A response to

Request for Comments on Patenting Artificial Intelligence Inventions.

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Written comments are due by October 11, 2019; subsequently extended to 08 November 2019 (see https://content.govdelivery.com/accounts/USPTO/bulletins/2617d88).
Written comments should be sent by electronic mail addressed to AIPartnership@uspto.gov.

This response is specific to the USPTO's above cited request for comments.

Title of response document: **Patenting Artificial Intelligence Inventions**

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Disclaimer: The views expressed in this document are those of the author.

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General Information: The author's evolving views on needed patent reforms and related matters as described here can be traced from the following publications:

Bera, R. K. AI Powered Society (September 28, 2018). Available at SSRN: https://ssrn.com/abstract=3256873. An updated version is available at Bera, R. K. AI Powered Society. Advanced Computing and Communications, March 2019, pp.59-85. https://acc.digital/aipowered-society/

Bera, R. K. Patent Examination Reforms (January 13, 2017). Available at SSRN: https://ssrn.com/abstract=2898819 or http://dx.doi.org/10.2139/ssrn.2898819

Bera, R. K. Patent Subject Matter Eligibility (December 11, 2016). Available at SSRN: https://ssrn.com/abstract=2883838 or http://dx.doi.org/10.2139/ssrn.2883838

Bera, R. K. Rethinking Patentable Subject Matter and Related Issues (December 4, 2015). Available at SSRN: https://ssrn.com/abstract=2699219 or http://dx.doi.org/10.2139/ssrn.2699219

Bera, R. K. Reforming the Patent System for the Post-Industrial Economy (September 22, 2015). Available at SSRN: https://ssrn.com/abstract=2664035 or http://dx.doi.org/10.2139/ssrn.2664035

Bera, R. K. A Minefield of Patents (July 14, 2015). Available at SSRN: https://ssrn.com/abstract=2630681 or http://dx.doi.org/10.2139/ssrn.2630681

Bera, R. K. A Rethink on the Expansive Scope of the Doctrine of Equivalents in U.S. Patent Law (May 30, 2015). Available at SSRN: https://ssrn.com/abstract=2612300 or http://dx.doi.org/10.2139/ssrn.2612300

Bera, R. K. How Valid are Judicial Exceptions in Subject Matter Eligibility in U.S. Patent Law? (May 10, 2015). Available at SSRN: https://ssrn.com/abstract=2604737 or http://dx.doi.org/10.2139/ssrn.2604737

Bera, R. K. Intellectual Property Rights: The New Wealth of Nations (March 3, 2015). Available at SSRN: https://ssrn.com/abstract=2572850 or http://dx.doi.org/10.2139/ssrn.2572850

Bera, R. K. Standard-Essential Patents (SEPs) and 'Fair, Reasonable and Non-Discriminatory' (FRAND) Licensing (January 29, 2015). Available at SSRN: https://ssrn.com/abstract=2557390 or http://dx.doi.org/10.2139/ssrn.2557390

Bera, R. K., Synthetic Biology and Intellectual Property Rights, in Biotechnology (Deniz Ekinci, ed), InTech, ISBN 978-953-51-2040-7, Chapter 9, pp. 195-232 (2015), http://www.intechopen.com/download/pdf/48297. (Book is available at http://www.intechopen.com/books/biotechnology and can be downloaded for free.)

Bera, R. K. Biotechnology Patents: Safeguarding Human Health, in Innovations in Biotechnology (Eddy C. Agbo, ed.), InTech, ISBN 978-953-51-0096-6, Chapter 15, pp. 349-376 (2012), http://www.intechopen.com/source/pdfs/28719/InTech-Biotechnology_patents_safeguarding_human_health.pdf. (Book is available at http://www.intechweb.org/books/show/title/innovations-in-biotechnology and can be downloaded for free.)

Bera, R. K. Synthetic Biology, Artificial Intelligence, and Quantum Computing. Book chapter in Genetic Engineering Technology and Synthetic Biology, Madan L. Nagpal (Ed.). IntechOpen, London, (to appear in 2019). For prepublication access visit https://www.intechopen.com/chapter/pdf-download/65149

Setting the context

Setting the context before responding to the USPTO's request for comments on patenting AI inventions is necessary because there appears to be an implied message that the USPTO is concerned with AI embedded in non-life machines and not AI-enhanced humans with, say, embedded AI chips in their natural neural net or AI machines embedded with living matter functioning as sensory and motor nerves controlled by a living central nervous system to deal with certain specialized information processing activities. If this indeed is the case, then the USPTO may be looking in an entirely wrong direction because the right direction would almost certainly demand that we adapt to such new environments or perish as have all other species before us in the genus Homo. *Homo sapiens* is the only extant human species.

AI, synthetic biology, and quantum computing are so rapidly advancing that it has made the *Homo sapiens* introspect and ponder where it stands in terms of its ability to act intelligently and innovatively vis a vis the human created world of intelligent machines. Patent Offices around the world have stayed inert for at least two decades in anticipating the future "where genetic engineering, artificial intelligence (AI), and quantum computing (QC) are coalescing to bring about a forced speciation of the *Homo sapiens*. A forced speciation will drastically reduce the emergence time for a new species to a few years compared to Nature's hundreds of millennia."[1] I believe that the "day is perhaps not far off when *Homo sapiens* itself will initiate its own speciation once it advances synthetic biology to a level where it can safely modify the brain to temper emotion and enhance rational thinking as a means of competing against AI-embedded machines guided by quantum algorithms."[2] If such a future begins to unfold within a century, a highly probable event If Ray Kurzweil's prediction about the future capabilities of AI machines—"By 2029, computers will have human-level intelligence")[3]--"turn out to be reasonably true, and genetic engineering continues at its present rate of development aided by advances in QC and in understanding RNA (ribonucleic acid)-mediated cellular activity using AI, artificially induced speciation of *Homo sapiens* by the end of this century may become possible before natural selection steps in anger."[4]

Based on his well-founded "law of accelerating returns" Kurzweil has forecast that

> 2029 is the consistent date I have predicted for when an AI will pass a valid Turing test and therefore achieve human levels of intelligence. I have set the date 2045 for the 'Singularity' which is when we will multiply our effective intelligence a billionfold by merging with the intelligence we have created.[5]
>
> Its consequences on the world's bulging population is perhaps unimaginable.

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[1] Bera (2019). Bera, R. K. Synthetic Biology, Artificial Intelligence, and Quantum Computing. Book chapter in Genetic Engineering Technology and Synthetic Biology, Madan L. Nagpal (Ed.). IntechOpen, London, (to appear in 2019). For prepublication access visit https://www.intechopen.com/chapter/pdf-download/65149

[2] Bera (2019).

