Quantum Realism Part I. The Observed Reality

Chapter 1. The Physical World as a Virtual Reality

Brian Whitworth, New Zealand

"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? The assumption that the physical world exists in and of itself has struggled to explain the findings of modern physics for some time now. An objective space and time should just be, but our space can contract and our time can dilate. Objective things should just exist but electrons in our world are probability of existence smears that spread, tunnel, superpose, and entangle in physically impossible ways. Cosmology also confirms that our universe just popped into existence over 14 billion years ago for no clear reason. *This isn't how an objective reality should behave!*

1.1. A STRANGE WORLD

This book explores a possibility that we normally dismiss out of hand, that the physical world is a virtual reality. The reader is asked to keep an open mind, as what is proposed is neither illogical, unscientific, or incompatible with physics. Nor is it a modern idea, as that the world is illusory is an idea whose roots go back thousands of years. It arises today because scientists have discovered that physical reality is stranger than we ever imagined.

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 world we see are long gone.

These theories exist because the findings of physics are equally strange, like Einstein's discovery that the sun bends light by curving the space around it, or that the earth's gravity slows down time, so 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). Yet while space, time, and mass vary with speed, the speed of light is strangely constant.

If relativity is strange then quantum theory is stranger, as it predicts that one electron can go through two slits at once to interfere with itself, entangled photons can ignore speed of light limits, and the vacuum of space can exert pressure, all of which experiments have confirmed. Einstein, who was as open to new ideas as anyone, thought that quantum theory made no sense, and that is because it doesn't. Yet its predictions have never failed. Physics has studied 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 theories of physics are 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 wrong. Modern physics began with Maxwell's wave equations in the 1860s, then Planck's constant in 1900, 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. They 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 found. 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? Theories usually increase understanding but in physics they seem to take it away. For example, wave-particle duality lets waves become particles, but this denies what waves and particles *are*. Given a choice between meaning and mathematics, physics long ago chose the latter, so quantum theory still isn't taught in high schools, because who can teach what makes no sense? Modern physics is a mathematical feast with no meaning, a hollow science built on impressive equations about quantum states that everyone agrees don't exist! And this way of no meaning was deliberate:

> "*… 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 has been described as fairy tale physics (Baggot, 2013) because imaginary particles from invisible fields in empty space make equations work for no good reason. But when fundamental physics stopped trying to understand its findings, it stagnated:

> "*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 cause isn't a few anomalies in an otherwise perfect vision. Quantum theory rules the micro-cosmic world of atoms and relativity rules the cosmic world of stars, so for these core theories to make no sense at all is big problem. Even worse, relativity and quantum mechanics contradict each other! 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).

This conflict tells us that something is wrong. Particle physics today is stagnating because its "*shut up and calculate*" doctrine has led to a denial of meaning that allowed myths to develop:

"*… 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, which is "*What is reality?*"

1.2. WHAT IS REALITY?

For thousands of years people have wondered about reality. Some eastern philosophers concluded that the world is an illusion but the west split between materialism, that matter is real, and idealism, that it 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 traces back to Aristotle, a student of Plato who studied under Socrates, a Greek philosopher who lived when the word meant lover (philo) of wisdom (sophia). Plato argued that physical forms are generated by pre-existing ideal forms, a view later called idealism. Aristotle didn't deny this, but noted that if ideal forms are abstractions, their causes could be found in physical things. Western science then focused on Aristotle's physical causes, while western religion focused on Plato's non-physical causes, but both saw the physical world as real.

Plato's premise was that a non-physical reality creates our world as the sun creates shadows on a wall[1]. This led western Gnostics to conclude that the world was a lie, created by a demiurge who was ignorant of the original reality[2]. In the East, Chan Buddhism held that a universal essence of mind generates the observed world like bubbles on a sea, and Hinduism saw the physical world as Maya, an illusion created by God's play (Lila*)*. Yet at any time, only a few ever truly believed that the physical world wasn't real in itself.

1.2.2. *Dualism*

The ideological war between western science and religion grew, until Descartes proposed the truce of dualism, arguing that "*I think, therefore I am*". Why not have mind <u>and</u> body, the soul of religion and the matter 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 problem with dualism is how can different realities interact? If mind and body don't interact, each is irrelevant to the other, as the mind can't affect the body. Or if they do interact, which was first? A mind that emerges from a physical brain is like the whistle of a locomotive, superfluous to the main action. Conversely if an ideal mind made our world, why did it make evil? Either way, if one is real, the other isn't, or at best irrelevant. And if the two realities are in conflict, why hasn't heaven purged earth already, or earth corrupted heaven? Or if mind and body are sides of the same coin, what is the coin?

Facing such challenges, dualism is less popular now than it was. One reality is simpler than two, so why not just have physical reality? Science calls the world it describes now real, and theology calls the future it describes real, but given a choice between now and later, many prefer now.

---

[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.

1.2.3. Virtualism

Yet as science and religion fight their age-old ideological war, another monism sits on the sidelines ignored by all, namely virtualism (Raspanti, 2000), that the physical world is generated by some other. The idea seems new but actually traces back to Plato's idealism, that the world reflects another reality. Pythagoras called numbers 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).

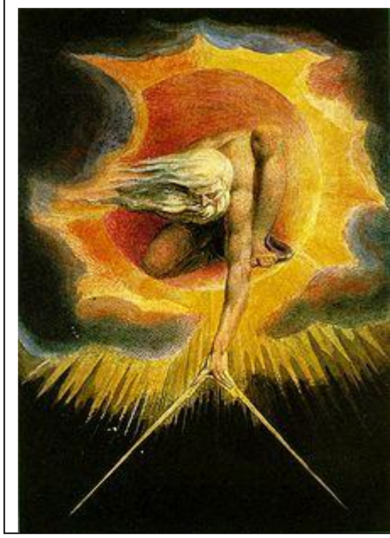

Figure 1.1. The Ancient of Days calculates the universe [3]

Our computers create virtual worlds but that our world is virtual is usually a topic of fiction, not physics. It leads to ideas like that space calculates (Zuse, 1969) and that reality computes (Fredkin, 1990), (Schmidhuber, 1997), (Rhodes, 2001), (Wolfram, 2002), (Lloyd, 2006), and (Tegmark, 2007). Plato's idealism is just as radical today as it was over two thousand years ago.

The issue is whether the physical world exists in and of itself alone, or whether something else causes it. The physical world as an objective reality needs nothing but itself to exist, so the prime axiom of current physics is that:

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

In contrast, virtualism proposes its antithesis, that:

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

These are mutually exclusive theses, as an objective world can't be virtual and a virtual world can't be objective. The virtual reality conjecture is essentially that:

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

Reality theories can't be logically proven (Esfeld, 2004), so that the world is virtual isn't certain, but physical realism isn't certain for the same reason, and to demand of one theory what another can't provide is bias. The unbiased way is to compare the evidence for both views impartially.

1.2.4. The reality options

The main reality options reduce to three:

1. *Physical realism.* That only physical reality exists, and it does so by itself alone.
2. *Dualism.* That physical reality exists, but there is also a higher reality beyond it.
3. *Virtualism.* That physical reality doesn't exist by itself alone, but is generated by something outside itself.

According to physical realism, matter observes itself, but how can dead matter do that? And how can matter make choices that prior physical events can't predict, as radioactive atoms do?

