the *monism* that there is only one reality and it is physical. Monism is simpler than dualism and the main monism today is physical realism. While scientists claim the physical world that they study is real, theologians claim that a future spiritual world is real, and people in general prefer now to later.

1.2.3. Virtualism

Yet as science and religion fight their age-old ideological battle, another monism stands on the sidelines ignored by all, namely *virtualism* (Raspanti, 2000), that physical world is an output created by some "other". The idea seems new but actually traces back to Plato's *idealism*, that the physical world *reflects* another reality. Pythagoras saw numbers as the non-material essence of the world, Plato felt that God geometrizes and Gauss believed that God does arithmetic (Svozil, 2005), just as Blake's *Ancient of Days* measures the world with his compass (Figure 1.1).

Figure 1.1. The Ancient of Days *calculates the universe* [3]

Computers today create virtual worlds but that the physical world is virtual is usually a topic of fiction not physics. That physical reality is a processing output leads to ideas like that *space calculates* (Zuse, 1969) and that *reality computes* (Fredkin, 1990), (Schmidhuber, 1997), (Rhodes, 2001), (Wolfram, 2002), (Lloyd, 2006), (Tegmark, 2007). Plato's view is still radical today.

In *physical realism* only the physical world exists, in *dualism* a higher reality also exists and in *virtualism* physical reality is an output of some "other". The latter denies the presumed "prime axiom" of physics that:

There is nothing outside the physical universe (Smolin, 2001).

Proposing instead its antithesis that:

Nothing in the physical universe exists objectively, of or by itself.

Virtualism gives the *virtual reality conjecture* that:

> *The physical world is a set of events output by some other, without which it would not exist at all.*

Physical realism in contrast proposes that the physical world is an objective reality that exists in and of itself, that needs nothing other than itself to exist.

These are mutually exclusive statements. An objective world that is inherently real can't be a virtual world and vice-versa. One can't logically prove reality statements (Esfeld, 2004), so that the world is virtual isn't provable but by the same logic, one can't prove that the physical world is an objective reality either. It follows that to demand of a new theory what the old one can't deliver either is bias. The scientific approach is to consider the balance of evidence for both views, which we now do.

1.2.4. The reality options

The reality options reduce to three:

[3] The Ancient of Days by William Blake, 1794.

1. *Physical realism.* That only the physical world exists and it does so by itself alone.
2. *Dualism.* That the physical world exists but there is also a higher reality beyond it.
3. *Virtualism.* That the physical world is a construct created by something outside itself.

In *physical realism,* a self-existent physical world observes itself as it is - but how then does matter observe? And in a purely physical world, random events like radioactivity that are by definition aren't predicted by prior physical events shouldn't happen.

In *dualism*, a real physical world is observed from a spiritual realm that also influences it but this *God of the Gaps* only explains what is left after science advances, which every day gets smaller.

In *virtualism,* another reality generates the physical world we see like images on a screen that only exist in appearance. Opinion is divided on whether this "other" is:

1. *Physical*. In The Matrix movie, a virtual New York seemed real to its inhabitants who only knew it by information, *just as we know ours.* When the hero disconnects from the matrix he falls back into another world where post-nuclear machines feed people virtual input while farming them for energy in vats. The physical world he previously "lived in" was a *construct* created by programs in another physical world. *In theory,* this is possible as by the Church-Turing thesis a finite program can simulate any specifiable output (Tegmark, 2007) but *in practice,* trying to simulate even a few hundred atoms with a conventional computer[4]:

   > "*… would need more memory space that there are atoms in the universe as a whole, and would take more time to complete the task than the current age of the universe.*" (Lloyd, 2006) p53.

   Since even a computer as big as our universe couldn't remotely do the job, this option is unlikely.

2. *Mental.* In this view, the physical world is a dream of the mind, e.g. in *solipsism* a self-existing observer dreams a world that isn't there at all. The *esse est percipi*[5] thesis, that the brain creates reality is shown by optical illusions but that doesn't imply no reality out there. As Einstein said, surely the moon exists when no-one watches it? Solipsism solves the quantum observer effect[6] but doesn't generalize well because if I'm dreaming you, you're just my pixels. And if no tree falls in a forest when no-one watches, how does history arise? Do we fabricate the millions of years of dinosaurs before we came along? If I am dreaming, why can't I dream the body that I want? For these and other reasons this option is unlikely.
3. *Quantum.* In this view, quantum processing[7] creates physical events that otherwise wouldn't exist. Physics currently rejects this option because it gives:

   > *"…no means of understanding the hardware upon which that software is running. So we have no way of understanding the real physics of reality.*" (Deutsch, 1997)

To assume that only the physical is real so what isn't physical can't be real is the sort of circular logic science warns us against. It is illogical to assume an answer then "prove" it by that assumption. Yet it is true that quantum entities aren't physical, because they appear and disappear in physically impossible ways, tunnel through physically impassable barriers, ignore the speed of light limit on physical interactions and superpose in physically opposed ways, e.g. quantum theory describes currents going

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[4] As Yogi Berra said: *"In theory there is no difference between theory and practice. In practice there is."*

[5] "Existence is perception", i.e. what is real is created by what we see.

[6] In quantum theory, observing a spreading quantum wave makes it take a physical point state, so this observer effect implies that observation is necessary to create a physical event.

[7] *Information* is defined as choosing a value from a set (Shannon & Weaver, 1949) and *processing* is defined as changing information.

both ways round a circuit at once, which can't happen in physical reality. But that quantum waves aren't physical doesn't mean they don't exist nor that we can't study them, as we study gravity that we can't see physically. To expect the quantum "hardware" that creates physical reality to follow the rules of what it creates makes no sense. The qubit of quantum processing is unlike the bit of physical processing for this reason.

That what isn't physical doesn't exist is an assumption not a fact. And that science can't study what it can't see is untrue, as quantum theory testifies. *Quantum realism*, that the quantum world creates the physical world, is both logically possible and scientifically acceptable, so this option is now explored.

1.2.5. Quantum realism

Quantum realism proposes that the quantum world *is real on its own terms* and it creates the physical world we see, just as a video game creates a reality that isn't real in itself. It isn't The Matrix movie idea that another physical world is creating ours because even computing *one electron* wave function that can spread over a galaxy then collapse to any point in it is beyond any physical computer [8]. Only quantum processing has the power to output the physical reality we see. Nor is it that we are dreaming because if I am dreaming you then you don't exist, leading to the solipsism that only I exist.

In quantum realism, only quantum reality exists and the physical world is just an *interface* so there is a real world out there but it isn't the one you see. What you see is a virtual reality that *represents* a physical world that isn't real in itself, so the observer and observed are real but the observation is virtual.

Quantum realism is a *monism* like physical realism but now the only reality is quantum. It is based on quantum theory, that physical events arise when quantum waves interact. The interaction is mutual, so when we observe a photon, it also "observes" us, as evidenced by the observer effect in physics. Unlike solipsism, this theory is universal, so a tree can't fall in a forest unseen because the ground it hits "sees" it[9].

One can compare the reality options in computer game terms as follows:

- *Physical realism.* A game running itself with no-one in charge.
- *Dualism.* A game running itself with the programmer struggling to regain control.
- *Solipsism.* A single player game that exists only for one person.
- *Quantum realism.* A massively multi-player game where every photon is a "player".

Figure 1.2 compares the reality candidates using Wheeler's universal observing eye, which depicts a self-observing universe. In physical realism, a physical reality somehow observes itself although matter has no ability at all to observe. In dualism, a higher reality observes the physical, although it is never explained how two different realities can co-exist. In quantum realism, quantum reality observes itself

[8] A Milky Way volume of 1.6×10^{60} cubic meters divided by a Planck volume of 4.2×10^{-105} cubic meters is about 551 bits, which for a 10^{-43} seconds Planck time is over 5×10^{45}Hertz of processing power for one quantum event. Even our best supercomputers are only just breaking the PetaHertz barrier (10^{15}Hertz), so to calculate even one quantum event is beyond all our best computers.

