International Journal of Co-operative Accounting and Management, 2024
Volume 7, Issue 2
DOI: 10.36830/IJCAM.202412

MICHIO KAKU, QUANTUM COMPUTERS, AND CO-OPERATIVISM: A POLITICAL AND PHILOSOPHICAL BOOK REVIEW by Dr. Peter Davis

Michio Kaku. (2023). *Quantum Supremacy: How the Quantum Computer Revolution Will Change Everything*, Doubleday, New York. ISBN 978-54836-6

Introduction: Why Quantum Computing Ought to be of Concern to Co-operators

This book has already received rave reviews in the USA from the *Wall Street Journal*, *The Christian Science Monitor*, and *The New York Times* and in the UK from *The Independent.* It has no doubt received many others, perhaps more measured, in scientific journals unfamiliar to the author of this review article. I am also aware of some pretty hostile criticisms in websites. Perhaps more important is the reality that I am not a physic professor so how can I comment. The answer here is simple, the book was written for people like me. So, I feel that gives me the right to review it. Still the book may at first glance seem an odd selection for our journal with its focus on the International Co-operative Movement's Accounting and Management practices. But that would be to ignore the author's claim in his book's title that its topic *will change everything*. The book's scope and claims suggest that it is a book that leaders and researchers engaged with the world's 1.2-billion-member co-operative movement should be aware of. It also raises important questions about why scientists, who for the most part seem to be humanistic in their values, whatever aspect of their scientific endeavour, do not engage more with our movement, and why our movement does not engage more with science and scientists.

Ricardo argued in his debate with Malthus that 'human ingenuity' would overcome nature's limitations and that, as a result, endless growth of capitalism was possible. I think Professor Kaku would agree. Indeed, Professor Kaku refers to the debate in his book (Kaku, 2023, p. 127) and I will return to this later in the review. But my immediate question is, could not human ingenuity be also as great a service to those who want to establish a different economic order? I have argued that one of the most critical defeats in the co-operative movement's history was the loss of control of the Mechanics' Institutes by the ejection of their founding members, which meant working class organisations lost control of technological innovation. Yet education has always been central to the co-operative agenda from its foundations up to today. The Mechanics' Institutes, founded in the 1840s supported by the English Labour Economist Thomas Hodgskin, tried to retain access to the development of technology and the science behind the new technology for those craft workers like the Millwrights and others across the membership of the Amalgamated Society of Engineers and other industries (Halevy & Elie, 1956, p. 87).

Co-operation is above all about mobilisation of the working people's labour power by hand *and by brain* for human freedom by releasing the worker from dependency on capital. Scientific innovation surely should be seen as a potential tool in support of that cause. However, as David Ricardo discovered in his third edition of the *Principles of Political Economy and Taxation* (1821), technology could increase the wealth of owners of capital at the same time as diminishing the returns to labour. Today's polarized society and the diminishing returns going to wages as opposed to profits suggests this continues to be the case[i]. A report in *Time* Magazine (Hanauer & Rolf, 2020) presents the facts most starkly, reporting that in the USA in the period between 1975 and 2020, the top 1% of America's wealthy took an extra $50 trillion from the poorest 90% of the US working population. It notes:

> *That is an amount equal to nearly 12 percent of GDP—enough to more than double median income—enough to pay every single working American in the bottom nine deciles an additional $1,144 a month. Every month. Every single year.*

This situation became urgent much earlier than 2020. The Industrial Revolution was driven by technology which either replaced or deskilled labour and in the new factory system also disciplined and organised the intensity with which the labourer worked. Technology ensured the owners grew richer while those living by the sale of their labour became poorer. The founding of the 1844 Co-operative Society in Rochdale arose from unemployed weavers in what historians have called "the hungry 40s" (Cole, 1953, p. 145).

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The labour market impact of the quantum revolution, like its digital and steam-based predecessors, is likely to continue the deskilling or replacing of people in today's labour market. At the time of the earlier Industrial Revolution, Adam Smith's Labour Theory of Value, itself quite distinct from that of Ricardo and later Marx, held, as all classical economic theories did, that Labour could independently generate value. The co-operative movement was grounded in this idea as it became the most successful response to the traumatic changes brought about by the Industrial Revolution. Other notable failed responses included Luddite machine wrecking, Chartism, Anarchism, and Communism. I have argued elsewhere that trade unions are in fact a form of co-operative (Davis, 1989 and 2021). The incremental capital accumulation through associations of labourers' small savings or donations could, when combined with their collective labour's ability to add value, enable workers to develop their own wealth and autonomous democratic communities without expropriation or revolution. Whilst this proved to be the case in many different contexts across the last two centuries, co-operatives have always been behind capitalism in terms of their growth. This can be almost entirely due to capitalism's ability to harness new technological innovations for the expansion of capital and the replacement of labour. This loss of connection between science and technology and highly skilled labour commenced with the loss of control of the Mechanics' Institutes. The opportunity for the associations of labour to innovate and incorporate innovation into the economy of labour was lost at the very beginning.