In contrast, dualism lets a mind observe and choose physical events, but the result is a "God of the Gaps" that only explains what is left after science advances, which every day gets smaller.

Finally, virtualism lets another reality generate and observe the physical world, but opinion is divided on what this other reality is, as follows:

---

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

1. *Physical*. In The Matrix movie, a virtual world seemed real to its inhabitants because they only knew it by information, just as we know ours. But when the hero disconnects from the matrix, he falls back into another world, where post-nuclear machines farm people for energy in vats, while feeding them a virtual reality. In the movie, he had been living in a construct created by programs in another physical world. In theory, this is possible because the Church-Turing thesis lets a finite program simulate any specifiable output (Tegmark, 2007), but in practice, 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.

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

2. *Mental.* Solipsism is that the physical world is a dream of the mind, that is dreaming what isn't there at all. Optical illusions show that our brains construct our reality, but that doesn't mean that no reality is out there. As Einstein asked Bohr, do you think the moon doesn't exist when no one is looking? Solipsism solves the quantum observer effect[5] but if I'm dreaming you, you don't exist at all. And if no tree falls in a forest that no-one observes, how does history arise? Did we fabricate the millions of years when dinosaurs roamed the earth, before we came along? And if I am dreaming, why can't I dream the body I want? For these reasons, this option is unlikely.
3. *Quantum.* In this option, quantum events create physical events that otherwise wouldn't occur. 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 we can only study matter then conclude that we can't study quantum events because they aren't material is circular logic. It proves a premise by assuming it. That quantum waves need physical hardware is to assume that matter is fundamental, which is the question asked. Quantum waves collapse in impossible ways, tunnel past impassable barriers, and ignore speed of light limits when entangled, so they can't be made of matter. But this doesn't mean they don't exist, or that we can't study them, as we study gravity that we can't see physically. To expect what creates matter to follow the rules of matter is illogical, hence the qubit of quantum processing is not the bit of physical processing.

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 isn't true, as quantum theory testifies. That quantum events create physical events is neither illogical nor unscientific, so let us now explore this option based on the evidence.

1.2.5. Quantum realism

Quantum realism is that quantum events cause physical events as quantum theory describes. If the physical world is virtual, what creates it can't exist physically, just as what creates a video game can't exist in the game it creates. The quantum world follows its own rules, not those of what it creates.

In the Matrix movie, another physical world simulates ours, but matter doesn't have the power to do that. Even to compute one electron wave function that spreads over a galaxy then collapses to a point in it is beyond current computing[6]. However quantum processing has that power.

---

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

[5] In quantum theory, observing a spreading quantum wave causes a physical event, so observation is necessary to create a physical event.

[6] A Milky Way volume of 1.6 $x10^{60}$ cubic meters divided by a Planck volume of 4.2 $x10^{-105}$ cubic meters is about 551 bits, which for a 10^{-43} seconds Planck time is over $5x10^{45}$ Hertz of processing power for one quantum event.

In quantum realism, there is a real world out there but it isn't the one you see. What you see is an interface that reflects it, as Socrates suggested. But to call it as a thought, as Plato did, is misleading. Quantum theory describes quantum waves that spread until they interact in a physical event that is a mutual observation. It follows that when we observe a photon, it also "observes" us, as the observer effect of physics suggests. Thus, a tree can't fall in a forest unseen because the ground it hits "sees" it[7]. This idea is explored in more detail in Chapter 6.

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

- *Physical realism.* A game that booted itself up, with no-one in charge.
- *Dualism.* A game that was booted up, but now the programmer has lost control.
- *Quantum realism.* A massively multi-player game, where every photon is a player.
- *Solipsism.* A single player game, that exists only for one person.

Figure 1.2 compares the first three options using Wheeler's self-observing eye universe. In physical realism, matter observes itself, though how it does that is unclear. In dualism, a higher reality observes matter, but again how it does so is unclear. In quantum realism, quantum reality observes itself using a virtual reality interface, just as quantum theory describes.

The options are that only matter exists so it must observe, that matter and mind exist at the same time so the latter observes the former, or that only quantum reality exists so everything observes.

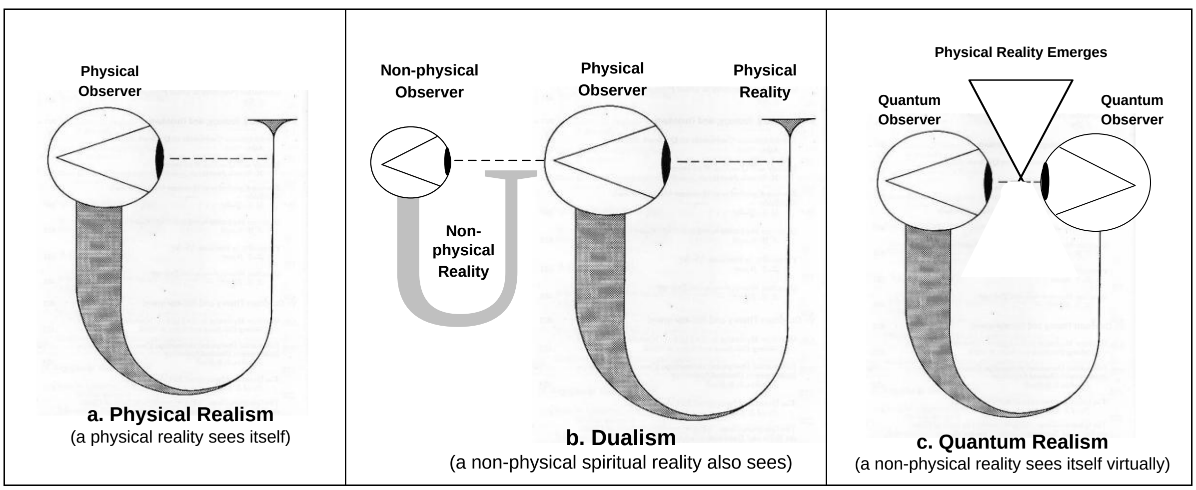

Figure 1.2. Comparing the reality options for an observer

1.2.6. The end of science?

If we are in a virtual reality, is that the end of science? If some characters in The Sims started to wonder if their world was virtual, they could test that theory against data from their world just as we

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.

[7] 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.*"

can. If they found that they lived in a world of pixels, where time can dilate and space can contract, where everything began at a past moment, they might conclude that it was true. They couldn't perceive what was generating their world but they could conceive it, as we do now. Yet science would still work, just as quantum theory still works even if we can't see what it describes. Science only needs observable evidence to work and a virtual reality provides that, so a virtual reality can support science, even if it isn't objectively real.

A virtual reality that seems real to its inhabitants can be called a local reality because it is real from within but not from without, just as Monopoly money can buy things in the game but not outside it. A local reality is always contained by another reality, while an objective reality exists by itself alone, so it doesn't need anything to contain it. A local reality is real internally because pixels can be real to other pixels. What is of the same nature can interact, so the earth is solid to us who are made of it, but to a neutrino it is just a shadow through which it flies. A local reality can thus be real to those within it but still unreal to those who are outside it.

1.3. THE PHYSICAL EVIDENCE

How can we know if our world is virtual 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, it presents but the catch is, only when I look. In contrast, an objective reality exists whether I look or not, so physical events shouldn't change when observed differently. Yet quantum theory predicts an observer effect, that how we observe events changes their properties, and the evidence agrees. In delayed choice experiments, photons observed differently take different paths to a detector. The physicist Wheeler concluded that we live in a participatory universe, where what we see depends on where we look, just as expected for a virtual reality. So, does our world exhibit any other tell-tale signs of virtualism?