[9] Knox's limerick on solipsism was: *There was a young man who said, "God, must think it exceedingly odd, if he finds that this tree continues to be, when there's no one about in the Quad."*
The anonymous reply was: "*Dear Sir: Your astonishment's odd: I am always about in the Quad. And that's why the tree, will continue to be, since observed by yours faithfully, God."*

by the virtual interface we call physical reality, as it is inherently able to observe.

In sum, physical realism allows only physical reality, dualism allows both physical and non-physical realities at once and quantum realism allows only quantum reality as the physical world is a virtual

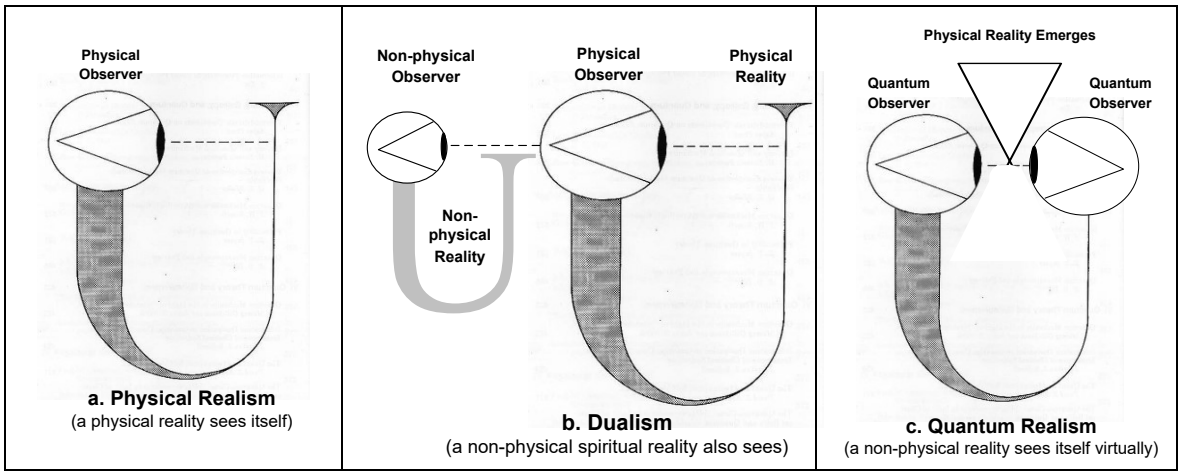

Figure 1.2. Comparing the reality options for an observer

reality. Let us now evaluate these options based on science not bias.

1.2.6. The end of science?

If it turns out that we do live in a virtual reality, is that the end of science? Suppose some characters in The Sims started to wonder if their world was virtual? They could test that theory against the data of their world just as we can. If they found they lived in a world of pixels, that their time and space could expand and contract, and that their world began at a specific moment in the past, they might conclude it was true. They couldn't *perceive* the processing behind their world but they could *conceive* it, as we now do. Yet their science would still go on, just as our quantum theory based on quantum states that are patently not physical at all remains a science. Science only requires real feedback to work and *the physical world as a virtual reality* still provides that.

A *local reality* seems real to its inhabitants but is actually within another reality that generates it[10], in contrast an *objective reality* exists in and of itself and isn't contained by anything else. A local reality is real from within but not from without, so just as Monopoly money affects what you can buy in the game but not outside it, the laws of physics govern physical reality but not the quantum reality that creates it. In general, *pixels are real to pixels* because they are of the same nature, just as the earth is "solid" to us who are made of earthy stuff but to a neutrino from the sun our whole planet is just a ghostly shadow through which it flies. In quantum realism, the physical world is a local reality that can support science even though it isn't an objective reality.

1.3. THE PHYSICAL EVIDENCE

How can one know if a world is a construct or not? Just looking isn't enough. A game world seems real because when I look left, a left view is shown and when I look right, a right view is shown. Wherever I look, the game world presents but the catch is *only when I look*. In contrast, an objective reality exists whether I look or not, so physical history shouldn't change depending on how I observe it. Yet quantum theory predicts an *observer effect* and the evidence agrees, e.g., in delayed choice experiments, photons choose different physical paths to a detector if we observe them differently. As Wheeler observed, we

[10] In contrast, an objective reality exists in and of itself and is not contained by anything.

live in a *participatory universe* where how you look affects what you see, just as in a virtual reality. So does our physical world manifest other tell-tale signs of being a virtual reality?

1.3.1. The signs of virtualism

All the following facts of physics are expected for a virtual reality but not for an objective reality:

1. *Our universe began.* All the stars and galaxies are receding from us at known rates, so we can calculate back to conclude that our universe started up[11] about fourteen billion years ago, in a first event that began not only our universe but also its space and time. Yet a *complete* physical universe can't *begin,* as by definition there is nothing outside itself to create it. To create itself, it would have to exist before it began, which is impossible. It doesn't make sense that a complete physical universe created itself out of nothing and current speculations on D-branes, wormholes, alternate universes, teleporting worlds and big bang oscillation theories don't help. In contrast, every virtual reality has a boot up that creates its space-time operating system based on *nothing within itself* (QR1.4.2).
2. *There is a maximum speed.* In our world nothing travels faster than light so light shone from a space-ship moving at almost the speed of light still leaves the ship at the speed of light. This limit makes no sense for an objective reality as matter moving at any speed should always be able to go a bit faster. In contrast, the transmission rate on a virtual screen is limited by its refresh rate, so the speed of light just reflects how fast the "screen" of space refreshes (QR3.2.4).
3. *Time and space are quantized.* According to quantum theory, time and space increase in tiny Planck steps, but a physical reality that constantly exists shouldn't require this. When field theory assumes continuity, it gives infinities that require a mathematical trick called *renormalization* to make them "magically" disappear. In contrast a virtual world is always made from irreducible pixels and cycles, so what physics calls Planck length and Planck time are the resolution and frame rate of our world, just as every video has a resolution and frame rate (QR2.2.1).
4. *Quantum tunneling.* Quantum tunneling is when an electron suddenly appears outside a field barrier it can't pass through, like a coin in a perfectly sealed glass bottle suddenly appearing outside it. Physical realism doesn't allow matter to move to a point where no intervening path is possible, yet it happens. In contrast, the frames of a virtual reality can easily "cut" from one frame to another without an intervening "path" to allow what is physically impossible (QR5.3.1).
5. *Entanglement.* It is physically impossible for two photons moving apart at the speed of light to affect each other but when they entangle, observing the spin of either forces the other to have the opposite spin, no matter how far apart they are. Einstein called this *spooky action at a distance* because it contradicts the speed of light limit but the evidence is that what should be physically impossible happens. In contrast, points on the screen of space are equidistant to the quantum server that creates them just as all the points on a screen are equidistant to its server, so if entangled photons merge servers, it is possible (QR3.8.5).
6. *Space curves*. According to relativity, the sun keeps the earth in orbit by "curving" the space around it but what can space curve into? It needs another dimension to do this but string theory's "curled up" extra dimensions don't do the job. In contrast, space as the 3D surface that our virtual reality presents upon can easily curve into a fourth dimension (QR2.4.1).
7. *Time dilates.* In Einstein's twin paradox, a man travels the universe for a year in a high-speed rocket then returns to find his twin brother on earth is an old man of eighty! Relativity predicts that time slows down at high speeds and particle research agrees. Physical realism can't explain this but every gamer knows that when the action is fast, the result is a slow-motion screen so moving at high-speed is expected to slow down time in a virtual reality (QR5.2.4).

[11] Colloquially called the "big bang", as if it were an explosion in an existing time and space, which it was not.