[3] Ray Kurzweil Predicts Computers Will be as Smart as Humans in 12 Years. Fox News. 2017. http://www.foxnews.com/tech/2017/03/16/ray-kurzweil-predicts-computers-willbe-as-smart-as-humans-in-12-years.html

[4] Bera (2019).

[5] Reedy C. Kurzweil Claims That the Singularity Will Happen by 2045. Futurism. 2017. https://futurism.com/kurzweil-claims-thatthe-singularity-will-happen-by-2045/ See also: Kurzweil (2010). Kurzweil R. How My Predictions are Faring. kurzweilai.net. 2010. http://www.kurzweilai.net/images/How-My-Predictions-Are-Faring.pdf and 'The future is better than you think:' Predictions on AI and development from Ray Kurzweil. ITU News, 29 May 2019. https://news.itu.int/the-future-is-better-than-you-think-predictions-on-ai-and-development-from-ray-kurzweil/
Ray Kurzweil (Author, entrepreneur, futurist and inventor) is the recipient of the National Medal of Technology, 1999.

Just days before the USPTO announced its request for comments in the Federal Register, a breakthrough processor for AI was announced with very impressive credentials:[6]

The world's largest chip:

- named the Wafer Scale Engine by Cerebras
- 56 times larger than the biggest graphics processing unit ever made
- 400,000 cores
- 18 GB on-chip SRAM
- 3,000 times more on-chip memory
- tightly coupled memory for efficient data access
- 33,000 times more bandwidth
- extensive high bandwidth communication fabric
- groups of cores work together

Technology is marching ahead at an exponential rate. The millennials can only imagine how wildly disruptive their life will be as they grow older. Their generation will be disrupted by the fact that super-intelligent machines can routinely conceive of ideas that no human being has entertained in the past, nor that machines can invent sophisticated and advanced technological tools that will surpass anything *Homo sapiens* can create.

The international order is undergoing a cataclysmic change caused by rising geopolitical tensions among major powers, growing disenchantment with the liberal order, slowdown in the global economy effected by automation and artificial intelligence. There is a continuing decline in global consumption of goods and services, a rising percentage of the global population with shrinking retirement savings, the rich getting richer but whose offtake from the consumer market is miniscule, a rising proportion of the educated middle class slipping to lower income brackets, etc. Populous countries like India and China with very low capacity to invent technology will be particularly hard hit being burdened by their massive populations and a lack of inventive culture. Such massive changes in the environment trigger speciation of species that are adversely affected.

Our successor species will most likely be in better control of their emotions, perhaps devoid of religious beliefs, obviously calculating and thinking rationally (we assume they will have a superior brain and a mind) and have around them immensely powerful machines to do their bidding. What use will they or can they have of *Homo sapiens* and their primitive notions of restricted period of monopoly over patentable inventions in which they will see neither novelty nor non-obviousness that could not be bettered by them or their AI embedded gadgets?

AI inventions by their very nature cannot be granted patent rights nor such rights protected. AI inventions at their core belong to abstract mathematics and their most complex applications are essentially controlled by algorithms that are mechanizable computations. In fact, we already know some of the tricks that would allow AI machines to develop and discover new algorithms in a mechanized way.

[6] See, e.g., Metz (2019). Metz, C. To power AI, start-up creates a giant computer chip. The New York Times, 19 August 2019. https://www.nytimes.com/2019/08/19/technology/artificial-intelligence-chip-cerebras.html and Kurzweil Network (2019). A breakthrough processor invented for AI. Kurzweilai.net, 20 August 2019. https://www.kurzweilai.net/making-headlines-a-breakthrough-processor-invented-for-ai

Patenting Artificial Intelligence Inventions

Rajendra K. Bera

Abstract

The exponential rise of science, technology, engineering, and mathematics (STEM) since the 1900s has completely changed the socio-economic context in which the Patent Act of 1790 and its successive amended versions were enacted. Since then the person of ordinary skill in the arts (PHOSITA) and in relation to this hypothetical person, the meaning of utility, novelty, non-obviousness, of an invention requiring human ingenuity and the manner in which the invention is to be disclosed to the public in exchange for a limited period monopoly over the invention by the inventor has undergone a sea change. In the last few decades, the world has seen a dramatic change in socio-economic-political structures, remarkable advances in STEM, e.g., in information and computing technologies, quantum computing, genetic engineering and synthetic biology, artificial intelligence, etc. These have had an enormous impact on the environment in which the *Homo sapiens* find themselves in. Such drastic changes are harbingers of natural speciation, an event that may not be too far off with unknown consequences. The species that succeed the *Homo sapiens* will likely be so far superior in intellect, intuition, and serendipity as to drive the *Homo sapiens* to extinction. This paper assumes such an unfolding scenario and therefore suggests interim changes to the patent system so that the present debilitating stresses it faces, especially in the form of litigation, are substantially reduced. Our successor species will then perhaps remember us based not solely on our fossil record but also on our ability to anticipate the future and prepare for it intelligently.

Key words: artificial intelligence, *Homo sapiens*, intellectual property, inventions, STEM.

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Part I

The evolving AI scenario raises human concern

1 Introduction

We, the *Homo sapiens*, have been around for about 300,000 years.[7] Records of our civilization date back approximately 6000 years. Some 12,000 years ago, man transitioned from being the nomadic hunter-gatherer to a pastoral-agricultural life of rearing animals and sowing seeds. Society structured itself into families; women took care of the household; men earned a livelihood. Then from about 1500 AD to the later half of 20th century, an industrial economy developed with an accelerated growth of industrial activity and mechanization of agriculture. In a span of five centuries, we discovered new power sources and with each such discovery the economy graduated from using animal power to steam power to fossil fuel power to electrical power and now information power. Along with changing sources of power, society too restructured itself into increasingly complex communities—extended families, cities, nations, alliances, institutions, modes of governance, dominions, *etc.*—and economies expanded their reach and scope from family businesses run locally to multinational corporations operating globally and employing millions of men and women. Women were gradually weaned away from the hearth to the power corridors of corporations, competing with men for power and success in all spheres of life—business, politics, arts, science, *etc*. Since the late 20th century the world began to transform at an unprecedented rate into a post-industrial economy which expects to ram its way to another future using wind, solar, and information power. This, in brief, is the progress of human civilization.