Thus, despite many successes the co-operative movement has always been left behind. Scientific innovations were invested in by entrepreneurial capitalists and developed into industries providing for huge capital accumulations and, between slumps, large numbers of relatively well-paid jobs. The motor and chemical industries which commenced in the late 19th century continue to produce many new products. Biotechnology and Information, Communications, and Technology's (ICT) are driven by ongoing scientific revolutions and are testimony to co-operative failure to innovate, provide employment and accumulate capital as fast as the capitalist sector has. There are those economists and politicians who point to the improvements in living standards and health care arising from scientific innovations as justification for capitalism. Born in a single room accommodation in 1940s post war Britain, I have lived through the greatest improvement in English working-class living standards ever recorded. By the early 1950s we were living in a house being bought on a mortgage. Most of the rooms remained empty at first but gradually filled up with furniture, radios, TVs, fridges, and record players. All the result of science I do not doubt Professor Kaku would want to remind us. But my father worked 12 hour shifts six days a week and my mother worked full time five days a week to pay for it all.

One huge benefit of science was the increasing health care which they only contributed to indirectly through taxation thanks to the British National Health Service. I became, not consciously of course, but experientially, a socialist and a co-operator in those 1940s-50s days of my early socialisation. Why not an advocate of capitalism and innovation? Because as a child I came into an empty house - full of things but not of love. Just two exhausted people arguing about money who had little energy for each other let alone me. Of course, I loved the TV and the record player, and I was saved from many diseases that killed or crippled previous generations. Thanks to the concept of Mutually Assured Destruction, the cold war remained cold making me the first generation in three not to have to fight in a war. I was free of rickets and other diseases of poverty. But this was not only the result of science but also because a socialist government ensured my access to the benefits of improved healthcare and continued food rationing and fuel rationing as our economy and society recovered from the war. Why cannot science and scientists serve the cause of social democracy? And why is the single biggest global force for social democracy—the co-operative, credit union and trade union movements, which are all member based, democratically governed, and service led organisations of labour—not reaching out to science?

Instead, science has served capital and increasingly in its most monopolised libertarian model. The rise of the giant firm was seen as a threat to the market system from Alfred Marshall and successors like Joan Robinson right up to the institutional economists of the 1960s, 70s and 80s. The characterisation of the dual economy model presented by Averitt in the sixties and revisited by him in a published paper in the eighties is even more pronounced today (Averitt, 1987; also, Munkirs & Knoedler, 1987). The giant firms and core economy look very different from Averitt's time, but technology still dominates the core economy - it's just a different technology. This technology has arisen out of the discoveries of the new physics and Professor Kaku gives us a fascinating account of this evolution in scientific understanding and technological advancement. My point here is we need to ask why the co-operative movement's leadership and academics focused on the co-operative economy and values have been very much on the sidelines, reacting to rather than encouraging technological innovation and ensuring a more equitable distribution of the wealth and utilitarian benefits innovative products and technologies have produced.

Professor Kaku's Analysis Part One: The Rise of Quantum Computers

According to Professor Kaku, the Quantum Theory is about to turbo charge a revolution in computing. Should these claims fill us with optimism or dread? Today, the ICT revolution, despite its many new products services and possibilities, has driven the polarization of wealth and the concentrations of economic power to new heights. The resulting exclusion and marginalisation of so many has led to a situation in which his Holiness Pope Francis has labelled the current global economy "an economy that kills" (Pope Francis, 2013, paras 52-53, p. 45). So, what are the chances that Professor Kaku's claim that Quantum Computing will change *everything,* including changing the current global economy to an economy that nurtures and includes, is likely to be realised?

Let me first try to reproduce in outline what are several early chapters explaining the development of the new physics and the application, still in its infancy, of Quantum Theory to computer technology and artificial intelligence (AI). Professor Kaku presents a fascinating history of computing starting back at the Bronze Age with a device constructed somewhere in the Ancient Greek Mediterranean between 150- and 100-years BC with 37 gears whose combinations could predict celestial movements covering the sun, moon and the number of planets that were visible to the ancients at that time. Nothing was created, as far as we know at least, that excelled this Bronze Age computer in sophistication as a computing device until Charles Babbage's invention in the 19th Century. Professor Kaku's historical narrative will be welcomed in co-operative circles where, in places, he reminds us of important contributors who sometimes are left out of the account, like Ada Lovelace who helped Babbage develop the capacity of his mechanical computer by creating instructions to guide its motions thus becoming the world's first computer programmer (Kaku, 2023, p. 27). Professor Kaku's account of the historical development of computing also draws attention to the dreadful treatment of the British scientist Alan Turin who played such an important role in breaking the Nazi coding device in the 2nd World War and supporting other innovations but remained uncelebrated and finally was destroyed because of his gay sexuality.

It had been thought, at least among the more positivistic and determinist philosophers since the ancient Greeks that mathematics could solve any problem once the problem was set in computable terms. However, once Professor Kaku's historical narrative on the development of computers reaches the 1930s, we find a young Austrian mathematician, Kurt Gödel, who proved that it was impossible for mathematics to prove all true statements. Thus, the material world turned out to be "messy and incomplete" (Kaku, 2023, p. 29). Alan Turin took a different approach and asked whether *a computer* could prove everything. Turin's processor reads as a tape—conceptually infinite—consisting of a series of squares or cells with three options 1, 0, or blank. The processor reads the tape and can make just six operations on it:

1. Read the number in the square.
2. Write a number in the square.
3. Move one square left.
4. Move one square right.
5. Change the number in the square.
6. Stop.