8. *Randomness*. According to quantum theory, radioactive atoms emit photons randomly, in a way that no prior physical story can explain and the evidence agrees. Randomness implies a non-physical cause, which physical realism doesn't allow, so it invented the many-worlds fantasy that every photon event spawns an entire new universe. In contrast, if the physical world is a virtual reality, random events are simply quantum server choices (QR3.5.3).
9. *Empty space isn't empty*. In physical realism, matter objects are real and the space between them is nothing but in the *Casimir effect,* flat plates held close in a vacuum experience a force pushing them together. Current physics attributes it to virtual particles that magically appear from the void but how can nothing produce something? Physical realism has no null particle but in a virtual reality, space is null processing. It is "empty" in the same way that a blank screen shows static not nothing, so if the distance is close to the pixel size, the static can produce a "pressure" (QR2.4.5).
10. *Particles are waves*. In Young's two-slit experiment, one photon can go through two slits at once to interfere with itself like a wave but still arrive at one screen point like a particle. Physical realism explained this by inventing wave-particle duality, that particles can be waves, but how can a particle act like a wave? In contrast, a photon processing wave can go through two slits to interfere like a wave but still arrive at a point like a particle if its "collapse" is a processing restart (QR3.5.2).
11. *Black holes.* A large enough mass in a small enough space collapses into what is called a black hole. Most galaxies, including ours, are said to have a black hole at their center. In physical realism, a black hole collapses indefinitely to an infinitely dense point called a *singularity,* but why then do black holes increase in size when they absorb matter? In contrast, in a virtual reality, space has a bandwidth that is the maximum processing it can hold. A black hole is then matter reaching the bandwidth of space, so it has a size and there is no singularity (QR5.4.6).
12. *Quantum superposition*. Quantum theory allows currents to simultaneously flow both ways around a superconducting ring in a superposition (Cho, 2000). This can't happen physically so physicists say the quantum states they calculate every day don't exist. In contrast, if the quantum world is real, quantum waves can superpose to explore all possible directions at once (QR3.8.1).
13. *Non-physical detection.* A bomb so sensitive that just one photon will set it off should be impossible to detect but a Mach-Zehnder interferometer can do just that (Kwiat et al., 1995). Physical realism has no explanation for this at all, as it can't attribute it to quantum acts it says don't occur. In contrast, if the quantum world exists, it follows the rules of quantum theory and they allow non-physical detection to occur (QR3.8.4).
14. *Retrospective action.* In delayed choice experiments, an observation made *after* a photon takes a path defines the path it took *before* the observation, implying that the future can affect the past. Physical realism leads to speculations that all time, like all space, already exists, allowing time travel and paradoxes like going back in time to kill your grandfather. In contrast, a photon as a quantum wave can take *all* paths until it restarts in a physical event, so there is no time travel (QR3.8.3).
15. *Anti-matter exists.* Quantum equations predicted anti-matter but physical realism has no reason for matter to have an inverse of the same mass but opposite charge. In contrast, if quantum processing generates matter, it can run in reverse to generate anti-matter, so anti-processing predicts anti-matter (QR4.3.5).

All the facts above contradict the theory that the physical world is an objective reality and support the theory that it is virtual. A scientific experiment to test both theories is proposed in QR4.5.9, but for now one can argue that:

If it looks like a duck and quacks like a duck, then it probably is a duck.

If the facts of physics deny physical realism, the Sherlock Holmes dictum applies:

When you have excluded the impossible, whatever remains, however improbable, is the truth.

The evidence so far is certainly a prima facie case that quantum realism is worth investigating further.

1.3.2. A prima facie case

How do physicists *know* that our physical world isn't virtual? Stephen Hawking explains:

> "*But maybe we are all linked in to a giant computer simulation that sends a signal of pain when we send a motor signal to swing an imaginary foot at an imaginary stone. Maybe we are characters in a computer game played by aliens."* in (Vacca, 2005) p131

He seems open to virtualism but the next sentence is "*Joking apart…".* Virtualism is a joke among the physics elite but given that physics can't explain dark energy or dark matter that make up over 90% of the mass of the universe, from whence comes this certainty? The reality of the physical world is taken as a fact but in logic it is just an assumption and in science it is just a theory.

The discussion of virtualism in academic circles is intellectually weak. In the 2016 Isaac Asimov Memorial Debate "*Is the Universe a Simulation?*", experts attack the naïve virtualism of a science fiction movie (The Matrix) but ignore the current status of quantum theory, which states that quantum waves acting in physically impossible ways create physical events when they are observed. All the evidence says this description is true but the possibility that quantum waves are real isn't addressed at all. Instead of taking the opportunity to critically review current physics, they attack a straw man, a fantasy movie with no academic credentials.

In an objective reality time doesn't dilate, space doesn't bend, objects don't teleport, empty space is empty and universes don't pop up out of nowhere. No-one would doubt that the physical world was objectively real, if only it behaved so. The previous facts are the sort of *circumstantial evidence* that a court would accept as warranting further investigation. There is clearly a case worth looking at but first, let us consider some implications of quantum realism.

1.4. IMPLICATIONS

Quantum realism proposes that quantum processing generates the physical world as a virtual reality. If quantum reality generates physical reality every moment, everything around you is real but it isn't what you see. The claim that the physical world is generated by the quantum world means that the laws governing physical events arise from quantum laws that work in a non-physical way. We then live in a dynamic quantum world not a dead physical world, in a participatory universe not an objective one. This contradicts the current dismal view of physics, of the universe as a dead machine winding down.

That the physical world is a virtual reality generated by quantum processing implies there must be:

1. *A processor*. Every virtual reality is generated by a processor.
2. *A boot-up*. Every virtual reality has to boot-up.
3. *Null processing*. Every virtual reality runs null processing when idle.
4. *A screen refresh rate*. Every virtual reality presents on a screen with a finite refresh rate.

Does the current evidence support these implications?

1.4.1. The processor

Some suggest that the physical world is both the processor *and* its output:

"*The universe is not a program running somewhere else. It is a universal computer, and there is nothing outside it.*" (Kelly, 2002)

But while computers process input to give output, most of the universe doesn't compute anything at all (Piccinini, 2007). For example, the sun inputs and outputs physical events not information.

In addition, that the physical world causes processing that causes the physical world is impossibly circular. When a program runs to generate an output, the output is apart from the processing as a cause that causes itself is an infinite circular act that can neither stop nor change. In contrast, our universe is changing and it will one day stop because it began. Every process that our computers run is always apart from its output, so the physical world can't be both the process and what it outputs. The physical world can no more compute itself than two hands can draw each other (Figure 1.3).

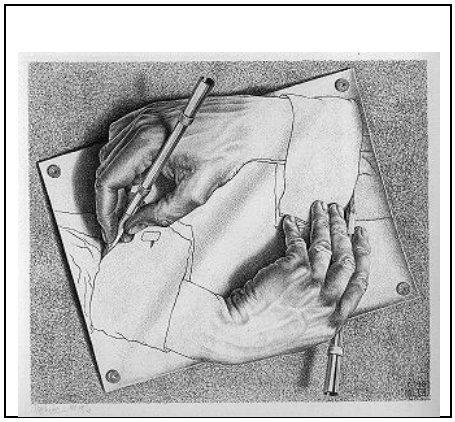

Figure 1.3. A physical world can't do this [12]

It is equally glib for physicists to talk of quantum processing occurring in *our* spacetime:

"*Imagine the quantum computation embedded in space and time. Each logic gate now sites at a point in space and time, and the wires represent physical paths along which the quantum bits flow from one point to another.*" (Lloyd, 1999) p172.

To embed quantum processing in a fixed space and time contradicts relativity, which doesn't allow a fixed space or time. If quantum processing creates a virtual physical world *and* its space and time, that processing can't exist in the space-time it created.