The post-industrial economy is based on knowledge-intensive services. It requires far less land and labour than manufacturing, but it needs huge capital investment and its appetite for science-rooted innovative technologies is ravenous. Its market is truly global. The skill levels required of even entry-level jobs are high and available jobs are low. The middle class that expanded rapidly in the industrial stage is now poised to deflate equally rapidly because machines can now surpass most humans across the population in skills. Mr. Average of the middle class is on the verge of losing his identity and his dignity, not just his income. The job market is churning, shrinking, and vaporizing. While machines can be easily fitted with artificial intelligence (AI), humans cannot. Ironically machines are neither looking for jobs nor do they need one; they are emotionless, oblivious of the past and the future, without any need for spiritual balms or companionship. Yet, they have the potential to obliterate humankind by unintentionally snatching their jobs because exceptional men configured machines to compute, while Nature has configured most other men for mere procreation. The industrial revolution and the patent system brought the pleasant prospect of improving humanity's collective lot. The AI

[7] Hublin, *et al*. (2017), and Richter, *et al* (2017). Prior to these papers, *Homo sapiens* were said to have been around for about 200,000 years.

revolution has caused fear that only a few can live in style amidst machines, while the rest will sink into poverty for want of a job.

Patent systems around the world are well aware of all this because the crucial inventions since the industrial revolution that brought us to this stage of human civilization was facilitated and protected by limited period monopolies granted by national governments and international treaties. Yet, no patent system in the world, till now, anticipated, much less understood the consequences of accelerating advances taking place in AI powered by advances in information and computing technologies, and parallel advances in genetic engineering and synthetic biology. Their confluence within an amazingly short span in recent human history has caught them by surprise, even though Ray Kurzweil, a prominent inventor of our times, a recipient of the National Medal of Technology (1999), futurist and entrepreneur, has been alerting the world for over two decades about the rising power of AI.[8] Based on his well-founded "law of accelerating returns" Kurzweil has forecast that

> 2029 is the consistent date I have predicted for when an AI will pass a valid Turing test and therefore achieve human levels of intelligence. I have set the date 2045 for the 'Singularity' which is when we will multiply our effective intelligence a billionfold by merging with the intelligence we have created.[9]

I differ from Kurzweil in one important respect—his optimism that humans will benefit from such a development, rather I believe they will cross a threshold of speciation and will become extinct. So, has the time come to sunset the patent system because our successor species will not only be dramatically different from us, but may eventually preside over our extinction to prevent us from competing for natural resources they need? Our legacy will not be our fossil record, but our amazing science, technology, engineering and mathematics (STEM) record for successor species to peruse and perhaps marvel.[10]

However, if the context does not change and we continue to live in a world where at least a large enough number of *Homo sapiens* continue to dominate life on Earth, even then there is a need to revisit all aspects of the patenting system: (1) the legal necessity to adapt the system to align with the needs of the millennials; (2) the need to overhaul the patent act; (3) the need for a novel appellate system to arbitrate on alleged patent invalidity, infringement, etc., and (4) above all a new definition of the inventor and his invention.

The patent system was intended to be an interplay between law and economics. That interplay has become increasingly murky. The modern world cannot be understood, let alone governed, without a multidisciplinary perspective held by all actors in the game. STEM has advanced so rapidly in the past few decades and so expansively that it has forced many middle-class families to rearrange their priorities, finances, and lives. Success in life now depends more on meritocracy than on inherited wealth. Today, education must be paid for by those who wish to gain from the benefits it brings. After an education, only the meritorious will survive in a lifelong rat race.

Once again, there is growing inequality globally. It would be wrong to look back at history and believe the past can point a way out of this inequality simply because

> History does present one clear-cut case of an orderly recovery from concentrated inequality: In the 1930s, the U.S. answered the Great Depression by adopting the New Deal framework that would eventually build the mid-century middle class. Crucially, government redistribution was not the

[8] Kurzweil (1999) and Kurzweil (2005).
[9] Reedy (2017). See also: Kurzweil (2010) and ITU News (2019).
[10] Bera (2019).

> primary engine of this process. The broadly shared prosperity that this regime established came, mostly, from an economy and a labor market that promoted economic equality over hierarchy—by dramatically expanding access to education, as under the GI Bill, and then placing mid-skilled, middle-class workers at the center of production.[11]

The goal of modern AI is to augment human intelligence. Since the 1930s, it has strived to facilitate humans to do super-intelligent work. Mechanization augmented human brawn thus providing humans more opportunities to exploit the power of the human brain by climbing over the brawn barrier. AI now augments the human brain but the *Homo sapiens* have no further opportunity to climb the brain barrier but to speciate to a new species with superior mental characteristics. That new species will likely have human-style innovation and serendipity built into its genes. The patent system and the *Homo sapiens* will then be on their way to a Darwinian extinction. Even without that, on an ominous front, new weapons like hypersonic missiles, artificial intelligence, and cyberattacks are already altering global power dynamics. The *Homo sapiens* may destroy themselves even before Nature has time to do so. The following observations tell us a lot about our in-built limitations.

> [O]ther transformational technologies, such as railroads, electricity, radio, television, automobiles and airplanes, all took several decades before they reached that comparable level of ubiquity. Society had the time to sort out the norms, rules and laws governing those technologies and the respective roles of government and the private sector.[12]

To add to our woes, *the Economist* notes,

> The "internet of things" has been gathering pace for years, but the revolution is about to go into overdrive. By 2035 the world could have a trillion connected computers, built into everything from clothes to cows. This will bring gains that are individually small but they will be compounded again and again across the economy. As the internet becomes all-pervasive, ever more companies will act like tech companies—as all-conquering "platform" monopolies, for instance, or adherents of the data-driven approach that critics call "surveillance capitalism". Arguments about ownership, data, privacy, competition and security will spill over from the virtual world into the real one.[13]

In its European edition, *The Economist* notes,

> The "single market", once breathtaking in its ambition to eliminate all internal EU barriers for goods, services, capital and people, has failed to keep up with the economies it was trying to shape. Europe's economy is losing ground to global rivals. A decade ago ten of the world's 40 largest listed firms by market value were based in the EU; now only two are—in 32nd and 36th place. Desperately few of the world's leading startups are European. If Europe wants to create prosperity and world-beating firms, it needs not just to reinvigorate the single market, but also to rediscover that original vision.[14]

AI augmented surveillance technology too is spreading rapidly, and not just to illiberal governments but also in liberal democracies and autocratic states. Presently Chinese and U.S. companies are the largest global suppliers of this cutting-edge technology. In the wrong hands, it is a dystopian technology. The future is already here and we are struggling to keep up. The middle class is on the brink of an economic slide and that can only mean a disaster for humankind. The comity of economists didn't see this coming! The global economic climate continues to increase in volatility. Some highly

[11] Markovits (2019).
[12] Gerstell (2019).
[13] See Economist (20190912a). The quote is from a summary emailed by the Economist on 12 September 2019 to a list of recipients it maintains.
[14] See Economist (20190912b). The quote is from a summary emailed by the Economist on 12 September 2019 to a list of recipients it maintains.

visible reasons include trade tensions between China and the United States, long-standing historical tensions in the Middle East, the continuing anxieties of Brexit, the rise of hardline economic nationalism, and the gathering force of populism. No one knows where humanity is heading; all we know is that the direction appears ominous. The economists are totally clueless; they are dazed.