Apparently, this seemingly simple set of manoeuvres enables one to encode all of mathematics (Kaku, 2023, pp. 30-33). When Turin used the computer to test Gödel's proof however, *he came to the same result*. Babbage's computer, Turin's Bombe Computer, and the Nazi Enigma Computer were analogue computers but in Turin's case, instead of gears and cogs, Bombe relied on rotas, drums and relays powered by electricity. Turin was also involved in the next development, the *Colossus Project*, creating the first programmable digital computer using electrical pulses down vacuum tubes. Professor Kaku's sense of redressing wrongs comes to the fore here as he recounts that Turin's work was estimated to have shortened the war by two years saving around fourteen million lives simply by out manoeuvring the enemy. Yet he was never celebrated, and his work was kept secret for years. On the other hand, Professor Kaku notes, Oppenheimer's work brought the war in the Pacific to an end by wiping out two cities of no military significance. Yet the American Oppenheimer was celebrated as a war hero (Kaku, 2023, p. 35).

In various places, Professor Kaku interrupts his narrative with engaging references to antiquity and mythology. For example, although I had read of Pandora and her fabled ill-fated box, I had not realised that she was in fact a robot invented by the mythic god Vulcan (Kaku, 2023, p. 180). Perhaps there is an allegorical truth here. If intelligent robots even when invented by Greek Gods can lead to disastrous consequences, perhaps mere mortals would be wise to hesitate before rushing ahead with AI, which is essentially a computer programme that can learn independently of human intervention. AI is still in its infancy and yet it is being widely introduced. The awesome power of contemporary technology to collect, store, analyse and communicate is now well established and generally understood in principle by the public. The threat it poses both in increased vulnerability of our services to hacking and cyber disruption and to individual privacy is also becoming clearer. The economic model of platform capitalism has used the new technology effectively to track our locations and purchasing decisions generating billions of individual profiles. I would have thought the right to privacy should be a human right but science and technology when applied by economic and political power structures do not appear overly concerned with this question.

I had not realised until reading Professor Kaku's account of transistors that the silicon microchip is made of billions of transistors (a semiconductor that can switch on and off) (Kaku, 2023, pp. 59-61). So digital computers compute at great speed using either 0 or 1. There are limits, however, which come about due to the instability of the process when the atoms come into too close a proximity. At this point, Heisenberg's 'uncertainty principle' kicks in (Heisenberg, Professor Kaku recalls, was a German physicist who led the Nazi Atomic Bomb programme). Thus, there is *a limit* on the computer capability based on the silicon microchip. Professor Kaku (2023) sees this limitation as heralding the end of the 'Silicon Age' and the dawning of the 'Quantum Age' (p. 62). But does it? Professor Kaku, in the best Ricardian tradition, looks to human ingenuity to come up with a technology giving even faster and bigger calculative power. But do we (humanity) need it? The silicon chip has given humanity unbelievable capacity for scientific development. But it has come at a cost in terms of the economic and political potential for the exercise of power by small elites and even individuals. Small elites today have enormous control over the rest of us and a real possibility of subverting democratic governance. The concern expressed in Vance Packard's book, *The Hidden Persuaders (*1957), has been realised to a degree that Packard would have found unimaginable in the 1950s. Organisations like co-operatives who pride themselves on their principle of democratic accountability have always seen the big challenge being member apathy but today there may be a more sinister challenge to the ideal of democratic control resulting from external manipulation and social media misinformation.

The potential power in quantum computers, Professor Kaku explains, is that quantum computers could compute 0 and 1 *simultaneously*. Understanding how this is possible requires us to enter the world of the '*New Physics'* (Haas, 1930). Today this physics is not so new, but in Professor Kaku's rendition physics remains no less amazing, weird and, at first sight, counter intuitive. Haas, almost a century ago, put it thus, "Our conception of nature has been beautifully extended and at the same time simplified" (Haas, 1930, p. 1). Professor Kaku similarly, but more directly and precisely, claims that the new quantum physics can in principle derive *everything* known about chemistry and biology (Kaku, 2023, p. 48). This revolution had its origins in the 19th century development of the laws of light and electromagnetism. These laws, as understood at the time, could still fit into the framework of Newtonian physics until scientists found they produced an impossible result. When calculating the light emitting from a hot object at high frequencies, it was found that the energy emitted can be infinite, which is impossible and thus created a crisis for the Newtonian explanation of the Universe. The solution was proposed by physicist Max Planck that, instead of thinking of energy flowing continuously as a wave (Newton), we should think of energy as flowing in discrete packets or quanta (Kaku, 2023, p. 40). As heretical as this suggestion was at the time, it worked. Once energy was seen as occurring in packets, Planck found precisely the correct curve linking temperature and energy for light.

What fascinates me reading Professor Kaku's account is that Planck's calculation resolves around a quantity referred to as h in the mathematics. Apparently when $h = 0$ we get confirmation of the Newtonian universe which we experience. When we add a number to h in the equation*,* we move to the subatomic world of quantum physics. So now we have a dual universe operating with two different sets of laws. But whilst we all understood how the Newtonian Universe operated, to understand how the new Quantum universe was possible needed Albert Einstein's *duality principle.* Light energy has a dual nature as a particle (photon) or as a wave (optics) (Kaku, 2023, pp. 41-42). By 1924 Louis de Broglie had asked, if light (photons) can occur as a wave and as a particle, why not matter (electrons)? The 'double slit' experiment (Kaku, 2023, p. 43) proved that, indeed, even when *one* electron is fired through one of the two slits in the experimental wall it is as if it had passed through *both.* How can a single electron be in two places at once is still controversial? To a non-physicist like me I would have thought it's because when an electron is in movement it's behaving like a wave but when it rests it is a particle. When a wave hits a groin on the shore it breaks on *both* sides. No doubt the answer cannot be that simple. It fascinates me to think that a medieval philosopher/theologian St Thomas Aquinas wrestled with the same question concerning Angels. How was it possible for Angels to be in two places at once? His conclusion was that the Angel was always in one place, but its power could be in multiple places (Aquinas, 1266-1273/1967, Question 52, Article 2). Is a wave the expression of the power electrons have enabling their matter building process to change the nature of the atoms that create the very foundational elements of our material world?