1.3.1. Fifteen features of virtualism

The following features are expected of a virtual reality but not an objective one (click link for details):

1. *A beginning.* Astronomers see the stars and galaxies moving away from us at known rates so they can calculate back that our universe began over fourteen billion years ago. But how can a universe that is all there is begin? There is nothing outside itself to create it, it can't create itself before it began because it didn't exist then, and a universe that came from nothing defies logic. Speculating on D-branes, wormholes, alternate universes, and teleporting or oscillating universes doesn't help. *In contrast*, every virtual reality is expected to boot up, in an event that also begins its space and time. It follows that the "big bang" was just when our universe booted up (1.4.2).
2. *A maximum speed.* Nothing travels faster than light in our world but this limit makes no sense, as a matter object should always be able to go a bit faster. *In contrast*, the pixel-to-pixel transfer rate of a screen is expected to be limited by its refresh rate. It follows that the speed of light limit just reflects the refresh rate of space (3.2.4).
3. *Space and time are digital.* Quantum theory requires time and space to change in tiny Planck steps, but an objective reality should be continuous not digital. *In contrast,* a virtual reality is always made of undividable pixels and irreducible cycles. It follows that our space and time are digital because our world has a resolution and cycle rate, respectively (2.2.1).
4. *Tunneling.* Tunneling is when an electron appears outside a field barrier it can't pass through, like a coin in a perfectly sealed glass bottle suddenly appearing outside it. Matter shouldn't move to a point that no path allows, but it does. *In contrast*, a virtual reality can cut from one frame to the next without an intervening path. It follows that tunneling is just matter jumping from one frame to next, as it always does (5.3.1).

5. *Entanglement.* Two photons moving apart at the speed of light shouldn't be able to affect each other but entangled photons do, as observing either spin makes the other have the opposite, regardless of distance. Einstein called it spooky action at a distance because it ignored the speed of light. *In contrast*, a server can alter any points of a screen instantly, regardless of screen distance. It follows that when photons entangle, their servers merge to instantly control both for any event (3.8.5).
6. *Space curves*. According to relativity, the sun keeps the earth in orbit by curving space around it, but how can a three-dimensional space curve? Our space can't curve into the imaginary dimensions of physics if they aren't real. *In contrast*, our space as a screen surface is expected to curve, as some TV screens do. It follows that our space is a three-dimensional surface that can curve into a four-dimensional quantum network (2.4.1).
7. *Time dilates.* Einstein argued that a man who travelled the universe in a high-speed rocket could return a year later to find his twin brother on earth was an old man of eighty! Relativity requires time to slow down at high speeds and particle research agrees, but how can matter alter time? *In contrast*, every gamer knows that their screen slows down during a big battle. It follows that time slows down at high speed because it takes longer to run more events in a virtual reality (5.2.4).
8. *Randomness*. Radioactive atoms emit photons randomly, in a way that physical history can't predict. Physical reality doesn't allow non-physical causes so the mechanical multiverse was invented, that every quantum event spawns a new universe, which is ludicrous. *In contrast*, in a virtual reality, the server is expected to choose screen events, not the screen. It follows what is random to us is just the quantum server choosing where physical events occur (3.5.3).
9. *Space isn't empty*. If only matter is real, the space between it should be nothing at all, 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 from the void, but how can nothing cause something? *In contrast*, a blank screen switched on isn't doing nothing, as it can show static. It follows that at close to the pixel resolution, the asynchronous null processing of space can produce a pressure (2.4.5).
10. *Wave-particle duality*. In Young's two-slit experiment, one photon can go through two slits at once, interfere with itself like a wave, then arrive at a screen point like a particle. Matter can't do this, so wave-particle duality was invented, that particles can be waves, but logically they can't. *In contrast*, a processing wave can go through two slits to interfere but still restart at a point. It follows that wave-particle duality is quantum waves restarting to look like particles in a physical event (3.5.2).
11. *Black holes.* A big mass in a small space can collapse into what is called a black hole. Most galaxies, including ours, have a black hole at their center. Matter is said to collapse to an infinitely dense point singularity, but why then do black holes increase in size when they absorb matter? *In contrast*, a virtual space is expected to have a maximum bandwidth that it can handle. It follows that a black hole is matter filling the bandwidth of space, so it has a size and isn't a singularity (5.4.6).
12. *Superposition*. Quantum theory lets superposed currents simultaneously flow both ways around a superconducting ring (Cho, 2000), which can't happen physically. *In contrast*, processing spreading on a network is expected to overlap, as each point can run many processes, up to its bandwidth. It follows that superposition is just processing overlapping as it spreads (3.8.1).
13. *Non-physical detection.* A bomb so sensitive that one photon will set it off shouldn't be detectable, but a Mach-Zehnder interferometer can do just that (Kwiat et al., 1995). Non-physical detection shouldn't happen, but in our world it does. *In contrast*, in a virtual world we don't know what lies behind a door but the system does. It follows that non-physical detection is when we trick the system to reveal what it knows (3.8.4).
14. *Retrospective action.* In delayed choice experiments, observing a photon as it travels defines its path before the observation, suggesting that the future can affect the past, which undermines all physics. *In contrast*, a virtual reality is expected to calculate every path but not choose one until the last

moment. It follows that retrospective action is a photon wave taking every path until a physical event chooses its physical path, so there is no time travel (3.8.3).

15. *Anti-matter exists.* Quantum equations predicted anti-matter but objective matter has no need for an inverse of the same mass but opposite charge. *In contrast*, if processing generates matter, it must also be able to run in reverse. It follows that anti-matter is just the processing behind matter running in reverse, so every matter entity must have an inverse, as it does (4.3.5).

The fifteen facts above suggest that the physical world is virtual not objective. A scientific experiment to test both theories is proposed in 4.5.9, but for now one can argue that:

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

Given these facts, the dictum of Sherlock Holmes applies:

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

The evidence so far establishes a prima facie case that the physical world is a virtual reality.

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 since 95% of the universe is dark matter and energy that they can't explain, where does this certainty come from? The tradition that matter is a self-existing substance seems obvious to them but in logic it's just an assumption, and in science it's just a theory. Matter is less than 5% of the universe, and no-one knows what the rest is, so the belief that only matter is real is misplaced.

The discussion of virtualism in academic circles is also intellectually weak. In the 2016 Isaac Asimov Memorial Debate "*Is the Universe a Simulation?*", experts attacked the naïve virtualism of The Matrix movie but ignored that quantum waves create physical events according to quantum theory. They attacked a straw man, a fantasy movie with no academic credentials, but ignored their own position.

In an objective world, 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 our world was objectively real, if only it would behave so. Instead, it provides the sort of evidence that a court would accept as worth investigating further. There is a prima facie case for virtualism, but what are the implications of accepting it?

1.4. IMPLICATIONS

If our world is virtual, the physical events we see are just images generated by quantum waves. Reality is then all around us, but it isn't what we see. We see objects that follow physical laws but those laws come from quantum laws that aren't physical. If we live in a world of dynamic waves not dead things, the universe isn't just a machine, but a virtual reality generated by processing implies:

1. *A processor*. A virtual reality must have a processor.
2. *A boot-up*. A virtual reality has to boot-up.
3. *Null processing*. A virtual reality has to have null processing.
4. *A screen refresh rate*. A virtual screen has to have a finite refresh rate.