Also, we should not forget the unabashed, provocative, and predatory nature of China's theft of intellectual property rights enshrined in the USPTO granted patents.[15] This example alone should suffice to alert all countries about the vulnerabilities of national patent systems.

2 How early inventions advanced human civilization

The emergence of *Homo sapiens* based on recent fossil records has been revised to date back to about 300,000 years ago.[16] The data further suggests that we didn't evolve only in East Africa. The timing, location, and behavioral changes of *Homo sapiens* since their emergence to their modern biology, especially the development of their brain and mind poses many intriguing questions. The emergence of our species and the Middle Stone Age appear close in time. However, innovations and inventions of technology had begun much earlier.[17] Two important examples are the Acheulean Handaxe (~1,700,000 Years Ago), first made by the hominin family about 1.76 million years ago in the Lower Paleolithic (a.k.a. Early Stone Age) and used well into the beginning of the Middle Paleolithic (Middle Stone Age) period, about 300,000–200,000; and the control of fire (800,000-400,000 Years Ago), possibly an invention of our ancestor, *Homo erectus* during the Early Stone Age (or Lower Paleolithic). Controlled use of fire ranks among the first great innovations. Fire is a source of light and heat to cook plants and animals, to keep predator animals away, to clear forests for planting, to heat-treat stone for making stone tools, and to burn clay for ceramic objects. Further, fires serve as gathering places, as beacons, and as spaces for ceremonial activities. The *Homo sapiens* (the only extant species of genus "Homo") invented art (~100,000 Years Ago; e.g., cave paintings); textiles (~40,000 Years Ago; e.g., the deliberate processing of organic fibers into containers or cloth); shoes (~40,000 Years Ago); ceramic containers (~20,000 Years Ago); agriculture (~11,000 Years Ago; "the partnership between plants and humans"); wine (~9,000 Years Ago); wheeled vehicles assisted by draft animals (~5,500 Years Ago; it provided the means to rapidly move abundant goods across a landscape, widened trade opportunities in terms of geography, customer base, craft specialization, collaborative exchange of technologies with distant competitors, etc.); chocolate (~4,000 Years Ago); etc.

During this period, inventions were few, but crucial for the survival of *Homo sapiens* in a world that was "red in tooth and claw" and allowed only the fittest to survive. Darwin's theory of evolution of life[18] posits that all life is related and that it descended from a common ancestor, including the *Homo sapiens*. It presumes life developed from non-life and that complex creatures evolve from less complex ancestors naturally through the random adaptation process of "descent with modification". Genetic mutations that survive in a given environment are passed on to the next generation while the weaker are eliminated from breeding. When enough beneficial mutations accumulate, a phase transition is triggered and an entirely different organism (not just a variation of the original) comes into existence. The fossil record provides overwhelming evidence in support of Darwin's theory.[19] It now appears that *Homo sapiens* are rapidly heading towards speciation triggered by advances in STEM mediated AI.

[15] Li & Alon (2019). See also: Bera(2019a).

[16] The original papers are Hublin, et al (2017) and Richter, et al (2017). See also: Callaway (2017). The earlier estimate of the emergence of *Homo sapiens* was approximately 200,000 years.

[17] See, e.g., Hirst (2019).

[18] Darwin (1859).

[19] See, *e.g.*, Dawkins (2010).

Biological evolution is not about individuals, it is about inherited means of growth and development that enhances the survivability of a population of a given species evolving in a given habitat. The most important characteristic of human evolution since the agricultural era began about 12,000 years ago is the emergence of an adaptive brain-brawn feedback system that continuously monitors and tweaks the environment to improve conditions for human survival. Humans have evolved not purely by physical adaptation in an environment but by also mentally adapting to and changing the environment by putting their mind to work in coordination with the rest of their body. Farming communities gradually developed groups with specialized roles, e.g., soldier, ruler, and eventually the institution of individual property rights. When individual farmers began owning and cultivating their plots of land, it created a competitive spirit that greatly boosted efficiency and productivity. That competitive spirit and individual ownership rights also gave rise to protecting intellectual property (products of the mind rather than the brawn) to further boost societal efficiency and productivity. In 1500 CE the world's population was 458 Million; in September 2019 it was 7.7 billion and growing. During this period the marketplace underwent a radical change:

> In the modern marketplace, knowledge is the critical asset. It is as important a commodity as the access to natural resources or to a low-skilled labor market was in the past. Knowledge has given birth to vast new industries, particularly those based on computers, semiconductors, biotechnology and designed materials.[20]

Along with this, the technology landscape too underwent a radical change:

> Western industrial technology has transformed the world more than any leader, religion, revolution, or war. Nowadays only a handful of people in the most remote corners of the earth survive with their lives unaltered by industrial products. The conquest of the non-Western world by Western industrial technology still proceeds unabated.[21]

Nothing perhaps underscored the remarkable breadth of human ingenuity in developing technology of that period than accomplishing the safe landing and walking on the Moon by two U.S. astronauts, Neil Armstrong and Buzz Aldrin, on 20 July 1969 and their subsequent safe return to Earth on 24 July 1969 with the event being broadcast live on TV to a global audience. In Adam Smith's days (1723-1790) such a feat was possible only in science fiction, fairy tales and mythology.

Contemporaneously, the information technology revolution had just begun and was poised to make an exponential climb in advancing technology propelled by Moore's Law. The millennials would embrace the technology and the products it produced as if born to it. In 1999, Ray Kurzweil would write a prophetic book titled[22] *The Age of Spiritual Machines*: *When Computers Exceed Human Intelligence*. Just three years earlier when IBM's Deep Blue computer defeated chess champion Garry Kasparov in game one of a six-game match on 10 February 1996, a threshold in AI was crossed. While Kasparov won the 6-game match on this occasion, he lost to IBM's Deep Blue supercomputer on 12 May 1997 in a 6-game rematch. Since then AI machines have been beating human champions in games left, right, and center: They beat human champions in Jeopardy (February 2011), the Chinese game Go (March 2016), Poker (January 2017), once again in Go by AlphaGo Zero (October 2017; it learnt on its own from a blank slate), again in chess (December 2017; the machine taught itself in four hours), *etc*. Of these, the most significant is AlphaGo Zero which learnt purely by playing against itself millions of times over. It began by placing stones on the Go board at random but swiftly improved as it discovered winning strategies. It is a big step towards building versatile learning algorithms. All this

[20] Bloch (1990), p. 9. Quote as reproduced at Warshofsky (1994).
[21] Headrick (1981), p. 4.
[22] Kurzweil (1999).

within a quarter century is a "giant leap" for mankind in AI and an ominous sign for *Homo sapiens* whose core survival resource is its vaunted intelligence. These developments are related to deep data and deep learning. A discussion beyond this is provided under the heading *Beyond the data-driven world* below (Section 4).