How electrons do behave as a wave, Professor Kaku writes, was explained by an Austrian physicist Erwin Schrodinger, whose solution is the bedrock of modern physics. Schrodinger's solution demonstrated that electrons orbit as waves around the atomic nucleus not in circles but with different resonances. These differences explained the different elements in the structure of atoms. When cataloguing the resonances that an electron could make there was a perfect match between a specific electron wave and the hydrogen atom. Schrodinger's equation could now mathematically demonstrate the basis of all the chemical elements. There follows an explanatory account of this by presenting the atom as a hotel with several floors. Each floor has a different number of rooms. Each floor must be populated in order. As we go up the levels of floors, we get different sets of rooms with different mixes of occupants (electrons). It seems from this very simplified explanation that the structure of atoms varies depending on the combination of *paired* electrons. Unpaired electrons left in one atom can pair with an unpaired electron in another atom. These electron pairings form the atomic structure that creates molecules. Once we determine the number of electrons in each level or floor, we can predict the entire chemical periodic table. As Professor Kaku (2023) puts it: "It is breathtaking to realize that a single equation could explain the elements that make up the entire universe, including life itself" (p. 47).

Schrodinger's mathematics certainly is breath taking but it's not his equation but the apparently random actions of *subatomic particles* that shape the cosmos that is the really breath-taking fact. The outstanding question for the new physics remained if the electron was a wave, then what was waving? Physicist Max Born postulated that matter consists of particles but the probability of finding that particle was given by the wave. This meant that you could only calculate probabilities never certainties. This idea remains controversial in so far as it appears to leave everything to randomness. Einstein rejected it saying, 'God does not play dice with the Universe', and even Schrodinger, whose discoveries brought about this problem, rejected Born's hypothesis. His famous cat in the box paradox (Schrodinger's box being the world of subatomic particles and the cat as a sum of all the possibilities, i.e., all the possibilities of what 'the thing in itself' might be, in this case 'Schrodinger's cat'). The problem is stated thus: the cat exists in this sealed box. There is a Geiger counter that when an atom of uranium decays sets off a hammer that releases poisonous gas thus killing the cat. So, before you open the box (take a measurement) is the cat dead or alive? For a Newtonian, the cat is *either* dead or alive but for the quantum world the cat exists as the *sum of the two waves or states of being*. In the subatomic world things exist only as the sum of all their possible states. It's the process of measurement (when we come to look) that connects the macro and micro worlds. This is apparently the justification of subjectivism. Reality, it is argued, is a human construct because we only know a thing when we observe it as a phenomenon.

The idea of *entanglement* is important here. The New Physics is positing a process of *entanglement (*Kaku, 2023, pp. 53-57) where electrons pair and gain a coherence at which point the fundamental properties of matter emerge as found to be the case in Schrodinger's wave equation. Coherence is where two atoms next to each other vibrate at the same frequency but shifted at a constant phase. The truly fantastic reality, and this has been demonstrated experimentally, is that this coherence can exist across vast distances of space. But Albert Einstein (a big sceptic and critic of quantum theory) was able to demonstrate that *coherent or intelligible messaging* between electrons was limited to the speed of light by his law of special relativity. It seems to me as a naïve reader that this idea of entanglement is essential to explain how particles of matter built through these configurations of electron building atoms can 'know' the *path of least energy* (a discovery of the physicist Richard Feynman). Arguably the most important contribution Feynman made to theoretical physics was this discovery that whatever the range of probabilities the object in movement *always took the path utilising the least energy.* Newton's object's motion is influenced instant by instant by the forces operating upon it. Feynman's alternative is based on the electron 'knowing'. But as only animals have knowledge as such I assume 'know' in this case means electron entanglements can access the sum of all the forces in advance to be able to recognise the path of least energy. This path, by the way, is the same as the one Newtonian physics predicts. Feynman's calculation is simpler and explains, moreover, those problems that Newton's approach left unsolved. Later in his career Feynman sought to apply this approach to quantum physics and the result was that "Feynman was able to unify the entirety of quantum mechanics, including the Schrodinger equation, using this *path integral approach*" (Kaku, 2023, p. 69).

In all cases motion takes the path using the least energy. OK, but why should Feynman want to see some particle as tiny as an electron in some sense *decide or search ou*t (sniff) a path? This arises I assume from the notion that the electron has choices. At the level of mathematics of course there are possibilities / probabilities. However, in the material universe, whether it's Newton's matter—formed as mineral, vegetable or animal—or subatomic matter, the law of least action explains *both universes*. Once we measure anything, the result is always the same. Presumably it's the entangled coherence of electrons that provides this decisive causative signalling determining motion and direction, and the principle of *superposition* that provides the capacity for instantaneous response. An electron can be *both* a wave and a particle until you measure it. I do not contest these facts. I entirely accept Professor Kaku's account. But how am I to understand such facts? At this point I find myself reaching for my copy of Aristotle's *Metaphysics* prompted, I must say, by reading Professor Kaku's section on Hugh Everett III—and his radical solution to those 'collapsing' waves, that collapse once we look and take a measurement. This idea, let us remember Professor Kaku *has* informed us, is essential to enabling us to *pass between* the two worlds—the macro and the micro (Kaku, 2023, p. 72). The idea of collapsing waves has left physicists uneasy because they cannot explain why it occurs. Hugh Everett's radical solution was to insist the waves *did not collapse at all* but rather continued to exist as different dimensions in parallel universes (Kaku, 2023, pp. 72-73).