Does the current evidence support these implications?

1.4.1. The processor

Some suggest that the physical world is both a computer 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).

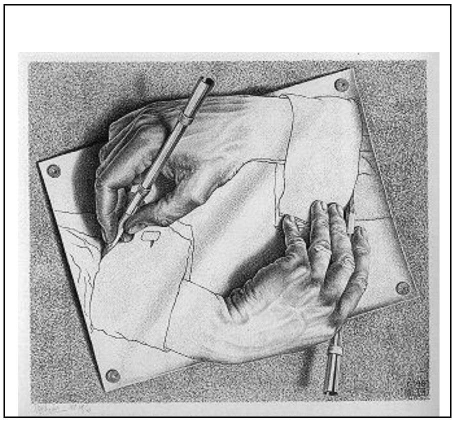

Figure 1.3. A physical world can't do this [8]

Computers output information but most of the universe doesn't do that at all (Piccinini, 2007), as the sun outputs light not information. For a computer's output to also be its only input is a circularity that can crash it. The result is an infinite loop that can't be stopped so, in simple terms, it hangs. But our universe is constantly changing so it can't be locked in an infinite loop. Logically, the physical world can no more compute itself than two hands can draw each other (Figure 1.3).

It is equally glib for physicists to talk of quantum processing occurring in space and time:

"*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 because it doesn't allow a fixed space or time. But what began our universe also began its space and time, so if quantum processing did that, it can't exist in the space and time it created. Only processing that isn't embedded in our world's space or time can generate it as a virtual reality.

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

1. *Calculable:* 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 isn't that our universe is virtual but that it could be. This option 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 calculating creates physical events is supported by many academics, including main-stream physicists like Wheeler, whose "*It from Bit"* suggests that processing (bit) can somehow create matter (it). In this option, processing doesn't just model the universe, it can cause it (Piccinini, 2007).

3. *Calculated:* That processing actually does cause physical reality is the final step, but few in physics support this "strong" view, that the universe really is a calculated output (Fredkin, 1990).

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

These statements cumulate as each assumes the previous, so what isn't calculable can't be produced by calculating, and what can't be produced by calculating can't be a calculated output. It is a slippery slope, as a calculable world that calculating might cause could be calculated, in other words virtual. The second option, that It comes from Bit, sounds good, but that matter causes information that causes matter is circular, and so as impossible as a perpetual motion machine. This reduces the above options to two: either physical reality exists by itself alone and just happen to be amazingly calculable, or it is actually calculated and so virtual. Matter is either a cause or it is caused, with no valid middle ground.

1.4.2. The boot-up

When you start a computer, it has to boot up, so could our universe have started like that? Last century, scientists supposed that our universe had always existed, so its parts transformed but the whole was in a steady state. They felt, quite reasonably, that a whole universe beginning at a point was unlikely. Then in 1929, the astronomer Hubble discovered that all the stars and galaxies around us are speeding apart from a first event that occurred billions of years ago, and finding the cosmic afterglow of that event around us confirmed it. There had been what the press called a "big bang".

This put physics in a quandary, as a universe that is all there is can't just begin. Either something else made it, or it made itself, or it came from nothing. If something else made it, as parents make a child, then it isn't all there is. If it made itself, it had to exist before its own creation, which is impossible. And that it came from nothing denies both physics and logic. That a complete system just began has no rational explanation.

Yet that our universe is both complete and began is oddly enough what most physicists believe today. Parmenides concluded that *Nihil fit ex nihilo* (*From nothing, nothing comes*) but physics now argues that from nothing everything came. Calling the initial nothing "*something that fluctuates*" (Atkins, 2011) doesn't help because nothing can't fluctuate. The first event couldn't have been 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? If a universe exploding from a point is irrational, how is the creation story of science today better than what came before?

The current reply to the question "*What was there before the big bang?*" is that before it, there was no time, but defining away a question doesn't answer it. A universe that began had to start somehow, so it is valid to ask "*How did it begin?*" For if time just began at some moment, could it suddenly stop today for the same reason? The key questions are:

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

That our physical universe made itself is impossible and that it came from nothing is inconceivable. In contrast, every virtual reality begins with a "big bang" that creates both its objects and its space and time. When Sim City boots up, nothing in that world began it, and before that event, the time and space of Sim City didn't exist.

It follows that the big bang was when our virtual universe booted up.

1.4.3. Null processing

Current physics can't explain why light waves travel at a fixed speed in empty space. Wave speed should vary with the medium, so the speed of a water wave depends on the elasticity of water. Nineteenth century scientists expected light to be the same, so its speed should depend on an ether that fills space. But the earth orbits the sun at 108,000 km per hour, and the sun goes round the galaxy even faster, so we can't be stationary relative to that ether (Figure 1.4). It follows that the speed of light should vary with its direction but in 1887 Michelson and Morley discovered that it was the same in every direction, so there was no physical ether.

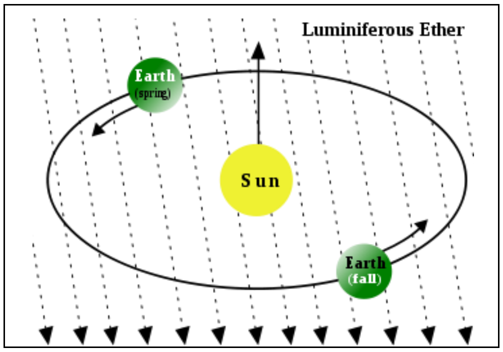

Figure 1.4. A physical ether

Einstein then traded Newton's absolute space and 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).

He changed the question from how light vibrates empty space to how it vibrates a space-time matrix, even though 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 a wave can define its medium of travel. The theory was fitted to the facts, which is backwards science!

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

1. Any object in that space needs a not-that-object boundary to be an object.
2. Unless there are only objects, there must be a "not-any-object", i.e. empty space.
3. If that space is nothing at all, then only objects exist, so there is 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.

Objects need a space boundary to exist but if that space is nothing at all, they can't move, or if it is something, what bounds it? The buck of thingness must stop somewhere and for us space is it. The paradox is that space can't be nothing, nor can it exist as the objects within it do. In a purely physical world, space is nothing at all, but both Einstein and Newton realized that was impossible:

"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).

Einstein's ether isn't the physical one that Michelson and Morley dismissed, but a medium that acts like nothing but is something. A physical ether has been discredited, but 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.

This "substance" has to be able to transmit light yet look like nothing at all. A physical substance can't do this but a null process can. In computing, a null process is what a computer does when it is idle[9], so even if one isn't pressing keys or moving the mouse, a 4 GHz computer still processes at about 4,000 cycles a second. Empty space as null processing has no output but it isn't nothing, so it satisfies the requirements for a non-physical ether.

Matter doesn't have a null element but processing does, so it can output an entity, like an electron or photon, and still represent empty space, just as a screen can show an image or not. Yet a blank screen without images is still doing something not nothing. Only turning the screen off stops it, but that also destroys any images on it, so if the screen of space turned off, our entire universe would disappear instantly, and us with it.

It follows that empty space is not empty at all but full of null processing.

[9] Null processing is the program that a processing unit runs when it is doing "nothing".