AI-created unemployment will be massive, disruptive, and destructive. It will begin with the spread of mental illness, ill-feelings against the world, jealousy against the prosperous, the craving to destroy, *etc*. It is already visible in populist nationalism, intolerance against immigrants, and distrust of globalism. The most vulnerable will be those born into the middle-class, brought up in cocooned security and the promise of a comfortable future if they did well in their rote education. When human intelligence is blunted by AI, and rote education disconnects with employment, the future appears dystopian.

The evolving socio-economic patterns are discernible only when viewed over multiple generations. Rising prosperity since the industrial revolution blinded us. With every rise comes a fall, just like the rise and fall of a pendulum. The downfall began about a decade ago. The economists did not see it coming. Their lack of deep STEM knowledge ensures that they will never be able to predict the future and hence their opinions, whatever they be, will be totally irrelevant and unwanted. For example, they did not foresee the impact of automation and the rise of AI and the consequences that may follow. As Zabal and Luria perceptively note:

> In retrospect, *the four and a half decades from 1933 to 1978 were a historical aberration*. The longer-term trend toward more inequality in capitalist economies, which prevailed before this period, has resumed after it. That leads us to conclude that *there may well be no technocratic or tax policy fix for capitalism's tendency to generate ever more inequality*. [23] [Emphasis in the original]

Further,

> The great exception in U.S. economic history, the brief period beginning in 1933, was not only an anomalous period of decreasing inequality but one that also established America's unrivaled economic and political dominance. That success was built upon a hard-to-reproduce, five-part perfect storm … [24]

That storm included expropriation, demand stimulus, unionization, war production, and postwar economic hegemony. "No single economic, financial, or political factor in isolation explains the U.S. postwar economic trajectory … that long-term trends toward inequality were only interrupted and then slowed by a surge in workers' bargaining power and a paring back of the wealth share of the top 1 percent of households."[25] The resurgence of income inequality is seen in the erosion of employee bargaining power vis-à-vis employers, and the inability of most newly minted college graduates to get and keep middle-class jobs. A downward socio-economic slide has begun. Much of the rise and concentration of economic power by the few drew momentum from the USPTO's lethargic recognition of the rapidly rising skill levels of the person having ordinary skill in the arts (PHOSITA) when granting patents. This flooded the market with unwarranted patents. Lacking STEM knowledge, the judiciary was helpless in bucking the trend and was reduced to entertaining and encouraging arguments over trivial matters as Burk & Lemley (2009) noted a decade ago:

> Despite repeated efforts to set out rules for construing patent claims … parties and courts seem unable to agree on what particular patent claims mean. … Literally every case involves a fight over

[23] Zabala & Luria (2019).
[24] Zabala & Luria (2019).
[25] Zabala & Luria (2019).

> the meaning of multiple terms, and not just the complex technical ones. Recent Federal Circuit cases have had to decide plausible disagreements over the meanings of the words "a," "or," "to," "including," and "through," to name but a few. … Even after claim construction[26], the meaning of the claim remains uncertain, not only because of the very real prospect of reversal on appeal but also because lawyers immediately begin fighting about the meaning of the words used to construe the words of the claims. … Patent attorneys seize on such indeterminacy to excuse infringement or to expand their client's exclusive rights. … [T]he patent system increasingly revolves around the definition of terminology rather than the substance of what the patentee invented and how significant that invention really is. … [C]ourts define the scope of legal rights not by reference to the invention but by reference to semantic debates over the meaning of words chosen by lawyers.[27]
> (Footnote added.)

This degeneration has been gradual and irreversible. In practice, the patent document is seldom written for full comprehension by relevant technical experts (a judicially ignored violation of the patent act that requires full and comprehensible disclosure of the invention) but for lawyers who, in patent litigation, must present their client's case to generalist judges ignorant of the technical arts that support the patent.

Lee rightly notes:

> In an ideal world, personal biases would be irrelevant to judging. The job of a federal judge is to fairly apply the Constitution and federal statutes to particular cases. If the law were perfectly clear and unambiguous [axiomatized], it would be irrelevant who was put in charge of interpreting it. Of course, law doesn't actually work that way. Congress has defined patent law using general terms like "obvious," "novel," and "process." The courts give concrete meaning to those terms through a series of precedents. Hence, the biases of a court can have a significant impact on how the law is interpreted.[28]

Thus, every 5-4 SCOTUS ruling is a lottery draw. And therein lies danger. Shapiro notes:

> I believe there is manifest danger in binding rulings, particularly in the field of patent law, made by courts that do not understand the issues before them. Justice Scalia's proclamation in Myriad[29] that the issues discussed were beyond the understanding of the court should raise serious red flags. Indeed, it is hard to imagine that any court, or system of law, can maintain institutional legitimacy, if it issues decisions that demonstrate misunderstanding of the field, or are not logically supported.[30]
> (Internal citation omitted.)

It is therefore imperative that issues related to patent validity and scope be decided by the Patent Validation Board (PVB) (see Section 10.1) and not the courts.

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[26] The process of determining how best to interpret the words that describe an invention in a patent in plain English.
[27] Burk & Lemley (2009).
[28] Lee (2012).
[29] SCOTUS (2013). Justice Scalia wrote: "I join the judgment of the Court, and all of its opinion except Part I–A and some portions of the rest of the opinion going into fine details of molecular biology. I am unable to affirm those details on my own knowledge or even my own belief. It suffices for me to affirm, having studied the opinions below and the expert briefs presented here, that the portion of DNA isolated from its natural state sought to be patented is identical to that portion of the DNA in its natural state; and that complementary DNA (cDNA) is a synthetic creation not normally present in nature."
[30] Shapiro (2015).

In a consensus study, the National Academies (of the U.S.) stated its position on the matter of "Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond". Its abstract said,

> Convergence of the life sciences with fields including physical, chemical, mathematical, computational, engineering, and social sciences is a key strategy to tackle complex challenges and achieve new and innovative solutions. However, institutions face a lack of guidance on how to establish effective programs, what challenges they are likely to encounter, and what strategies other organizations have used to address the issues that arise. This advice is needed to harness the excitement generated by the concept of convergence and channel it into the policies, structures, and networks that will enable it to realize its goals.[31]

3 When STEM changed the face of man-made inventions

Along with Ray Kurzweil's prophetic predictions about the future capabilities of AI machines—"By 2029, computers will have human-level intelligence")[32] we add a salient observation from Richard Ogle in his book, *Smart World*:

> [I]n making sense of the world, acting intelligently, and solving problems creatively, we do not rely solely on our mind's internal resources. Instead, we constantly have recourse to a vast array of culturally and socially embodied *idea-spaces* that populate the extended mind. These spaces … are rich with embedded intelligence that we have progressively offloaded into our physical, social, and cultural environment for the sake of simplifying the burden on our own minds of rendering the world intelligible. Sometimes the space of ideas thinks for us.[33]

This smart world also faces unprecedented demographic changes due to variations in mortality, life expectancy, and a youthful population in countries where fertility is high. As Fig. 1 shows, the world is already heavily overpopulated. In the next three to four decades, the population of the more developed countries is likely to stagnate at about 1.3 billion. Their population is ageing and would decline but for migration. The populations of Germany, Italy, Japan, and several states of the former Soviet Union that broke away are also expected to decline by 2050.[34] The world's flexibility to cope with such unprecedented socio-economic changes is untested.