If our universe is virtual, it must be finite because what is infinite can't be computed, and indeed it is. Equally all the laws of physics must be calculable, which again they are. An abstract like π can be infinite as long as it doesn't represent a physical thing, which it doesn't. So the universe could be:

1. *Calculable:* Most scientists accept that processing *could* calculate physical reality based on the Church-Turing thesis, that a finite program can simulate any specifiable output (Tegmark, 2007). This is not determinism, as not all definable mathematics is calculable, e.g. an infinite series. If our world is specifiable, even probabilistically, in theory a program could output it. The idea is not that the universe *is* a computer simulation but that it *could* be. That it could be a virtual reality would be falsified by a non-computable law of physics but none has ever been found. Indeed, our world has an algorithmic simplicity beyond all expectations:

   > "*The enormous usefulness of mathematics in the natural sciences is something bordering on the mysterious and there is no rational explanation for it*." (Wigner, 1960)

2. *Calculating*: That some sort of calculation creates physical events is supported by many academics, including main-stream physicists like Wheeler, whose "*It from Bit"* statement implies that processing (bit) somehow creates physical things (it). Now processing doesn't just *model* the universe, it *causes* it (Piccinini, 2007).

3. *Calculated:* That processing actually does calculate physical reality is the final step, but few in physics support this "strong" view, that the physical world is just an output (Fredkin, 1990).

These statements cumulate, as each assumes the previous, so that which isn't calculable can't arise from any calculation, and that which can't come from any calculation can't be a calculated output. It is a slippery slope, as a *calculable* reality that is caused by some *calculating* could be *calculated*, in other words virtual. But while the second option, that **It** does indeed come from **Bit**, sounds good, it is impossible for a physical world to compute itself. Logic reduces the above options to two: either the physical world exists by itself alone and just happens to be mathematically calculable, or it is in fact

[12] "Drawing Hands" by M. C. Escher, 1948

calculated and thus a virtual output. The physical world is either processor or output and there is no valid middle ground.

Quantum realism concludes that *non-physical quantum processing generates physical reality*.

1.4.2. The boot-up

Last century science thought the physical universe was *complete* so while its parts could transform, the whole had to remain in a *steady state.* "Big bang" theorists challenged this view on the stage of science, arguing against respected scientists who felt quite reasonably that a universe "exploding" out of nothing was highly unlikely. In 1929 the astronomer Hubble found that all the galaxies are receding from a first event that occurred billions of years ago, and finding that the cosmic background afterglow of the first event was still visible all around us confirmed that there was a first event.

This left physical realism in a quandary, as a physical universe that *began* was either created by something else or created itself. If it was created by something else, as a child is from its parents, then it wasn't complete. Or if it created itself, it had to exist before its own creation, which is impossible. A *complete* system can't just magically *begin*.

Yet that our universe is both *complete* and also *began* is oddly enough what most physicists believe today. Parmenides concluded that "*Nihil fit ex nihilo"* or "*From nothing, nothing comes*" but physics now concludes that from an initial nothing, everything came. Calling that initial nothing "*something that fluctuates*" (Atkins, 2011) doesn't help because "nothing" doesn't fluctuate. The first event wasn't a "*quantum fluctuation of the vacuum*" because it also began space, so if matter just popped out of space, what did space pop out of? Revising reality to allow something to come from nothing doesn't work. A better story is needed than that nothing "exploded" from a dimensionless point to create everything.

Current physics answers the question "*What was there before the big bang?"* by saying that before the big bang there was no time, but "defining away" a question like this isn't an explanation. A universe that *began* had to arise somehow so it is valid to ask "*How did it arise?*" For if time and space just began for no reason, could they suddenly stop today by the same logic? The key questions are:

1. How could matter begin with no time or space for it to exist in?
2. How could space begin with no time for it to begin in?
3. How could time begin with no space for it to flow in?

That our physical universe created itself is impossible and that it came from nothing is inconceivable. It can't be a massive quantum fluctuation still adjusting because that would need a space and time that didn't exist before the first event.

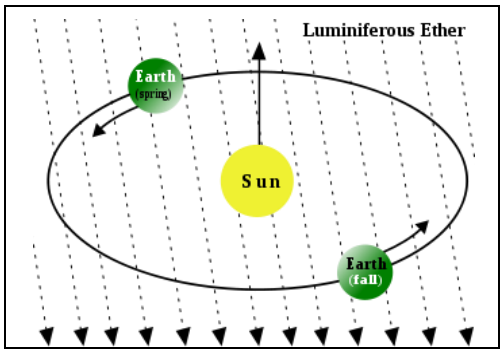

Figure 1.4. A physical ether[13]

In contrast, every virtual reality has to start up with a "big bang" that creates not only the objects in it but also its space and time. When virtual world like Sim City starts up, it comes from nothing *in that world* and before that the time and space *of that world* didn't exist.

Quantum realism concludes that *the "big bang" was when our virtual universe booted up*.

1.4.3. Null processing

Physical realism struggles to explain how light waves travel in the void of space. Water waves move as fast as the elasticity of the water medium allows and the same is true

[13] See Wikipedia http://en.wikipedia.org/wiki/File:AetherWind.svg

of every physical wave. At the end of the nineteenth century it was expected that light, as a wave, would move at a speed defined by the elasticity of an *ether* that fills all space. As the earth orbits the sun at 108,000 km per hour and the sun orbits the galaxy even faster, we can't be stationary with respect to such an ether (Figure 1.4). The speed of light should vary with direction but in 1887 Michelson and Morley found that it was the same in every direction, so there could not be a physical ether.

Einstein then traded Newton's absolute space and absolute time for an equally absolute space-time where:

> *"…absolute space-time is as absolute for special relativity as absolute space and absolute time were for Newton …"* (Greene, 2004, p51)

This changed the question from how light vibrates empty space to how it vibrates a space-time matrix but the latter gives no basis for elasticity either. In an example of reverse logic, the speed of light is now said to define the elasticity of space, so *the wave defines the medium it passes through!* Fitting theory to facts is not what science is supposed to do!

To understand the problem, imagine a space that contains things as an ocean contains fishes:

1. Any object in that space needs a not-that-object boundary to exist.
2. Unless a world is entirely objects, it must contain a "not-any-object", i.e. empty space.
3. If that space is nothing at all, the world is only objects and so has no basis for movement.
4. If that space exists as objects do, the logic returns to #1, so it needs another "space" to exist in.

A thing needs a not-itself boundary to exist but if that is also a thing then nothing can move. The buck of "thingness" must stop somewhere and for us space is it. It follows that space cannot exist as the objects it contains do but neither can it be nothing. In a purely physical world, space is "nothing at all" but both Einstein and Newton saw that space must be something for objects to move in it:

> *"According to the general theory of relativity space without ether is unthinkable; for in such a space there would not only be no propagation of light, but also no possibility of existence for standards of space and time ..."* (Einstein, 1920, in May 5th address at the University of Leyden)

Note that his term "ether" isn't the physical ether that Michelson and Morley dismissed but describes that which *acts like nothing*. While a physical ether has been discredited, a non-physical one has not:

> "*Since 1905 when Einstein first did away with the luminiferous aether, the idea that space is filled with invisible substances has waged a vigorous comeback*." (Greene, 2004) p76

The paradox is that while space physically acts like nothing, it must actually be something, and the Casimir effect, that space exerts a "pressure", supports this.

When a computer has nothing to do its processor doesn't sit idle but runs a *null process*[14]. Even if one isn't pressing keys or moving the mouse, a 4 GHz computer still processes about 4,000 times a second. If empty space is null processing it is nothing only in the sense that it has no output but it is something in that it is an activity. A virtual space that is null processing doesn't need to exist in another space because it is something itself, namely quantum processing.

In processing terms, space is *the null element*, so empty space is a processing output that only differs from an electron or a photon in that it happens to be null. Whether quantum processing outputs an electron or space is like whether a screen point has a value or not. Even a blank screen, with no images on it, still refreshes at some cycle rate so it isn't nothing. If one turns a screen off, to see it in itself, that destroys the images upon it, so if the quantum screen turned off, the physical universe including its space and time would disappear instantly.