1.4.4. The screen refresh rate

This book began when I wondered why the maximum speed in our world is that of light. Einstein deduced that nothing can go faster than light from the facts, but didn't explain why. Objective things could just go faster and faster, so why can't they? The thought then occurred that perhaps the speed of light is a screen limit, just as my computer screen can only run at a certain speed.

In a virtual world, space is measured in screen pixels and time is measured in processing cycles. Asking what happens between cycles or pixels is like asking what happens to a movie between its frames, or a picture between its dots, when neither movie nor 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 at 10^{43} times a second seemed continuous to our instruments until recently. Planck length and time are the pixels and cycles of our virtual reality.

If so, the maximum transfer rate from one point to the next is one pixel per cycle, or 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, just reflect our units, but in quantum units, the speed of light is just one pixel per cycle.

It follows that the refresh rate of space limits its transfer rate, which is the speed of light.

1.4.5. What is real?

What is real? 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 Mir sword didn't physically exist but it was real enough for people to own, sell, and kill for, so for all practical purposes, it was real. Bitcoins don't physically exist either but they have real effects. If we limit reality to what exists physically, then bitcoins worth billions of dollars aren't real! Clearly that isn't right, so let us define reality as what exists to an observer.

Adding the observer to the definition works if quantum theory is correct, that every physical event has an observer. This definition lets a dream to be real to a dreamer but not to others. It isn't solipsism, that we create all reality, but that we each construct our own reality. This lets disciplines like sociology, psychology, and computing study social, experiential, and information systems that are real. For if information wasn't real, 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 also lets scientists study computers in informational, experiential, and social terms (Whitworth & Ahmad, 2013).

In Figure 1.5, the observations of science emerge from physical events, so an engineer can see a cell phone as hardware while a programmer sees it as software. There is one reality, the phone, but engineers and programmers can view it differently. We can see hardware to solve a hardware problem, or software to solve a software problem.

Thus, hardware can exist without software but software can't exist without hardware, because it emerges from it. In general, social structures emerged from human experiences (Bone, 2005) that emerged from nerve information that emerged from brain events because seeing reality in social terms helped us survive (Hogg, 1990). Science is based on observations that can change with the subject.

The Mir sword didn't exist physically but it was an information entity in the Mir database, a cognitive entity experienced by its owner, and a social entity in the Mir community, so it was real in these terms. If a fantasy is real to only one person, the Mir sword was not that. It existed by common consent and

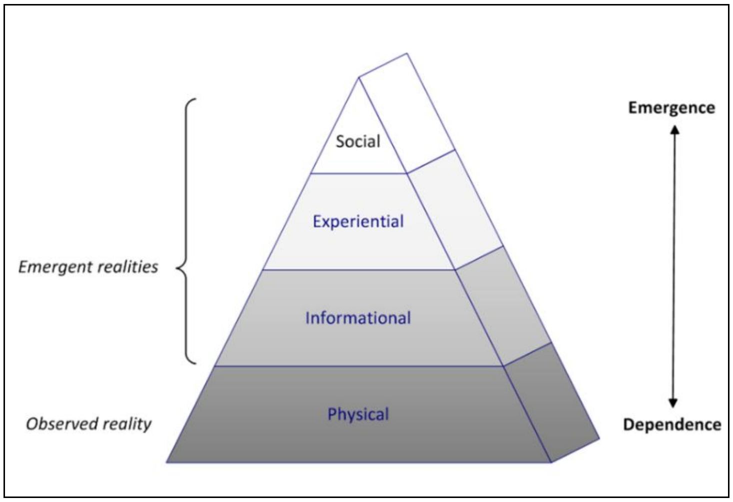

Figure 1.5. The observations of science

was even a scientific 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.

In Figure 1.5, a group or nation isn't a thing, it is an observation of shared experiences. An experience isn't a thing, it is an observation of brain information. And information isn't a thing, it is a way of observing physical events. Current physics makes matter the basis of all reality views but virtualism questions this assumption, by suggesting that a thing isn't a thing either, just a view of quantum reality.

Quantum realism argues that all reality derives from quantum reality as a view. As the great eighteenth century philosopher Kant concluded, we only ever see phenomena, views of reality, not noumena, or reality itself (Kant, 2002). In Figure 1.6, physical reality emerges from quantum reality, so it exists when we look but not when we don't.

Our observer-observed reality isn't objectively real, but is a world based on images necessarily fake? Imagine looking at yourself in a mirror. You see your body in the mirror but if you don't look, the image doesn't exist. It is objectively unreal, because nothing exists where the image apparently is, but we take it as real because it shows us how we look. It follows that an image that reflects reality isn't fake, even if it doesn't exist objectively.

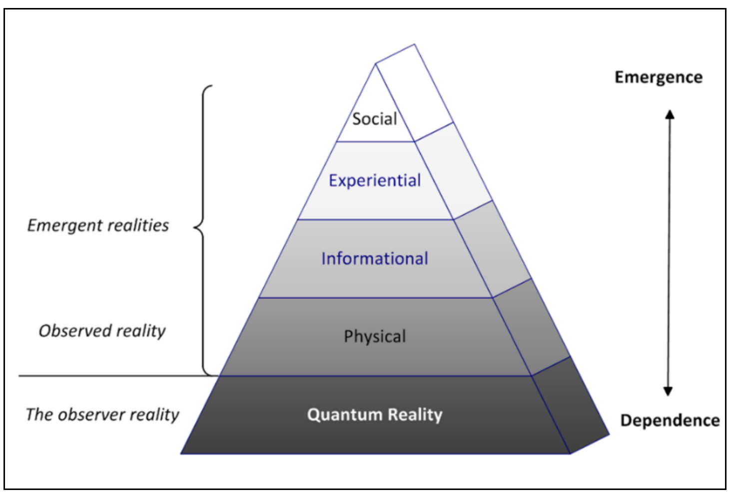

Figure 1.6. Physical reality emerges from quantum reality

If images that reflect reality aren't fake, a virtual world isn't fake if it reflects real quantum causes, so this world isn't a movie made-up, or a dream imagined, but a reflection of quantum reality.

Quantum reality is the base of Figure 1.6 because it provides the observer. Each reality level leads to the next, as in Figure 1.5, but now the base is quantum not physical. Physical events emerge from quantum events just as information emerges from physical events. It follows that we live in a local reality (1.2.6) not a fake one, where what we see, like the Mir sword, is locally real but not objectively so.

1.5. EVALUATING QUANTUM REALISM

How can science evaluate quantum realism? The method proposed is to reverse engineer the physical world based on the method of design science.

1.5.1. The method of science

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

"*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).

Science doesn't tell us what the physical world is but how to study it. It limits the questions we ask to those we can check, so theories about a multiverse (Tegmark, 1997), reloading reality (Schmidhuber, 1997), or nesting virtual realities (Bostrom, 2002) that aren't testable by observation are outside science. In contrast, that the physical world is virtual is a statement about this world, so it is testable by observation, as will be shown.

The method of science is to contrast mutually exclusive theories with respect to the evidence and reject the least likely, so theories must be falsifiable. Virtualism 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, although its falsifications are called unsolved mysteries (Aspect et al., 1982).

Quantum theory is a science because it is testable by observation, even though quantum waves aren't physical. 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 science only requires a theory to predict observables, not to be about them. For example, that our universe began long ago is accepted by science based on the evidence, even though we can never observe it. If science can decide that our universe began, it can decide if it is virtual or not. Quantum realism doesn't contradict science but engages its spirit of enquiry.