Opportunities for digitizing and automating tasks are far from being over. The more cognitive tasks are automated and embellished with language processing and pattern matching, and enhanced with mechanized physical dexterity, mobility, and sensory perception, the bigger will be its impact on depriving human workers of jobs performing these tasks and on division of labor in a society. Eventually, *inter alia,* assembly line workers, taxi drivers and long-haul truckers (Google/Waymo, Tesla, nuTonomy, Uber, and many others have already invested in self-driving vehicles) will have to seek other forms of employment. Machines capable of perceptual tasks, *e.g.*, language translation, speech recognition, text reading, computer vision will begin to replace human specialists in pathology, radiology, security, language translation, paralegal work, and many others.

Hardware for implementing AI software continues to progress rapidly as are energy sources that power the hardware. Beyond mere speed up and energy efficiency, other important technologies are advancing too. These include mobile Internet, IoT, cloud computing and storage, AI, autonomous vehicles, robotics, virtual and augmented reality, virtual personal assistants, fitness trackers,

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[31] NAP (2014).
[32] Fox News (2017).
[33] Ogle (2007).
[34] See, e.g., UNPF (2017).

everything cloud, 3D printing, hyperloop, drone services, renewable energy, and machine learning. And finally, there is bionics leading to a future population of super-humanoids capable of forming a society and running the world.

Population of the Earth (in billion markers)

Year	Population	Year	Population
1804	1 billion	1999	6 billion
1927	2 billion	2012	7 billion
1960	3 billion	2024	8 billion
1974	4 billion	2048	9 billion
1987	5 billion		

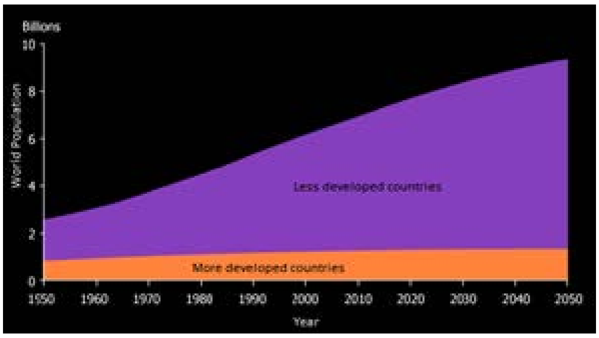

Fig. 1 (Left) World population growth. (Right) World Population Growth, 1950–2050.
Source: *World Population Prospects: The 2010 Revision,* United Nations, 2011, http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2010/WPP2010_Volume-I_Comprehensive-Tables.pdf Note the rapidly increasing population size in the less developed countries.

Just days before the USPTO announced its request for comments in the Federal Register, a breakthrough processor for AI was announced with very impressive credentials:[35]

The world's largest chip:

- named the Wafer Scale Engine by Cerebras
- 56 times larger than the biggest graphics processing unit ever made
- 400,000 cores
- 18 GB on-chip SRAM
- 3,000 times more on-chip memory
- tightly coupled memory for efficient data access
- 33,000 times more bandwidth
- extensive high bandwidth communication fabric
- groups of cores work together

Technology is marching ahead at an exponential rate. The perceived goal of AI researchers is no longer the mere mimicking of Mr average in intelligence but exceeding those of the best intellectuals. The millennials can only imagine how wildly disruptive their life will be as they grow older. Their generation will be disrupted by the fact that super-intelligent machines can routinely conceive of ideas that no human being has entertained in the past, and that machines can invent sophisticated and advanced technological tools that will surpass anything *Homo sapiens* can create.

The millennials now face unprecedented survival challenges in the future. The most challenging of them will be their ability to adapt to the new world by competing against AI-embedded humanoids they are themselves creating. A biological evolution of intelligent life is waiting to happen, triggered by the *Homo sapiens'* quest to understand the Universe not according to the scriptures but according to science. The *Homo sapiens* are on their way to becoming an endangered species within a century.

Imminent speciation may sound alarming, but it is scientifically plausible. The domesticated dog is a prime example that man is the instigating factor on Earth in changing the environment. It is he who could

[35] Metz (2019). See also: Kurzweil Network (2019).

domestic a wild species through genetic breeding in a very small fraction of the time that Nature would have required. And now that man has learnt the secret of creating new species in a lab, the time is not too far when he would be doing it on a mass scale. The domestication of the grey wolf into dogs happened long before the Industrial Revolution (1760-1840), before literature and mathematics, and before bronze, iron, and agriculture. This ancient partnership between man and animal entwined the fate of the two species. "The wolves changed in body and temperament. Their skulls, teeth, and paws shrank. Their ears flopped. They gained a docile disposition, becoming both less frightening and less fearful. They learned to read the complex expressions that ripple across human faces. They turned into dogs."[36] What will be our fate when the *Homo sapiens* speciate? What kind of territorial rights will we share with the new species? Who will be the master and who the slave?

Technology development began to rise sharply coinciding with the birth of the millennials. Fig. 2 summarizes the situation as it is developing for the millennials. A distinctive aspect of emerging technologies is their ability to create necessities or a 'must possess feel' not felt before. It is highly visible in myriad digital communication-plus devices ubiquitously available and affordable. Instant communication links that connect humans and devices via the Internet of Things (IoT) is now increasingly taken for granted. It has set in motion a disruptive restructuring of society by an "unseen hand" into a malleable global structure where people are tagged with a profile matrix that includes lifestyle, nationality, education, employability, religion, *etc*., usually in that order of importance. Society increasingly celebrates the individual than the family. The first millennials were born in the incipient stages of this disruption when it began affecting family structure and lifestyle, employment, skilling and reskilling opportunities caused by rapid automation of many hitherto human activities (physical and mental), and the welfare management of a growing population of retirees who are culturally alienated from their millennial progenies who in turn face an uncertain and unpredictable job market. The old socio-economic structure is crumbling, and a new stable structure is yet to take shape.

AI disruption has created diminished human employment opportunities, job stability and job quality. Key factors in societal well being are prosperity through gainful employment, individual well-being through good mental and physical health, sustainability through economic means and environmental upgradation, and justice and trust through ethical, moral and law enforcement standards. Recent events have shown that a socio-economic phase transition is underway.