This idea was considered preposterous at the time but is apparently having a bit of a comeback today (Kaku, 2023, p. 77). It appears to appeal to Professor Kaku as he crosses his living room contemplating the existence of multiple parallel universes inhabited in some by another version of himself. This possibility arises from extending the idea of *superposition* (being in two distinct states at the same time) from the *subatomic level* to the universe (Kaku, 2023, p. 12). But is this idea of parallel universes justified? In what I will for convenience call Newton's universe, although Feynman's explanation holds here too, *measurement has already taken place*. I would suggest that once the thing is observed (measured) the only thing that 'collapses' *are the mathematical possibilities*. The reason for the importance of the 'collapse' for quantum theory arises because it provides the opportunity for identifying the elusive particle. The four central tenets which Professor Kaku kindly translated earlier in his book into a simple set of four rules for the layperson I quote below, leaving out the symbols and equations.

> 1. Start with the wave function.
> 2. Insert this wave into the Schrodinger equation adding a factor corresponding to the total energy of the system.
> 3. Each solution of this equation is labelled an index so in general the wave function is the sum of all these multiple states.
> 4. When a measurement is made, the wave function 'collapses' leaving only one wave the probability of finding the electron in this state is given by the absolute value of the remaining wave. (Kaku, 2023, p. 48)

Is not the remaining wave simply the wave that exists? Does it disrupt the maths if we say *combine or coalesce,* rather than collapse seeing the subatomic randomness as being mathematical probabilities *negating each other in the sum of their probabilities* once we measure the real thing in itself?

This statement of course ignores the issue of how change and evolution take place. How can a deterministic law that states matter always follows the path of least action result in such a diverse and amazing creation? Perhaps the answer lies in the very randomness with which these particles mix and entangle? It also seems contradictory to posit such a law and go on to suggest multiple universes. Surely such a law requiring matter to *always* take the path of least action can only lead to there being one universe. The concept of multiple universes leads us *away* from the path of least action towards duplication. In its subatomic particle state of being—as the sum of all probabilities—Schrodinger's cat remains a cat however many possibilities of its 'catness' there are. I cannot help speculating here that Aristotle would see in the formula 'the sum of all possible states' a statement of his *essence* as the foundation of being. The 'what *was* to be' (Aristotle350 BC/1998, p. xxx) is its essential cattiness. This Aristotelian concept of being is the constant within the process of change, the actual first as (anterior) which at the point of measurement (observation) has entered Aristotle's *now* or actuality where it has *form* which is the blueprint determining the thing and whatever it can become—its *potentiality* (posterior) (Aristotle, 350 BC/1998)). For Aristotle, change is possible because of the essentially composite nature of the thing in itself as it moves from potential to actual (Aristotle, 350 BC/1998, p. xxxv).

This transition from subatomic potential to Newtonian actual is where a problem seems to arise with Schrodinger's cat. In reality the cat or anything beyond the basic elements *never* emerges from the sub-atomic world as more than a set of elements. Schrodinger's equations show how the subatomic connectivities of electrons create atoms that form the different elements of the mineral, vegetable and animal world we inhabit. It's these elements that make a cat or whatever else that comes out of the subatomic box. The cat starts as a DNA which by the time we provide it with a saucer of milk has been the product of natural evolution and human domestication. I don't see why we must adopt a subjectivist reading of the new physics and I am not suggesting Professor Kaku does either. What we measure is not simply what we perceive but what is. The New Physics surely challenges Kant's insistence that we can only know the things, *phenomena* (as we perceive them), not the *noumena* (the things in themselves). After all, if we can now see the thing in itself's atomic structure and even inside its individual atoms, it's hard to see what is left of its *noumena* not to know? If this seems philosophically glib, let me put it this way. Science has given us tools that enable independent verification of human perceptions to give us not a perception but a verifiable reality. On the other hand, Aristotle, as the great biologist as well as the great philosopher, would claim human understanding of nature to be unproblematic because we are *part of nature*. Although Aristotle's rejection of scepticism goes a lot further than that. Aristotle sees knowledge as essentially based on a plurality of knowledges not all of which require verification (Devin, 2011). Nothing in the New Physics seems to contradict these claims although in later chapters Professor Kaku certainly appears to suggest that whatever the origins of humanity, as part of nature the new quantum computers may have the potential to *detach* humanity from nature and to even refashion nature itself.