Quantum realism concludes that *empty space is null processing not nothing*.

[14] Null processing is the program a central processing unit (CPU) runs when it is doing "nothing".

1.4.4. The screen refresh rate

This project began when I wondered why our world has a maximum speed. Einstein *deduced* that nothing goes faster than light from the facts but *didn't explain why*. In an objective world, things could just go faster and faster, so why don't they? The thought then occurred that perhaps the speed of light reflects a processing limit, just as my computer screen can only run at a certain frame rate.

In a virtual world, distance is measured in pixels and time in cycles. A simulation has no time except that defined by its processing cycles and no space except that defined by its screen pixels. Asking about the time between cycles or the space between pixels is like asking about a movie between its frames or a picture between its dots, when neither the movie or the picture exist then. A movie running 70 frames a second *seems* continuous to us because our eyes only refresh 30 times a second. Likewise, a physical universe that refreshes in Planck time, at 10^{43} times a second, *seemed* continuous to our instruments until recently. Nothing is shorter than a Planck length and nothing is briefer than Planck time so physical reality has pixels and cycles, like a virtual reality on a screen.

If so, the maximum speed anything can move from point to point is *one pixel per cycle.* This implies that the maximum speed for our universe is Planck length divided by Planck time, which is indeed the speed of light. The values we use, like 186,000 miles per second or 299,792,458 meters per second reflect that the units we use, but in quantum units the speed of light is just *one*.

Quantum realism concludes that *the speed of light is always the maximum possible because it is one quantum pixel per quantum cycle*.

1.4.5. Is reality fake?

Is a virtual world necessarily a fake world? Consider the following case:

> "*In June 2005, Qiu Chengwei, a Chinese national, won a virtual sword in the online game* ***Legend of Mir 3****. He lent the sword to a fellow gamer Zhu Caoyuan who subsequently sold it [on eBay]. When Qiu reported the incident to the police he was told a virtual sword was not real property and was not protected by law. Qiu went to the home of Zhu and stabbed him to death in a very real crime for which he is now serving a life sentence.*" (Power, 2010) p188

The stolen sword didn't physically exist but it was real enough for those involved to own, sell and kill for. It follows that for all intents and purpose, the Mir sword was real, even though was virtual. As another example, Bitcoins are worth billions but they aren't physical things, so if the current definition of reality as "What exists"[15] means what exists physically, then Bitcoins don't exist. A clearer definition of reality is "*What exists to an observer*".

This definition still applies to physical reality because every physical event requires an observer by the observer effect in physics. Adding the observer to the definition lets us to say that a dream is real to the dreamer but not to others. It doesn't imply that we unilaterally create all reality as in solipsism, just our reality. That *every reality event is an observer-observed interaction* disciplines like sociology, psychology and computing to study social, human and information systems that are *real*. For if information wasn't real[16], or if cognition wasn't real, or if society wasn't real, the sciences of computing, psychology and sociology would be the study of unreality. It then follows that informational, personal and social realities *emerge* from physical reality (Whitworth & Ahmad, 2013).

[15] At https://en.wikipedia.org/wiki/Reality reality is that which exists, but every case has an observer.

[16] Also called *mathematical realism* (Penrose, 2005).

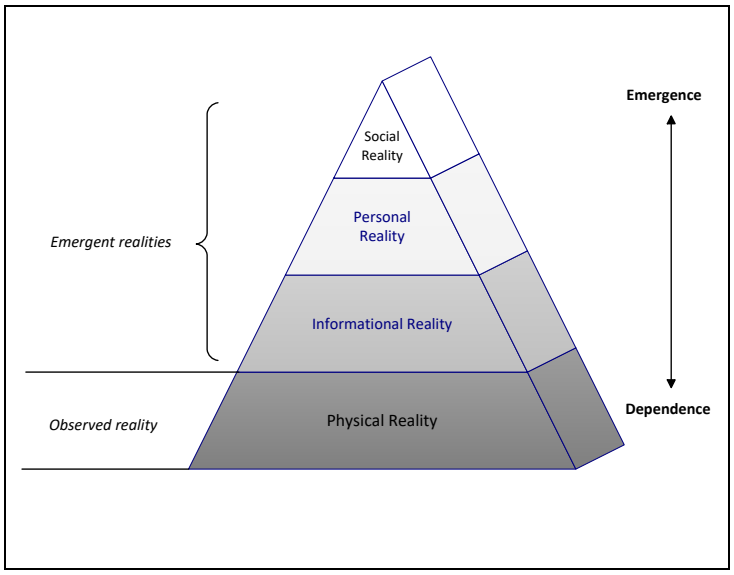

Figure 1.5. A reality pyramid based on physical reality

That informational, personal and social realities are alternate ways of viewing physical reality lets sociology study social systems, psychology study human systems and computer science study information systems *that are real* (Figure 1.5).

Note that these different views of reality exist *at the same time*, so a cell phone is simultaneously hardware *and* software. There is one reality but we differentiate hardware and software as *different views of the same reality.*

Software emerges from hardware as it can't exist without it but hardware can exist without software. The observer *chooses* a hardware view to solve a hardware issue and *chooses* a software view to solve a software issue. In Figure 1.5, each *reality level* emerges from the one below as a higher way to view reality. Social structures emerge from human meaning (Bone, 2005) that emerges from nerve data that emerges from physical brain events because seeing reality in social terms helped survival (Hogg, 1990).

In this approach, the Mir sword didn't exist physically but it existed as an information entity in the Mir database, it was a cognitive entity in the mind of its owner and it existed to the Mir community, so it was real by the new definition. If a fantasy is real to only one person, the Mir sword was not that. It existed by common consent and was even a *scientifically real* subject of research. In a society, to sell what one doesn't own is unjust so as the police had no remedy the owner took justice into his own hands.

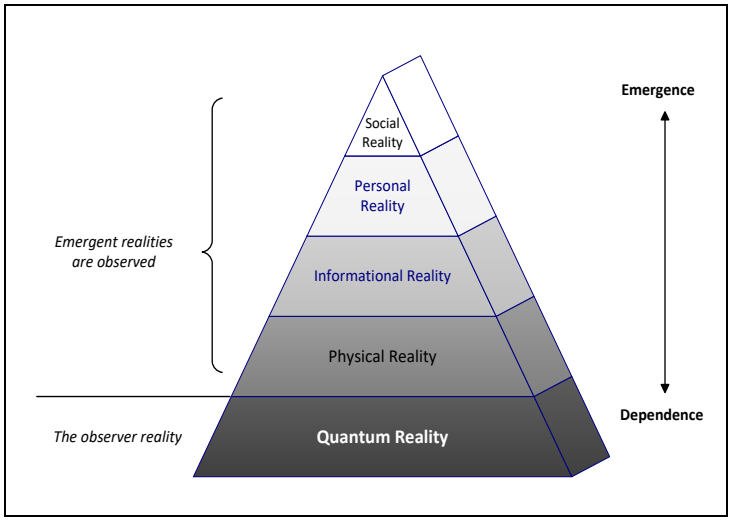

Figure 1.6. A reality pyramid based on quantum reality

If social constructs emerge from human thoughts that emerge from nerve information based on physical events, is the physical world the end of the line? *Physical realism* says it is, arguing that everything reduces[17] to physical events, so only physical events *really exist*. But if matter was the end of the reality line, it would be able to observe but no-one has ever proposed how it can do that.

That every physical event is an observation suggests that the physical world *is also an observer effect.* Quantum theory agrees, as if quantum waves become physical events when observed, physics is *just another reality view*. As the great eighteenth century philosopher Kant concluded, we see *phenomena* not *noumena,* a view of reality not *things as they are in themselves* (Kant, 2002).