Phase transitions are disruptive, and in socio-economic contexts where no mathematical model to describe them exists, are unpredictable. Social "scientists", economists in particular, are completely clueless as to the disruptive nature of AI and the cataclysmic effect it will have on *Homo sapiens*. To understand the problem, one needs to understand what we mean by intelligence and knowledge and how the best of human minds use their brains (natural neural network) to create artificial neural networks to augment and amplify the power of the human brain. Human created technology did a superb job when it came to human brawn power (e.g., in robotics); it is now trying to repeat it on human brain power. Its first glimpse of success came when Alan Turing showed that computing can be completely mechanized by using mathematics![37] Actual computer hardware came later notably with the ENIAC (Electronic Numerical Integrator And Computer)[38] in 1945 developed in the United States by Army Ordnance to compute World War II ballistic firing tables. Since then mechanized computing power has grown at the phenomenal pace captured in Gordon Moore's Law[39] (see the log-linear relationship of transistor counts for microprocessors in Fig. 2) and doing arithmetic ceased to be an intelligent activity (*creating* new mathematics remains an intelligent activity). AI is now well on its way to mechanize an immense amount of "intelligent" activity that a few years ago created well-paid jobs on a large scale. AI is now poised to make millions of even well-

[36] Yong (2016).
[37] Turing (1936).
[38] Moye (1996).
[39] Moore (1965).

educated people unemployable. The hardest hit will be those whose skill levels are so low that they can be replaced by machines at a low cost.

Using technology to improve well-being and smoothen disruptive change was a very fortunate outcome of the industrial revolution because the potential for improving skill levels and the means to do it was possible and affordable on a large scale to improve employee productivity. That is no longer the case for the millennials in the AI-dominated future. That future abounds in data and AI, and connectivity and platforms. Employability now demands innovation skills and labor fluidity to match demand with availability. With the global population bursting at the seams and performing at abysmal skill levels when pitted against advancing AI, only a miniscule fraction of the world's population can be gainfully employed.

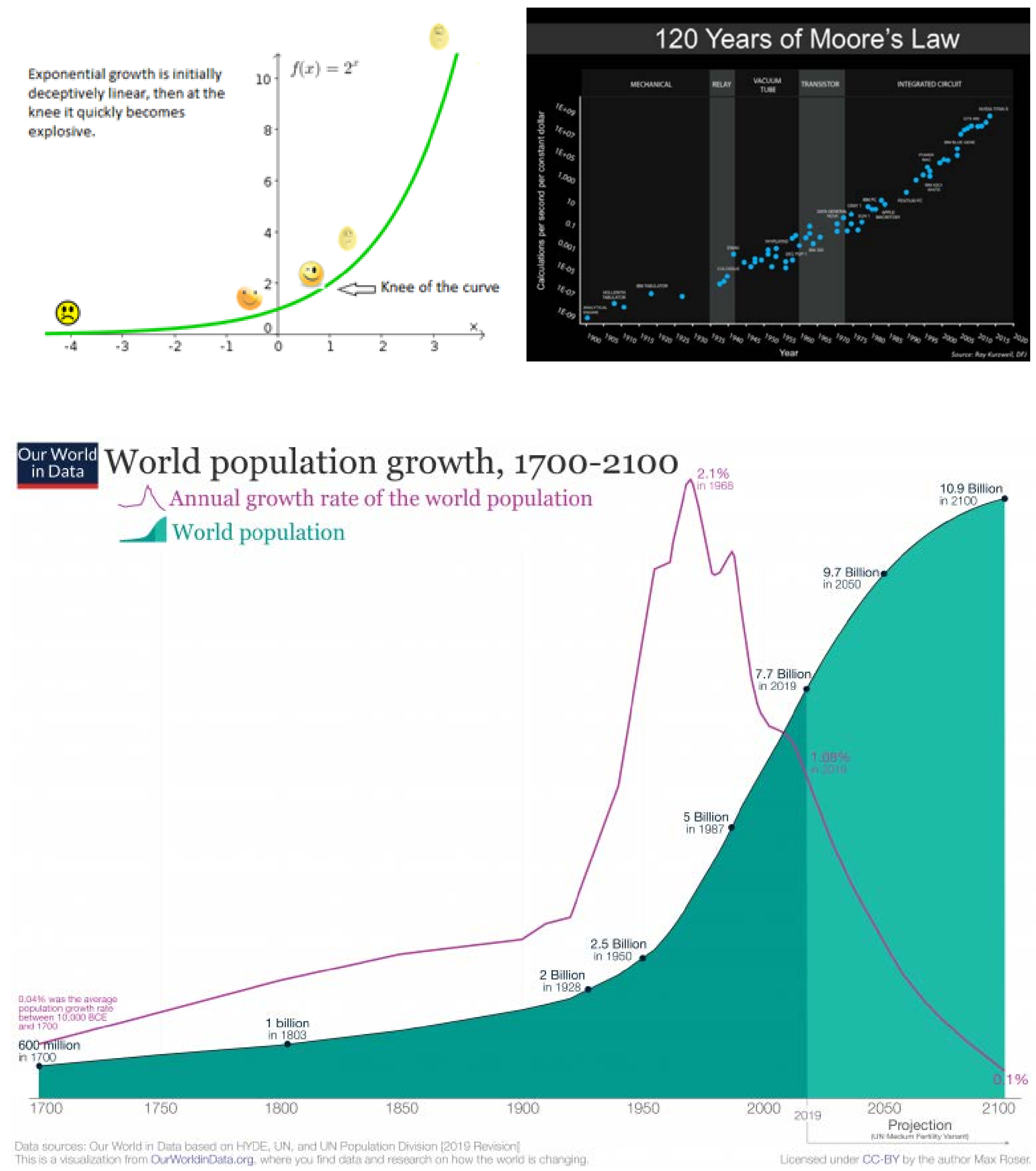

Fig. 2 Exponential growth. Source: (Top left) Author. Nature of exponential growth. (Top right) Steve Jurvetson. An updated version of Moore's Law (based on Kurzweil's graph). Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Moore%27s_Law_over_120_Years.png