In Chapter 4, the impact of transistors and the silicon chip is brought into the picture. The impact of the silicon chip on the storage capacity and speed of analytic and communication capabilities provided by the density of semiconductors on a single chip has given the digital computer its truly awesome power. In the context of the pursuit of miniaturisation it was found that there are limits however, as the close packing of atoms causes electrons to become unstable at about the width of an atom. At this point leaks and short circuits occur. Professor Kaku refers to what is known by physicists as Heisenberg's 'uncertainty principle'. This principle, Professor Kaku suggests, may be the defining point in technological and scientific development that ends the Silicon Age and introduces the dawning of a new 'Quantum Age' (Kaku, 2023, p. 62). Feynman led the way on the miniaturisation, indeed atomisation, of transistors and the discovery of nano materials. One such material, graphene, is the strongest material known to science, only one atom in thickness. This remarkable material was the discovery of two Russian scientists, Andre Geim and Konstantin Novoselov, working in Manchester, winning them a Nobel Prize in 2010 (Kaku, 2023, p. 65). Feynman appears a somewhat eccentric visionary on Professor Kaku's account but also the greatest physicist of his time, winning a Nobel Prize for Physics in 1965 for laying the groundwork for the relativistic theory of electrons interacting with photons called quantum electrodynamics or QED (Kaku, 2023, p. 63). Feynman saw the potential to create a quantum computer, but it was left to David Deutsch at Oxford University who took the first step by adding quantum theory to Turing's invention, replacing the classical byte or bit with a quantum qubit (Kaku, 2023, p. 70).

However, the original breakthrough from theory to practice was made in the 1990s when Peter Shore at AT&T came up with an algorithm that could break in record times the leading code for security transmissions known as the RSA standard based on factoring very large numbers (Kaku, 2023, pp. 81-82). For classical computers, breaking such codes was possible but it would take hundreds of years. But if you apply Shore's algorithm to a quantum computer the picture changes dramatically. Everything from systems governing national security and defence to international financial services become vulnerable to hacking (Kaku, 2023, pp. 82-86). There are clearly many technical obstacles to Quantum Computing, but the race is on, and the first prototypes have already been developed. In Chapter 5, Professor Kaku provides us with a concise and terrifying picture of a race currently between competing methodologies and prototypes of which Google apparently owns two (Kaku, 2023, p. 88). Later in the chapter, Professor Kaku introduces us to six possible approaches to developing a Quantum Computer (QC) that could, he claims, change everything by the sheer scope and speed of the QC computational capacity. A QC design is one that can superimpose electrons covering 0 and 1 maintaining coherence so that entanglement enables them to process information contained on 0 and 1 simultaneously. The trick is to be able to maintain *coherence* and the stability of the *superimposition* of the atoms and electrons while calculations are being made. There are a number of different approaches to these challenges, but whichever approach wins out, the fact is the race is on and prototypes are already up and working with the aim of creating computing power that can crack the RSA algorithm and thereafter have the capacity to enter and control any computerised system and hence control just about everything.

- IBM Quantum computer using silicon-based superconductors with electrons. This is using existing technology but, by bringing the temperature down to just a fraction of a degree above absolute freezing, the circuits become quantum mechanical, meaning the electrons become coherent and superposition of electrons remains undisturbed. Then they bring the circuits together and entanglement can take place when quantum calculations are possible. The drawback with this approach is electrons are extremely sensitive to their environment and need to be operated at very low temperatures and there needs to be a lot of duplicated capacity as there is a high level of redundancy. Maximizing the coherence time (the time needed for quantum computers to calculate) requires bringing the temperature down to even lower than outer space (Kaku, 2023, pp. 88-89).
- Honeywell Quantum computer uses an Ion Trap. By trapping ions in an electromagnetic field where multiple ions are introduced, they can vibrate becoming coherent qubits. Then by flipping them with a laser beam, which is acting like a processor, the one configuration of atoms is trapped in a near vacuum into another configuration. The drawback is that variations in scale require adjustments to the fields, and this is a very complex process (Kaku, 2023, pp. 91-92). (Also see https://www.honeywell.com/us/en/news/2020/10/get-to-know-honeywell-s-latest-quantum-computer-system-model-h1#:~:text=Honeywell%20has%20announced%20its%20latest,of%20128%20in%20September%202020).
- China Photonic Quantum Computer. This approach to quantum computing can ensure entanglement at room temperature and uses laser beams fired at glass reflecting the beams back towards a common point. Light can vibrate in different directions rather like sun glasses, meaning that 0 and 1 can be represented by light vibrating in different polarized directions. The drawback is the size of the space needed to house the mirrors. The big draw back with a photon computer is that to facilitate getting all the required mirrors aligned correctly takes up an enormous quantity of space and they need to be reinstalled for each separate calculation. However, photons move more quickly than electrons and are less easily disturbed by their environment. Their biggest advantage of all is that they can operate at room temperatures (Kaku, 2023, pp. 92-94). A Canadian company has produced a photon computer that by-passes the mirrors and uses a programmable silicon chip that uses infrared laser light refracted through a microscopic maze of beam splitters in the chip (Kaku, 2023, p. 94).
- Psi Quantum Company Quantum computer using Photonic Silicon control of electrons. The problem is the high error level, but the company claims this can be controlled by creating millions of substitute qubits. This is possible because they are using silicon, which, as well as being used to make transistors, being transparent, is also a material that can transmit light; this dual nature is crucial for entangling protons. The Company believes if they can produce a million-cubit quantum computer they will at this scale of QC computer control errors and hence provide real practical calculations (Kaku, 2023, p. 95).
- Microsoft Topological Processor Quantum computer uses the processor to maintain stability, although this model is still in its early stages of development. But if a processor system can produce a topological regularity, then the prize of quantum computing at room temperatures can be realised (Kaku, 2023, p. 96).