1.5.2. Reverse engineering the physical world

The scientific method, in a nutshell, is to assume a theory is true, then see if it predicts what happens. If it works, we accept it, if it doesn't, we reject it. This is how quantum theory arose. In contrast, the way of faith is to find facts that support a belief and ignore those that don't.

Design is a science when it builds a logical model, implements it, then tests it against expectations. Computing uses this approach, as information systems are designed in theory, built in practice, then tested against requirements, in an iterative process (Hevner et al., 2004).

Reverse engineering is the subset of design science that discovers the processes behind an application. The method is to specify the outputs, best-guess the processes involved, then check outputs predicted against those observed, and repeat until consistently correct, where the proposed design must be falsifiable. Quantum simulations use this method to predict atomic events.

Reverse engineering the physical world then involves the following steps:

1. *Specify*: Specify the physical world outputs (physics).
2. *Design*: Design processes that could produce those outputs (computer science).
3. *Validate*: Compare expected with actual outputs (experiments).
4. *Repeat:* Repeat steps 1-3 to achieve design consistency (quantum realism).

The consistency constraint is critical, as while it is easy to satisfy one requirement, satisfying many is much harder. In addition, the design should:

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

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

1. *Spurious*. Spurious models add no value, as they need new assumptions or parameters to explain every new fact.
2. *Coincidental*. Coincidental models work for a while, by luck, but fail over time, as they cherry-pick cases to support the model and ignore those that contradict it.
3. *Useful*. Useful models aren't actually true, but can be stepping-stones to new research.
4. *Valid*. Valid models not only explain observed reality in many ways, but also predict new effects that are later found to be true.

If physics describes physical events and computer science describes processing events, whether the physical world is generated by quantum processes is a question that design science can evaluate. The following chapters reverse engineer the world in a physics from scratch approach (Tegmark, 2007 p6). It derives space, time, matter, and energy from first principles, to deduce rather than assume the charges of electrons and neutrinos (4.3.2) and predicts that matter came from light (4.5.9).

1.6. SHIFTING THE PARADIGM

Quantum realism is the inverse of physical realism because it makes the quantum world real and the physical world imaginary, rather than the reverse. It is a paradigm shift, just as when we shifted from thinking the sun orbits the earth to realize that it is the reverse. Paradigm shifts are usually resisted because they challenge traditional assumptions. The first resistance is often Occam's razor, that the traditional view is simpler, then to defend its foundations, and only finally to scientifically test the new paradigm. Yet the biggest obstacle to any new paradigm is the belief that we already know everything.

1.6.1. Occam's razor

Occam's razor is to not multiply causes unnecessarily by preferring the simpler theory. A century ago, Bertrand Russell argued that life isn't virtual 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 argument still apply today? It is still common sense that there is a reality out there apart from us, but that our entire universe once existed at a point isn't common-sense at all. Today, common-sense is just as likely to accept that our universe booted up from a small beginning.

The direction of Occam's razor has also changed. In Russell's time, physics was based on a few particles, each with mass, charge, and spin, but now it needs forty-eight particles, that have twenty-four properties, plus five invisible fields, that generate fourteen virtual bosons, just to explain the basics. To explain inflation, neutrinos, or dark matter, needs even more fields, particles, and bosons. And our best universal theory, string theory, needs eleven dimensions to work at all.

It’s hard to imagine anything more complex than physics today so if it is preferred, it isn’t because of its simplicity! In contrast, the following chapters explain the same facts using one quantum process, one extra dimension, and one quantum field. Last century, physical realism may have been the simpler theory, but not today. Fast forward a hundred years and quantum realism is far simpler than physical realism, so now Occam’s razor cuts the other way.

1.6.2. The foundations of physical realism

Modern science began when Aristotle concluded that, for all practical purposes, physical events have physical causes. Physics today now argues that physical reality, defined as matter and energy in space and time, is all there is. Physical reality is said to be conserved, continuous, complete, and fundamental, but lately cracks have appeared in these foundations that required theoretical patches, as follows:

1. *Conserved*. If physical reality is all there is, it must be conserved in total. Parts of it can transform, as water turns into vapor, but the total must be in an eternal steady state. Unfortunately, big bang theory cracked this pillar last century, as what suddenly began isn’t eternal. One patch used to cover up this fault is the speculation that a big crunch will follow the big bang, in an ongoing oscillation that is in effect a steady state.
2. *Continuous*. If physical reality is all there is, space and time must be continuous, without gaps. If time had gaps, matter wouldn’t exist continuously and so couldn’t be all that exists. If space had gaps, something beyond space would have to cause that. Unfortunately, assuming continuity in field theories creates infinities, and what is infinite is impossible. The patch used to cover up this crack was a mathematical method called renormalization, that Feynman called a “dippy process”. Essentially, it just defines the problem away.
3. *Complete*. If physical reality is all there is, everything must have a physical cause, but events like atomic decay have no physical cause. No physical history can explain when a radioactive atom emits a photon. Quantum theory adds that quantum collapse is random, so every physical event involves randomness. The patch in this case was the ludicrous idea that every random choice creates an entire new universe, to give a multiverse that has no randomness.
4. *Fundamental*. If physical reality is all there is, particles of matter or energy should be fundamental but according to quantum theory, entities exist as quantum waves that only become particles when

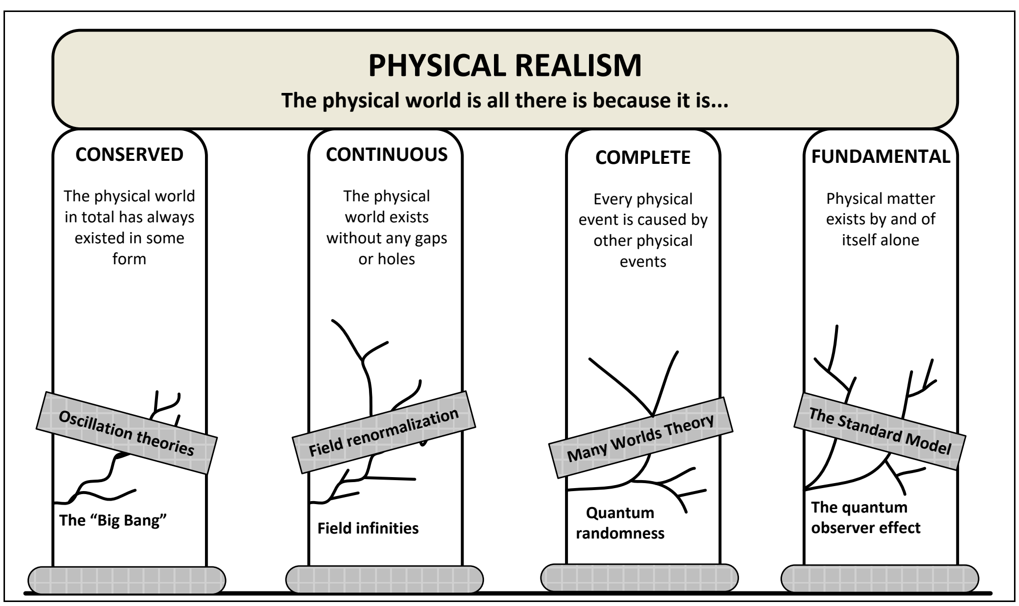

Figure 1.7 The four pillars of physical realism

observed, and the evidence agrees. The patch for this crack is the standard model of physics, that uses virtual particles to explain observed effects like gravity. It lets physicists talk about particles while using equations based on waves.