[17] Physical reductionism is based on *logical positivism*, a nineteenth century ideology that only what is observed is real, that today masquerades as an axiom of science. It falsely holds that science should only *reference* the physical, unlike the *empiricism* of Locke and Hume that theories must be *tested* by physical observables.

If physical reality is an observer effect, it only exists when we look, just as my image in a mirror is an observer effect that only exists when I look. If I don't look my body still exists but if I observe the mirror, an image appears. The image I see isn't in itself real but it represents my body reality.

Quantum realism concludes that the same applies to world around us, that it exists when we look but when we don't, what exists is quantum reality. Figure 1.6 puts quantum reality at the bottom of the reality pyramid because it provides the observer. Physical reality then emerges from it just as information reality emerges from physical reality. Quantum realism is that the physical world we see is an image generated by a real quantum world that we don't see. It isn't fake, any more than an image in a mirror is fake, because quantum reality actually exists, but neither is it real in an objective sense.

1.5. EVALUATING QUANTUM REALISM

How can quantum realism be evaluated? The scientific method proposed is to reverse engineer physical reality to make predictions that support or deny it.

1.5.1. Science and quantum realism

Science is a way to ask questions of reality not a set of fixed ideas:

"*Science is not about building a body of known 'facts'. It is a method for asking awkward questions and subjecting them to a reality-check, thus avoiding the human tendency to believe whatever makes us feel good.*" (Pratchett et al., 1999)

It limits not the questions we ask but how we answer them, so to question physical reality doesn't deny science but engages its spirit of inquiry. Quantum realism is a question about this world, not an untestable meta-physical speculation on universes beyond ours (Tegmark, 1997), that virtual universes can be saved and restored (Schmidhuber, 1997) or the idea that virtual realities create each other (Bostrom, 2002). These speculations are beyond the scope of science but quantum realism a*s a statement about the world we see* is open to the scientific method.

Science doesn't test theories in isolation but forms mutually exclusive hypotheses and *rejects the least likely*. It doesn't "prove" theories but given two falsifiable alternatives, picks the best. Quantum realism is *falsifiable* because any incomputable physics would disprove it:

"*… the hypothesis that our universe is a program running on a digital computer in another universe generates empirical predictions, and is therefore falsifiable*" (McCabe, 2005) p1

If the physical world wasn't computable it couldn't be virtual, but it is. Physical realism is falsifiable too but its falsifications are called unsolved mysteries (Aspect et al., 1982).

Quantum theory is a science even though it refers to quantum states that aren't by definition physical because being able to observe what a theory describes isn't a demand of science, and never has been:

"*Atomism began life as a philosophical idea that would fail virtually every contemporary test of what should be regarded as 'scientific'; yet, eventually, it became the cornerstone of physical science."* (Barrow, 2007) p3

Current physics has unobservable quarks, invisible fields and virtual particles so it can hardly make visibility a demand of science. There is no need, as what science must observe are a theory's predictions not its parts. A first event that we can never observe is now accepted based on the evidence we can. If science can decide there was a big bang based on evidence, it can decide if physical reality is virtual or not based on evidence. Quantum realism doesn't contradict science, but denying it does.

1.5.2. Reverse engineering physical reality

The scientific method in a nutshell is to make an assumption then test it to see what happens. Scientists evaluate a theory by assuming it is true then analyzing it to see if it predicts facts or not. In computer science, this involves *designing* a logical model, *implementing* it and then *testing* it against expectations.

Design science follows this method, as an information system is first designed in theory then built and tested against requirements in an iterative way (Hevner et al., 2004). *Reverse engineering* is a subset of design science, where given an output, one deduces the processing behind it. The method is to first best-guess the processing involved, then validate the output this processing predicts against the observed output and repeat until the results are consistent. Scientists that run quantum simulations to predict physical results use this method.

The following chapters will use this method of reverse engineering to answer the research question:

"*Does quantum processing generate physical reality?*"

The steps are as follows:

1. *Specify*: Specify the physical world output (physics).
2. *Design*: Design quantum processing to satisfy those requirements (computer science).
3. *Validate*: Compare the expected output with the actual output (science).
4. *Repeat:* Repeat to achieve a consistent design (quantum realism).

The consistency constraint is critical, as while one can easily "fit" a system to one requirement, satisfying many at once is much harder. In addition, the design should:

1. *Follow computing best practice.* Use established computer science principles.
2. *Satisfy Occam's razor.* Given a design choice, take the simpler option.

The aim is to *reverse engineer* the physical world, to derive the laws of physics from information first principles. A scientific theory can't *choose* what it explains so quantum realism must explain *all* of physics including space, time, energy, matter, gravity, magnetism, spin and charge. Cherry-picking cases to find selected programs that mimic some world properties isn't a new kind of science but an old kind of bias (Wolfram, 2002). Reverse engineering physical reality could reveal quantum realism to be:

1. *Spurious*. A spurious model adds no value because it needs new assumptions or parameters to explain every new fact. Spurious models always have a back-door excuse.
2. *Coincidence*. Coincidental models work for a while by luck but fail over time as supporters have to cherry-pick cases to support the model and ignore those that contradict it.
3. *Useful*. A useful model isn't necessarily true but opens up productive new research that increases knowledge. It is a useful as a stepping-stone.
4. *Valid*. Based on a few assumptions, a valid model matches observed reality in many ways and predicts something new that contradicts established models but is later found to be true.

Given the circumstantial case presented earlier, quantum realism may provide useful insights even if it isn't entirely true. If physics describes physical events and computer science describes processing events, whether quantum processing produces physical events is a question design science can evaluate.

1.6. A NEW THEORY

When science encounters a new theory that purports to explain what an old one did and more, it uses *Occam's razor* to choose between them and examines their *assumptions* to find any flaws. A *paradigm shift* that changes theoretical foundations is always difficult to introduce but the biggest obstacle facing any new theory is the *delusion of omniscience*, the belief that we already have all the answers.

1.6.1. Occam's razor

Occam's razor is not to multiply causes unnecessarily and to prefer the simpler theory. A century ago, Bertrand Russell denied the idea that life is a dream by appealing to common sense and Occam's razor:

> "*There is no logical impossibility in the supposition that the whole of life is a dream, in which we ourselves create all the objects that come before us. But although this is not logically impossible, there is no reason whatever to suppose that it is true; and it is, in fact, a less simple hypothesis, viewed as a means of accounting for the facts of our own life, than the common-sense hypothesis that there really are objects independent of us, whose action on us causes our sensations*." (Russell, 1912)

Does the same logic apply to virtualism? It is still common-sense that something out there causes things apart from us but the "objects" of current physics that cause things are virtual particles like gluons that pop out of empty space then disappear in the effect. A physics where space curves, entities teleport and time dilates is no longer a "common-sense hypothesis". It isn't common-sense that a universe of matter exploded from a point of no dimensions or that light waves vibrate nothing. Today, common-sense might agree that our universe booted up and that light waves move on the screen of space.

In Russell's time, a few elementary particles with a few properties like mass, charge and spin were enough but modern physics needs forty-eight fundamental particles, twenty-four fitted properties, five invisible fields and fourteen virtual particles to explain just the basics. To explain more, such as inflation, neutrinos and dark matter, needs more complexity in the form of new fields, particles and parameters. String theory, its best attempt at a universal theory, needs at least eleven dimensions to work. It's hard to imagine anything more complex than physics today so it isn't preferred due to its simplicity! As the following chapters show, quantum realism can explain the same facts using one fundamental process, four dimensions and one field.

Physics based on physical realism was once the simpler theory but that isn't true today. Fast forward a hundred years and *Occam's razor cuts the other way,* as virtualism is now a simpler theory.

1.6.2. The assumptions of physical realism

Science began when Aristotle concluded that, for all practical purposes, physical events caused physical events, so matter was assumed to be the primal substance. Modern physics adds energy to the term "physical" because light is massless and also time and space. All this to support the 2,000-year-old idea that the physical world is real, where "physical" is taken to mean matter, energy, space and time.