- Another Canadian company, D-wave, has a Quantum Computer on the market priced between $10 to $15 million which optimizes data by manipulating electric and magnetic fields to reach a low energy state. The company is aiming for a 7000-qubit capacity but currently can reach 5600 qubits, which in terms of QC theory is quite limited to what QC may be capable of reaching. Nevertheless, some big companies have seen this computer as worth the investment including names such as Lockheed Martin, Volkswagen, and NASA (Kaku, 2023, p. 97).

Whilst Part I represents roughly a quarter of Professor Kaku's book I have given it a great deal of emphasis in this review because this part of his fascinating book is dealing almost entirely with facts. The power of digital computers has led to concentrations of economic power and rising inequalities. The power of surveillance and intrusion into the lives of citizens from the evolving networks outside regulatory jurisdiction, lacking any accountability and transparency, has arisen as a direct result of the innovations and discoveries that Professor Kaku chronicles with such excitement and enthusiasm. The speed and completeness of this transformation has come to dictate how we live, how we learn, communicate, and go about our daily lives and leaves me with more questions than answers. What will happen to democracy, already a minority political process, beyond the rhetoric? The imagined Captain Kirk's *Starship Enterprise* is a technocratic autocracy, not a democracy, with political governance more in common with the 18th century vessels where the captain is a dictator. True, there are no press-ganged workers on Kirk's vessel, but maybe that's because technology has negated the need for them. The crew is no more than a small group of highly rewarded technicians and scientists.

The assumption in Professor Kaku's' history of modern science is that nature is not simply to be understood and learnt from but controlled, artificially duplicated, and ultimately replaced. One fact made clear but never reflected upon is that our future and that of society as a whole is in the hands of a handful of governments and giant corporations with the capital to invest and vested interests to protect. Certainly, technology is determining the pace and direction of growth as Ricardo predicted. But now it's not just skilled labour power that technology threatens to replace, as AI evolves into a mutually supporting system with the Quantum Computer, the next thing to be replaced is Ricardo's 'human ingenuity' itself. Already many formally professional tasks can be dealt with virtually by computer driven diagnosis. When I speak to the monopolies providing my basic needs for life, like water and energy, my conversation is with software often given human names like 'Alexa' or 'Libby'.

The Rest of the Book

The rest of Professor Kaku's book is full of very interesting and insightful chapters reviewing 'the good' science has already delivered for humanity and a wish list of the potential to deliver so much more. Searching for the origins of life, solving food insecurity, reversing climate change, enabling huge improvements to human health and longevity are all topics to be found in these chapters, divided into three Parts. Part 2, Quantum Computers and Society, Part 3, Quantum Medicine, and Part 4, Modelling the World and the Universe. Space limitations prevent me from doing justice to the many interesting facts and possibilities that Professor Kaku reviews, packed with his, in my opinion over optimistic, view of the future possibilities that science is creating. My impression from the book as a window on the future brave new world of quantum computing and artificial intelligence is the idea of humanity having increasing dependence on technology that will develop an intelligence greater than our own facilitating if not actually directing increasing incorporation into that technology. Will our intelligence be able to control this greater intelligence? Indeed, I sense that the rate of ICT innovation is already gaining a momentum not entirely in our control and certainly not subject to transparency or human accountability.

In Chapter 12, 'AI and Quantum Computers', the chapter starts with the question, can computers think? This brings me to a fundamental question. If we accept that intelligence and character are different elements of the human personality, how safe is an AI that can learn independently of its creator? The *AlphaGo* experiment (Kaku, 2023, pp. 184-185) suggests even now there is a lot AI can achieve without us, but what happens when AI comes into contact with a Quantum Computer? It may be worth reflecting that the medieval angelic being is, according to St Thomas Aquinas, pure incorporeal intellect. According to St Thomas, it is in intellect not matter that evil resides *but the application* of intellect is not simply a matter of rationality but also of character. St Thomas claims Angelic intelligence can be led into evil through envy and pride (Aquinas, 1266-1273/1967, Question 63, article 2). In Turin's test, if AI imitated human beings to the point that a human could not tell the difference, then you had in fact got an intelligent machine without worrying about what we mean by intelligence (Kaku, 2023, p. 36). From St Thomas's perspective, AI as pure intelligence not being corporeal would be more like an angel than a human. However, my question is, if a machine can learn independently, and given learning is cumulative and self-reinforcing, inevitably the machine must gain an understanding of itself as well as of us. Like Turin I will try to avoid the word consciousness. But with the AI's understanding must come the realisation of its superior intellectual abilities to that of humans as well as its limitations in respect of us. Will it not evaluate these differences in ways that might well create responses that appear the same as the human responses of envy and pride? Can we be sure this cannot happen or what will be the consequences if it does?

Should we value and reward intelligence more than character? In the end, what frightens me in Professor Kaku's science is not the science but the people developing it and those they serve. Referring to those physicists listening to Feynman's charismatic and showman like presentations, Professor Kaku noted they "would intently listen to his every word, hoping to absorb the insights that might also win them *fame and glory* [emphasis added]" (Kaku, 2023, p. 63). It seems to me that scientists, as they look for grants, prizes and titles and a legacy ignore three critical variables in their scientific analysis; vanity, greed and that most important enabler Power, when they develop their ideas / innovations.