Figure 1.7 shows the four pillars of physical realism, their cracks, and the resulting patches. This model survives by being well-established not by being well-founded, for if physical reality 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 be self-existing.

That physical reality is conserved, continuous, complete, and fundamental therefore equates to saying that it is eternal, all-pervading, all-powerful, and self-existing, all properties once attributed to God. Physical realism essentially uses scientific terms to dress up physical reality with the same properties that were once attributed to the divine, so it is an ideology as well as a theory of science.

The tradition of materialism is routinely defended rather than questioned, but science can't prove its assumptions about physical reality any more than religion could prove its beliefs about God. Instead of thinking a book has all the answers, it is now thought that physical reality does. But if physical reality is eternal, why did it begin? If it is all-pervading, why are there Planck limits? If it is all-powerful, what explains random events? If it is self-existing, why does quantum theory say that it is generated?

To accept physical realism today one must believe that matter began itself, that infinities can be defined away, that photons can spawn new universes, and that virtual particles can cause real effects. To say that physical realism has shaky foundations is an understatement, but what is the alternative?

Science can't challenge physical realism until an alternative is proposed, and that is quantum realism. It proposes that physical reality is virtual and so impermanent, digital, contained, and dependent. A universe that began is impermanent, not eternal. A universe of pixels and cycles is digital, not all-pervading. A universe that has random events is contained, not all-powerful. A universe that is generated is dependent, not self-existing. To attribute divine properties to what is impermanent, digital, contained and dependent is foolish, so quantum realism is proposed to replace it.

1.6.3. A paradigm shift

The philosopher Kuhn distinguished normal science that grows theories, from paradigm shifts that change their foundations, where the foundations of a theory are the axioms it is built on. Changing foundations is hard, so Kuhn argued that science involves long periods of normal science interspersed with occasional revolutionary paradigm shifts (Kuhn, 1970).

For example, Euclid's assumption that parallel lines can't converge was accepted for two thousand years, until it was realized that on curved surfaces like the earth, parallel longitudes do converge (at the poles). Changing that axiom gave hyper-geometries that work on curved surfaces, and made Euclid's geometry the special case of a flat surface. Einstein's relativity was also a paradigm shift that made its predecessor, Newton's mechanics, a special case. Science sometimes has to change its foundations to advance.

What then are good theory foundations? Chaitin argued that good axioms support more than one fact (Chaitin, 2006), based on Gödel's proof that all theories are incomplete (Gödel, 1962). Good theories use a few axioms to predict many facts. Ignoring this criterion by adding new axioms for every new fact increases size not success, just as putting a shack on every new plot of land gives a shanty town not a city of skyscrapers. That a theory isn't increasing knowledge is a sign that a paradigm shift is needed. It is increasingly obvious that particle physics today is in this category, as.

"*One experiment after another is returning null results: No new particles, no new dimensions, no new symmetries.*" (Hossenfelder, 2018).

It is also obvious that it has had to add new axioms to explain new facts for a while now, so particles and fields have increased but not their predictions. Gravitons were assumed to explain gravity, but predicted nothing new. Virtual particles with mass were assumed to explain neutron decay, but again predicted nothing. A Higgs field was assumed to explain how those particles had mass, but it also led nowhere. The field has increased in complexity but has made no breakthrough in decades, suggesting the need for a paradigm shift.

The shift proposed is to base physics on waves, as quantum theory does, not on particles, as materialism does. This change seems radical but disruptive innovations are often the price of progress (Sandström, 2010) and physics already uses wave equations, so the practice won't change. For example, Schrödinger's equation stays the same but it now describes what exists, not what doesn't. In general, the equations don't change but their meaning does. Giving quantum theory a semantic heart might not seem important but just as giving up geocentrism led to new directions in astronomy, giving up materialism suggests new directions in physics, like colliding light not matter (4.5.9). Yet this paradigm shift challenges the belief that we have all, or nearly all, the answers already.

1.6.4. A query of everything

Science has long challenged our human tendency to make ourselves the center of things, so:

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

For example, we once thought we were the center of the universe, because we thought the sun and stars moved around us. Being the center of it all made us feel good, so the question "*Where are we?"* didn't arise because we already knew the answer. We were obviously at the center of everything, so when Galileo and Copernicus challenged geocentrism, they also challenged the ego idea that the universe revolves around us. Science now tells us that we live on a little planet circling a medium star, in a galaxy of a hundred billion stars, in a universe of at least that many galaxies. Mankind is like a colony of bacteria dominating one leaf of one tree in a vast forest, but this ego blow was the price we had to pay to understand astronomy.

We also thought we were the center of all life, because we thought that animals and plants were put there just for us. Being at the center of life made us feel good, so the question "*When did we begin?*" wasn't asked either, as again we thought we knew. The center of life was obviously there from the beginning, so when Darwin challenged creationism, he also challenged the ego idea that life revolves around us. Science now tells us that humans only evolved from animals a few million years ago, after dinosaurs had ruled the earth for two-hundred million years, until a meteor wiped them out. Mankind is just another species, and bacteria, insects, and plants all exceed us in biomass, but this ego blow was the price we had to pay to understand biology.

Today, we think we are the center of our body, because we think we are in charge it. Being in charge makes us feel good, so the question "*Who am I?*" isn't asked because yet again we think we know. We are obviously at the center of the body because we can observe it, so when science now challenges the dualism that a mind controls the body, it also challenges the ego idea that our bodies revolve around a central self. Science now tells us that our brains have no center, equivalent to the central processing unit of a computer, so if the cortical hemispheres are surgically "split", each takes itself to be "I" (Sperry & Gazzaniga, 1967). We aren't even the center of our own bodies, but this ego blow is the price we have to pay to understand neurology.

The trend is clear, our ego puts us at the center of things and science repeatedly shows that we aren't. We aren't the center of the universe, or of life, or even of our own body, but old habits die hard. We still think that reality revolves around us, that what we see is real because we see it so. Being the knower of reality makes us feel good, so the question "*What is real?*" isn't asked because again, we think we know. Obviously, matter is real, so when quantum realism challenges materialism, it also challenges the ego idea that we know reality. Science is now telling us that the physical world isn't reality central because something else causes it. If physical reality existed by itself alone, it couldn't have begun, but it did. Light couldn't travel in empty space, but it does. Space couldn't curve nor time dilate, but they do. And random events that physical history can't predict would be impossible, but they aren't. We aren't at the center of anything physical, but this ego blow is the price we have to pay to understand our existence.

Table 1.1 shows that there is nothing illogical or unscientific about quantum events causing physical events. It may shock the ego but it fits the facts of physics. The only thing denied is the delusion of scientific omniscience (Sheldrake, 2012), the egoism that we already know everything, or are about to but for some loose ends. This delusion implies a Theory Of Everything (TOE) but what if everything doesn't objectively exist? The idea that we are in a local reality makes quantum realism a query of everything, not a theory of everything.