The *belief* that only the physical world exists is based on four assumptions about it, namely that it is:

1. *Conserved*. A physical world that is all there is must be conserved. It can *transform*, as clay turns into a bowl, but must always exist. Unfortunately, the failure of steady state theory to compete with big bang theory last century cracked this pillar, as what began from nothing isn't conserved. The physical realism *patch* is the speculation that our universe oscillates in a big bounce[18].
2. *Continuous*. A physical world that is all there is needs a continuous space and time to exist in but continuity creates infinities that contradict this assumption, so physics invented the mathematical patch of *renormalization*, a technique that Feynman called a "dippy process".
3. *Complete*. A physical world that is all there is implies that everything has a physical cause but random events like atomic decay have no physical cause by definition and quantum theory adds that *every* physical event is random to some degree. The many-worlds fairytale, that every quantum event creates an entire new universe, was a *patch* that caught the public imagination.
4. *Fundamental*. A physical world that is all there is implies fundamental particles that need nothing else to exist but quantum theory states that physical events only occur when quantum waves are

[18] In Big bounce theory a big crunch follows a big bang in an ongoing oscillation that is in effect steady state.

observed and the evidence supports it. Physics pasted over the quantum observer crack by the *patch* that virtual particles appear from nowhere to explain whatever an observer sees

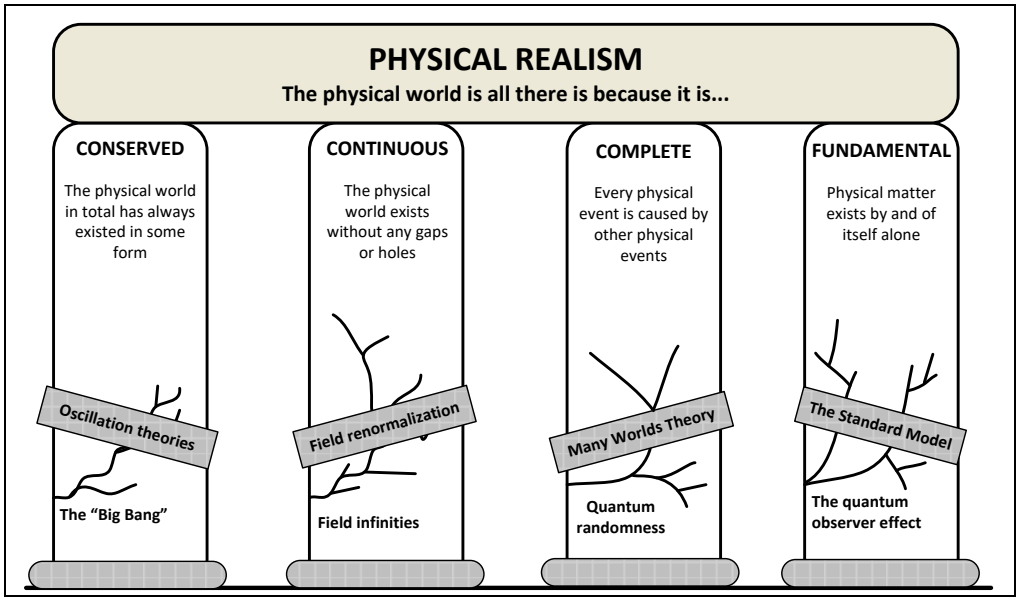

Figure 1.7 The four pillars of physical realism

Figure 1.7 shows the four pillars of physical realism, their cracks and the resulting patches. The implications of these assumptions are that if the physical world is always:

a. Conserved, then it must be *eternal*,
b. Continuous, then it must be *all-pervading*,
c. Complete, then it must be *all-powerful*, and
d. Fundamental, then it must *self-exist*.

That the physical world is conserved, continuous, complete and fundamental equates to saying it is *eternal, all-pervading, all-powerful* and *self-exists*, all properties attributed to God in religious times. Physical realism dresses up the properties of God in scientific terms and applies them to physical reality so it is more an *ideology* than a conclusion of science.

Oddly enough, the assumptions of physical realism have never been subject to scientific scrutiny. No experiments contrast them with an alternative because none has ever been credible. They are accepted based on tradition but current physics can't prove its assumptions about physical reality any more than religion could prove its assumptions about God. If the physical world is always conserved, why did it begin? If the physical world is continuous, why are there Planck limits? If the physical world is complete, why does quantum randomness occur? If the physical world is made of fundamental particles, why is the observer necessary in quantum theory and relativity?

To believe physical realism today one must believe that physical matter came into existence by itself, that a mathematical trick can deny the infinities of continuity, that every photon event spawns a new universe and that virtual particles routinely pop out of empty space to make things happen. To say that physical realism has shaky foundations is an understatement, so it is time to consider another paradigm.

Quantum realism denies all the assumptions of physical realism. A virtual world that is created from nothing in that world isn't always conserved. A virtual world made of pixels presented in quantum cycles isn't continuous. A virtual world output by quantum processing isn't complete. A virtual world that requires an observer can't be fundamental. To attribute the properties of God to a virtual reality that began at a past instant and is generated by quantum events at every moment is pure foolishness.

1.6.3. A paradigm shift

Kuhn called changing the foundations of a scientific theory a *paradigm shift* (Kuhn, 1970), where a theory is built on *axioms* as a house is built on *foundations*. The axioms of a theory are that upon which it is built, so changing them isn't easy. For example, Euclid's geometry axiom that parallel lines can't converge was accepted without question for two thousand years before it was realized that on a curved surface like the earth, parallel longitudes do converge (at the poles). Changing that axiom allowed *hyper-geometries* and made Euclid's geometry just the zero-curvature case. This paradigm shift allowed a theory that was originally a single apartment to became a set of apartments.

Chaitin, following Gödel, argued that good axioms explain more than they assume (Chaitin, 2006), so just as putting a shack on every new plot of land gives a shanty town not a city, adding a new axiom to explain every new fact is inefficient. Good axioms should be able to support more than one fact, just as good foundations should be able to support more than one building floor.

However, adding parameters to explain new facts has been the norm in physics for some time now. The result is that current physics, with its many parameters, particles and fields, is suffering from the theory equivalent of urban sprawl. String theory failed because it had too many assumptions, like a city that needs more land and money than anyone has. A city can only spread so far before it has to use skyscrapers to make better use of land, and for the same reason adding new fields and particles to explain new effects like dark matter, radioactive decay, neutrinos, inflation and quark attraction is no longer cost effective in theoretical terms. A paradigm shift that changes axioms is needed.

In science, changing axioms is disruptive, just as changing a building's foundations is, but the result can be worth it because *disruptive innovations* (Sandström, 2010) don't necessarily deny past progress. For example, allowing curved surfaces still included Euclid's geometry as a special case and Einstein's theory of relativity also included Newtonian mechanics as a special case.

In the same way, quantum realism doesn't change the equations of physics, only their *interpretation,* so Schrödinger's equation is the same except it now describes what is real not fictional. The value of this change *is that it allows new directions,* for just as knowing that the stars don't revolve around the earth gave new directions in astronomy, knowing that the physical world is generated by quantum processing allows new directions in physics.

Changing Wheeler's "It from bit" to become "*It from qubit*" allows a "*Physics from scratch"* approach (Tegmark, 2007 p6), where the charges say of electron, quarks and neutrinos can be derived from quantum processing first principles (see Chapter 4). Yet paradigm shifts always face another barrier - the hubris that we already have all the answers.