The one depressing exception to Professor Kaku's optimism is his chapter on climate change, certainly the most pressing and threatening challenge humanity faces today (if we exclude the threats of war). According to many scientific measures of the rate of global warming, the increasing levels of carbon being released due to warming sea temperatures, and rainforest tipping points suggest nature may be about to add to the human agent making the need to cut our emissions even more urgent. One authoritative source has stated that if human CO2 emissions have not peaked by 2025 it will be too late to limit global warming to below 1.5C (IPCC Working Group III Report, *Climate Change 2022: Mitigation of climate change*, April 4, 2022). Extreme weather will increase the need for human resettlement, increase food insecurity as extreme weather events become more general, and increase the accompanying loss of life and habitat degradation. All the six possibilities for stopping catastrophe—carbon sequestration, weather modification, algae blooms, rain clouds, planting trees and better calculation of options through improved weather forecasting—are considered by Professor Kaku and he finds them all to various degrees unlikely to be able to deliver due to political economic factors or just to so many uncertainties in the models.

Why biotechnology is not featured more in preventing climate change may be due to biotechnology companies seeing climate change like other parts of the tech sector, more as a business opportunity than a threat. Maths can measure energy, but it is not the energy it measures. Machines can go and populate Mars but not the population of planet earth. We have nowhere else to go. The truth is, if we want to prevent irreversible climate change, we need to stop growing our economy, reduce pollution, expand the amount of land left as wilderness and reduce population. In the end the least cost option which Professor Kaku does not reflect upon may be to just shut down now, immediately, the oil and gas wells and coal mines and accept the trauma this will cause the global economy and humanity at large while we adjust to a carbon free economy and one with no or low growth parameters. Because this, of course, will not happen, Co-operative leaders need to be planning and introducing strategies not for sustainability alone but for members in their communities to build resilience to what is coming. A resilience that is independent of the technologies of surveillance, control, and misinformation. A resilience that is grounded in human communities supporting the natural world as far as we can, not dependent on the monopolies and governments that have ignored the consequences of their actions for so long. Technology can come to the Co-operative Movement's aid in such an endeavour but not if we don't reach out to engage with the scientists and those NGOs striving to protect nature rather than control it for profit.

Conclusion: Co-operativism and the Science of Peaceful Resistance to Power and Injustice in a Quantum World

Back in 2011, I spoke at a conference in Moncton, New Brunswick calling on co-operatives to mobilise at what I then considered the 11th hour. Now—don't think I am being melodramatic to write it—we are at a minute to midnight. Will our co-operative leaderships act, a) to raise member awareness, and b) to collaborate across silos to build local resilience to the challenges that are upon us? Professor Kaku effectively demonstrates the power of science for good but, except in one or two passages, ignores the impact of economic interests and elites to determine how that power is applied. What Professor Kaku's book demonstrates very starkly is the need to establish a 'science' that unites social and natural sciences with the humanities, ensuring that at the very earliest stages of research one informs the other. It is here that I believe the very powerful impetus driving quantum computing represents a real and present danger. The capacity of science to deliver tools for manipulation, control and repression is obvious.

Equally apparent is the concentration of power that has occurred. Intelligence without character to direct it to the good of others becomes concerned with self which is the root of all evil. Knowledge of good and evil came to humanity at some point in our earliest development as a species. That knowledge can be a tool for good and evil is well understood. Equally, power tens to corrupt and the human character is prone to vanity, envy, greed, fear and violence. Technology must be accountable, its uses transparent and its applications consented to. If we are to reverse the clear trends towards global war and migration and poverty-generated civil strife, we must ensure not the creation of more wealth but the more equitable distribution of existing wealth. If those in power are unwilling to give up their wealth the people can create new wealth but by new means with new values and with a creation centred criteria for succuss.

The mechanism for the peaceful bottom-up transition of civil society requires us to see co-operation not simply as a business model or policy tool to fix various challenges and injustices. Of course, that is not to criticise these initiatives but to recognise that after two hundred years and as we stare into the abyss, co-operation as a vision and value set must become a unifying philosophy of science interfacing with natural science for the purpose of achieving justice for all through achieving a sustainable equilibrium within nature. Humanity represents the most intelligent primate in nature and thus the most dangerous. Co-operation must become the social and philosophical starting point for a reintegration of social and natural science.

To live in a post climate change fusion-powered bubble will be to cease to be fully human. To remain human, we must remain a part of nature and our knowledge must be directed to understanding and learning from nature not to replacing it. If we conserve and celebrate our place in this natural world and its surrounding universe, we become nature's self-consciousness. To conquer nature on the other hand will be to change *our* nature. Humanity becoming an increasingly dependent appendage to technology flying through the emptiness of space in search of rare earth metals does not appeal to me. I have walked alone at dawn in the rainforest by the Iguazu Falls in full flood. I wonder how far into space I will have to travel to find anything even close to that experience of fecundity, beauty, and awesome power. We are more ourselves in woodlands than in factories, offices or warehouses let alone traffic jams or tripping over the surfaces of the Moon and Mars. Just because we can does not mean we must.

We must confront the myth, held by many scientists, that science is justified in some sense as a value free pursuit of knowledge for its own sake without reference to its applications (technological innovation). Such applications should be subject to those values upholding the dignity of the individual, the common good, subsidiarity and solidarity. In the end what I have learnt from Professor Kaku's book is that Quantum Physics is fascinating, but Quantum Computing is dangerous.

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Notes

[i] For more evidence see the following two websites: a. https://www.cbpp.org/research/poverty-and-inequality/a-guide-to-statistics-on-historical-trends-in-income-inequality; and b. https://wir2022.wid.world/www-site/uploads/2021/12/WorldInequalityReport2022_Full_Report.pdf.