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 running both entangled photons 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*. Light is a processing wave that can interfere but still reboot to be a particle at the 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. Why is it hard to argue for dualism, for a mental 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 movie? How does it differ? (1.2.5)
6. How are quantum realism and physical realism the same? How are they different? (1.2.5)
7. Could science still operate in a virtual reality? (1.2.6)
8. What physical evidence fits the theory that the physical world is a virtual reality? (1.3.1)
9. Why do many physicists 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 that is all there is create itself in a big bang? Give reasons. (1.4.2)
12. How did our space begin if there was no time for it to begin in? (1.4.2)
13. How did our time begin if there was no space for it to begin at? (1.4.2)
14. How can space be both nothing and something? (1.4.3)
15. Why can't anything go faster than light? (1.4.4)
16. Is physics more scientific because it studies real physical events? (1.4.5)
17. Is quantum realism falsifiable? Is physical realism falsifiable? (1.5.1)
18. How can quantum realism be evaluated scientifically? (1.5.2)
19. What is Occam's razor? Does it support physical realism? (1.6.1)
20. Is the physical universe eternal, all-pervasive, all-powerful, and self-existing? (1.6.2)
21. Does quantum realism change the equations of physics? If not, what does it change? (1.6.3)
22. Is quantum realism a theory of everything (TOE)? If not, why not? (1.6.4)

REFERENCES

Aspect, A., Grangier, P., & Roger, G. (1982). Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities. *Physical Review Letters*, *49*(2), 91–94.

Atkins, P. (2011). *On Being: A scientist's exploration of the great questions of existence*. Oxford University Press. https://en.wikipedia.org/wiki/Peter_Atkins

Audretsch, J. (2004). *Entangled World: The fascination of quantum information and computation*. Wiley.

Baggot, J. (2013). *Farewell to Reality: How fairytale physics betrays the search for scientific truth*. Constable.

Barrow, J. D. (2007). *New theories of everything*. Oxford University Press.

Bone, J. (2005). The social map and the problem of order: A re-evaluation of "Homo Sociologicus." *Theory & Science*, *6*(1).

Bostrom, N. (2002). Are you Living in a Computer Simulation? *Philosophical Quarterly*, *53*(211), 243–255.

Chaitin, G. (2006). The limits of reason. *Scientific American, 294*(3), 74–81.

Cho, A. (2000). Physicists Unveil Schrodinger's SQUID. *Science*, *287*(31 March).

Deutsch, D. (1997). *The Fabric of Reality*. Allen lane.

Esfeld, M. (2004). Quantum Theory: A Challenge for Philosophy! In J. Audretsch (Ed.), *Entangled World* (pp. 271–296). Wiley-VCH.

Everett, H. (1957). "Relative state" formulation of quantum mechanics. *Rev. of Mod. Phys., 29*, 454–462.

Ford, K. W. (2004). *The Quantum World: Quantum Physics for Everyone*. Harvard University Press.

Fredkin, E. (1990). Digital Mechanics. *Physica D*, 254–270.

Gödel, K. (1962). *On Formally Undecidable Propositions*.

Greene, B. (2004). *The Fabric of the Cosmos*. Vintage Books.

Gribbin, J. (2000). *The Search for Superstrings, Symmetry, and the Theory of Everything*. Little, Brown & Company.

Guth, A. (1998). *The Inflationary Universe: The Quest for a New Theory of Cosmic Origins*. Perseus Books.

Hafele, J. C., & Keating, R. E. (1972). Around-the-world atomic clocks: Observed relativistic time gains. *Science*, *177*, 168–170.

Hevner, A. R., March, S. T., & Park, J. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105.

Hogg, M. A. (1990). *Social Identity Theory*. Springer-Verlag New York.

Hossenfelder, S. (2018). The Present Phase of Stagnation in the Foundations of Physics Is Not Normal. *Nautilus, November*.

J. Khoury, B. A. O. (2001). Ekpyrotic universe: Colliding branes and the origin of the hot big bang. *Phys. Rev. D64*, *12*.

Kant, I. (2002). Critique of Pure Reason. In M. C. Beardsley (Ed.), *The European Philosophers from Descartes to Nietzsche*. The Modern Library.

Kelly, K. (2002). God is the Machine. *Wired*, *10*(12).

Kuhn, T. (1970). *The Structure of Scientific Revolutions: Vol. Second Edition, Enlarged*. The University of Chicago Press.

Kwiat, P. G., Weinfurter, H., Herzog, T., Zeilinger, A., & Kasevich, M. A. (1995). Interaction-free Measurement. *Phys. Rev. Lett.*, *74*, 4763.

Lloyd, S. (1999). Universe as Quantum Computer. *arXiv:Quant-Ph/9912088v1, 17 Dec*.

Lloyd, S. (2006). *Programming the Universe. A Quantum Computer Scientist Takes On the Cosmos*. Alfred A. Knopf.

McCabe, G. (2005). Universe creation on a computer. *Stud.Hist.Philos.Mod.Phys.36:591-625*.

Nikoli´, H. (2008, Access Date). *Quantum mechanics: Myths and facts*. Http://Arxiv.Org/Abs/Quant-Ph/0609163v2.

Piccinini, G. (2007). Computational modelling vs computational explanation: Is everything a Turing machine and does it matter to a philosophy of mind? *The Australasian Journal of Philosophy*, *85*(1), 93–115.

Power, A. (2010). The online public or cybercitizen. *SCRIPTed - A Journal of Law, Technology & Society*, *7*(1). http://www2.law.ed.ac.uk/ahrc/script-ed/

Pratchett, T., Stewart, I., & Cohen, J. (1999). *The Science of Discworld*. EBURY PRESS/Random House, London.

Raspanti, M. (2000). *The Virtual Universe*. Authorhouse.

Rhodes, R. (2001, Access Date). *A Cybernetic Interpretation of Quantum Mechanics*. http://www.bottomlayer.com/bottom/Argument4.PDF

Schmidhuber, J. (1997). A Computer Scientist's View of Life, the Universe and Everything. In C. Freksa (Ed.), *Foundations of Computer Science: Potential-Theory-Cognition Lecture Notes in Computer Science* (pp. 201–208). Springer.

Sheldrake, R. (2012). *The Science Delusion*. Coronet Books.

Smolin, L. (2001). *Three Roads to Quantum Gravity*. Basic Books.

Smolin, L. (2006). *The Trouble with Physics*. Houghton Mifflin Company.

Svozil, K. (2005). Computational Universes. *Chaos, Solitons & Fractals*, *25*(4), 845–859.

Tegmark, M. (1997, Access Date). *The interpretation of Quantum Mechanics: Many Worlds or Many Words*. arXiv:Quant-Ph/9709032v1.

Tegmark, M. (2007). The Mathematical Universe. In R. Chiao (Ed.), *Visions of Discovery: Shedding New Light on Physics and Cosmology*. Cambridge Univ. Press.

Tegmark, M., & Wheeler, J. A. (2001). 100 Years of the Quantum. *Scientific American*, *Feb*, p68-75.

Vacca, J. (2005). *The World's 20 Greatest Unsolved Problems*. Prentice-Hall.

Whitworth, B., & Ahmad, A. (2013). *The Social Design of Technical Systems: Building technologies for communities*. The Interaction Design Foundation.

Wigner, E. (1960). The Unreasonable Effectiveness of Mathematics in the Natural Sciences. In *Communications in Pure and Applied Mathematics, vol. 13, No. I*. John Wiley & Sons, Inc.

Wolfram, S. (2002). *A New Kind of Science*. Wolfram Media.

Zuse, K. (1969). *Calculating Space*. MIT.