1.6.4. The delusion of omniscience

Scientific progress has always contradicted the hubris that we already know, hence:

"*Since our earliest ancestors admired the stars, our human egos have suffered a series of blows*." (Tegmark, 2007)

Medieval Christianity taught that God put the earth at the center of the universe and then created us. No-one asked "*Where is earth in the universe?*" because it was assumed to be known. When Galileo challenged the axiom of earth centrality, he also challenged the idea that *we are the physical center of the world*. We now know that we live on a little planet circling a small star, two-thirds of the way out of an average galaxy of a hundred billion stars, in a universe of at least that many galaxies. Mankind is like a species of bacteria dominating one leaf on one tree in a vast forest, which somehow hurts! Yet the ego blow that we aren't the *physical center* of things was the price of new knowledge of astronomy.

Even so, it was believed that humans were created apart from animals, so no-one asked "*How did mankind arise?*" because it was again assumed known. When Darwin challenged the axiom of human creation, he also challenged the idea that *we are the biological center of the world*. We now know that

modern humans have been on the planet for less than a million years and were a minor species for most of that time. In comparison, dinosaurs ruled the earth for two-hundred million years before being wiped out sixty-five million years ago by the meteor event that let mammals evolve. It is estimated that 99.9% of all species that have ever lived are now extinct, so our chances of dominating the earth for long aren't high. Our state is so fragile that even a little virus can disrupt it! It is easy to forget that bacteria, insects and plants all exceed us in biomass and many species have more genes. Yet the ego blow that we aren't the *biological center* of life was the price of new knowledge of biology.

Modern neuroscience now challenges the ego itself, the idea that we have a center from which all our actions originate and to which all sensations go. The question not asked this time is "*Who am I?*", again because it is assumed to be known but studies of the brain find that it has no processing center equivalent to the CPU (central processing unit) of a computer. The highest processing of the brain, the cortex, is divided into two hemispheres and if they are surgically disconnected, each acts like a brain in itself, taking itself to be "I" (Sperry & Gazzaniga, 1967). The conclusion is that even the ego self is an illusion, as we don't have a *psychological center* either.

Chapter 6 addresses the mystery of consciousness, how *two* hemispheres can generate *one* "I", but the trend is clear: our egos repeatedly see us *at the center of things* and science repeatedly finds that we aren't. Is the last ego delusion that the ego itself is a delusion? It seems unlikely, as every generation thinks it has all the answers - until the next generation finds that it doesn't.

Quantum realism challenges the oldest centrism of all, that the physical world is the center of reality. We assume that *reality is what we see because we see it* but who are we to define reality? The fact that we see reality as physical doesn't make it so. Is it not hubris to assume that what we see is what is? The idea that physical reality is generated by quantum reality shocks the ego but fits the facts, as Table 1.1 shows. There is nothing illogical about the idea that a reality we don't see creates the reality we do, and at the same time provides a basis for what science can't explain – the observer.

It is ironic that scientists who fought the church's dogmas for so long now push the dogma of physical realism. It is a Scientific Delusion that science knows everything about reality but for some loose ends. The Delusion of Scientific Omniscience, the myth that science knows everything or is about to, led to the dream of a *Theory of Everything* (TOE), an equation that defines the future and ends science. A little humility would reveal that we can't put the universe in an intellectual box because we are a part of it, and a part can't contain the whole. The hubris of physical realism is to treat physical reality like a God.

It is for this reason that quantum realism is a *query of everything* not a theory of everything. The price of scientific progress this time is to abandon the delusion of scientific omniscience.

Table 1.1. Chapter 1 summary: Physical realism vs. quantum realism

Physical realism	Quantum realism
The big bang. The universe began from nothing in a "big bang" that also made our time and space	*The boot-up.* The universe began when it booted up, which also made our time and space
Maximum speed. The speed of light is a universal limit for no known reason	*Maximum rate.* The refresh rate of the quantum network defines the speed of light
Quantization. Mass, energy, time and space are quantized at the Planck level, for no known reason	*Digitization.* Mass, energy, time and space are quantized because the universe is a digital system
Quantum tunneling. A physical quantum entity can suddenly appear past an impassible barrier	*Quantum restart.* Quantum processing spreading on a network can restart at any point in the spread
Photons entangle. Entangled photons connect faster than light, which is physically impossible	*Processing merges*. A merged quantum process runs both entangled photons and connects them
Space curves. Mass "curves" space for no known reason in a physically impossible way	*Screens curve.* Space as a 3D screen can curve into another dimension just as a 2D screen can
Time dilates. Time dilates near massive bodies and at high speeds for some unknown reason	*Processing slows*. The load of high mass and high speeds slows down processing time cycles
Random events. Random radioactivity, not due to prior physical events, shouldn't occur	*Server choices*. Random events in a virtual reality arise from server processing choices
Space is empty? Space as not-matter should be empty but it isn't, by the Casimir effect	*Space is full!* In a virtual reality, space is "full" of null processing that can explain the Casimir effect
Waves are particles. That light waves interfere but still arrive at a screen as point particles is ascribed to the "miracle" of wave-particle duality	*Photon waves reboot*. A light wave is a processing wave that can interfere but still reboot at a point where it overloads the screen
Black holes. Are points of infinite mass density that for some unknown reason have a size	*Black holes*. Are regions where matter fills the bandwidth limit of space, so they have a size
Non-physical detection. Has been proved to occur although it isn't possible in a physical world	*Non-physical detection*. The non-physical rules of quantum theory predict non-physical detection.
Retrospective events. In delayed-choice studies, photons choose their physical path to a destination *after* they arrive, denying causality	*Just-in-time choices*. Delayed-choice photons take every physical path to a destination and choose one *after* they arrive, preserving causality
Anti-matter. Matter has an inverse of equal mass but opposite charge for some unknown reason	*Anti-matter*. Matter processing implies anti-processing of equal mass but opposite charge

ACKNOWLEDGEMENTS

Thanks to Onofrio Russo, NJIT, for arousing my interest, and to Cris Calude, Tom Campbell, Jonathan Dickau, Andrew Eaglen, Ken Hawick, Belinda Sibley, Ben Iscatus, Bruce Maier, Mason Mulholland, Matthew Raspanti, Ross Rhodes, John Ringland, Claudio Soprano, Andrew Thomas, Ram Vimal, Bryan Warner, Marty Wollner and Tim Jones for useful comments and critiques. And thanks to my son Alex, who helps me think more clearly. Still, the mistakes are mine alone.

DISCUSSION QUESTIONS

The following questions are addressed in this chapter. They are better discussed in a group to allow a variety of opinions to emerge. The relevant section link is given after each question:

1. Why is current physics a "hollow science"? What is missing? (1.1.2)
2. What is the problem with dual realities, a spiritual world as well as a physical one? (1.2.2)
3. How does an objective reality differ from a virtual reality? (1.2.3)
4. Has science proved that the physical world is an objective reality? (1.2.3)
5. How does quantum realism agree with The Matrix? How does it differ? (1.2.5)
6. How are quantum realism and physical realism the same? What is the difference? (1.2.5)
7. Could science still operate in a virtual reality? (1.2.6)
8. Give three physical facts that suggest that the physical world is a virtual reality. (1.3.1)
9. Why does physics deny that quantum events cause physical events? (1.3.2)
10. Can the physical world compute itself? Give reasons. (1.4.1)
11. Could a physical universe create itself in the "big bang"? Give reasons. (1.4.2)
12. Could the big bang have been a quantum fluctuation? Give reasons. (1.4.2)
13. How could space be both nothing and something? (1.4.3)
14. Why can't anything go faster than light? (1.4.4)
15. Is physics more "scientific" than the other sciences? Give reasons. (1.4.5)
16. Is quantum realism falsifiable? Is physical realism falsifiable? (1.5.1)
17. How can quantum realism be evaluated scientifically? (1.5.2)
18. What is Occam's razor? Does it support physical realism? (1.6.1)
19. Is the physical world eternal, all-pervasive, all-powerful and self-existing? (1.6.2)
20. Does quantum realism challenge the equations of physics? If not, what does it do? (1.6.3)
21. How has ego deluded us in the past? What ego delusion does quantum realism challenge? (1.6.4)

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