4 Beyond the data-driven world

Current AI research is centered around a set of computing technologies that tries to mimic how humans use their nervous system and sense organs to sense, learn, reason, and act. For example, deep learning is a form of machine learning based on layered representation of variables called neural networks. These are widely used in applications that rely on pattern recognition. Natural language processing (NLP) and knowledge representation and reasoning was used by IBM Watson to win the Jeopardy competition in 2011.[40] Watson used a series of complex search algorithms and some heavy-duty computing power to find answers with the highest probability of being correct.[41] (I have reservations about pursuing NLP. What needs to be done is developing a language that does not admit ambiguity because each of its messages can then be pinned to a specific context through a web of connections.) With present day NLP methods, when the context is narrow and unambiguous, it is powerful enough with potential for further growth in web searches, self-driving cars, health care diagnostics and targeted treatments, *etc*. AI and robotics are now in wide use in agriculture, food processing, fulfillment centers and factories where they accentuate jobless economic growth. Once a new, context discriminating, man-machine *lingua franca* is created for universal use, AI will advance exponentially. Beyond this lies the vastly challenging task of discovering axiomatic systems that can encapsulate massive amounts of as yet unconnected data/observations. Here is a profound insight from Gregory Chaitin:

> [A] scientific theory is a computer program that calculates the observations, and that the smaller the program is, the better the theory. If there is no theory, that is to say, no program substantially smaller than the data itself, considering them both to be finite binary strings, then the observations are algorithmically random, theory-less, unstructured, incomprehensible and irreducible.[42]

This, I believe, describes the heart and soul of AI, i.e., a successful AI-system should be able to discover an axiomatic-system that looks at vast amounts of data, categorizes the data by doing a correlation analysis, creates a random set of samples and gleans common "features" among members of this random set, proposes a parsimonious set of axioms and rules of inference that would reproduce the observed features *and* predict new features as "theorems" where one is forever trying to see if x = y or not (*x* and *y* are two validly constructed statements or axioms in the axiomatic system). Parsimony is the key attribute by which an AI system must be measured for its excellence and effectiveness. While seeking parsimony one should always bear in mind the impossibility of proving the consistency and completeness of any axiomatic system to which Gödel's theorems[43] apply, the limitations of the computing powers of a Universal Turing Machine,[44] the limitations imposed by the postulates of quantum mechanics[45] and that information is physical[46] and hence governed by the laws of physics.

I see AI at a juncture where physics was in the early 1900s when quantum mechanics burst on the scene. It put physics and our perception of Nature on an entirely different conceptual footing. Likewise, AI researchers must decide what we mean by intelligence and cognition and thus what it means to be human in an AI-driven world. Our survival will depend on how we integrate with AI-machines.

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[40] Best (2013).
[41] Lynley (2011).
[42] Chaitin (2003).
[43] Gödel (1931).
[44] Turing (1936).
[45] Nielsen & Chuang (2000).
[46] Landauer (1961).

5 Speciation of the *Homo sapiens*

A breakthrough in technology is assured when synthetic biology, AI, and quantum computing eventually integrate into creating new life forms through forced speciation that will likely lead to a superspecies, the humanoid. This will likely make the *Homo sapiens* extinct (all earlier species, *e.g.*, *H. habilis*, *H. erectus*, and *H. heidelbergensis* as well as the Neanderthals (*H. neanderthalensis*), the early form of *Homo sapiens* called Cro-Magnon, and the enigmatic *H. naledi* in the *Homo* genus are now believed to be extinct[47]) or domesticated by them (as the wolves were domesticated into dogs). This will completely overturn all predictions about the rate and directions of AI advances that are currently favored.[48] As I have noted recently

> We envisage a world where genetic engineering, artificial intelligence (AI), and quantum computing (QC) will coalesce to bring about a forced speciation of the *Homo sapiens*. A forced speciation will drastically reduce the emergence time for a new species to a few years compared to Nature's hundreds of millennia. … Accelerating speciation mediated by *Homo sapiens* via domestication, gene splicing, and gene drive mechanisms is now scientifically well understood. Synthetic biology can advance speciation far more rapidly using a combination of clustered regularly interspaced short palindromic repeats (CRISPR) technology, advanced computing technologies, and knowledge creation using AI. The day is perhaps not far off when *Homo sapiens* itself will initiate its own speciation once it advances synthetic biology to a level where it can safely modify the brain to temper emotion and enhance rational thinking as a means of competing against AI-embedded machines guided by quantum algorithms.[49]

The repercussions of forced speciation will be enormous. The role of natural humans and humanity's faith in spirituality if humanoids take charge will undergo a sea-change. Such a biological evolution of intelligent life, triggered by the *Homo sapiens*' curiosity-driven quest to understand the Universe within a rational, axiomatized framework will force humanity to reassess the meaning of life, its place and significance in the Universe, and above all its ability to merely survive, much less survive with dignity.

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[47] Encyclopaedia Britannica (2019).
[48] *See*, *e.g.*, Stone (2016).
[49] *See*, *e.g.*, Bera (2019).

Part II

Vulnerabilities of the patent system

6 A stressed out patent system

The entire U.S. patent system is stressed out and functioning with well-intentioned Band-Aids. The patent system needs to be redefined starting from what is a patentable invention, who qualifies as an inventor, what are the attributes of a PHOSITA with respect to a given patent under examination and correspondingly what should be the qualifications of a patent examiner. It is now clear that the judiciary should not be involved in any aspect of patent litigation until the validity of the patent-in-suit is established by an independent statutory body (we suggest a Patent Validation Board (PVB), see Section 10.1) whose decision will be final and binding on all. The patent law needs an overhaul given that a steady stream of inventions will now automatically flow from organizations even without incentives from its employees and AI-embedded machines. In the future, our primary source of inventions will be AI machines. Unlike the 18th century, the artisan inventor is longer the prized source of inventions around whom the patent system was built. The modern inventor is a STEM researcher, savvy in using information technology, is part of a funded research team with the goal of building a patent portfolio for a corporation that needs to stay competitive in the marketplace and to weaponize itself against IP litigation. Several past judicial decisions, e.g., those related to patentable subject matter and the doctrine of equivalents must be revisited, and all such matters should be decided by the PVB. We also note that the judiciary itself will undergo a radical change in its functioning when AI begins to invade its portals.

Much of the confusion and consequent opportunistic patent litigation that arises today is due to the three judicially created exceptions to the U.S. Patent Act's broad patent-eligibility principles: 'laws of nature, natural phenomena, and abstract ideas' whose scope and limitations remain unclear and confusingly dealt with in litigation. From our modern understanding of physics, mathematics, algorithms, computations, life sciences, and information we conclude that a rigid adherence to the exceptions to maintain *stare decisis* in jurisprudence is irrational. It is also anachronistic because the judiciary lacks the deep understanding of STEM, which post-1900 has undergone dramatic changes. Consequently, the patent system is wading in a quagmire of its own making. In particular, the judiciary errs in believing that the laws of nature are known to mankind and therefore they are "part of the storehouse of knowledge of all men" and "free to all men and reserved exclusively to none." In fact, no human knows what the real laws of nature are, and they will never know;[50] physicists "know" them only as conjectures which are open to refutation.[51] The laws of Nature constrain all men and all activities in the Universe.

6.1 Since Galileo—inventor and physicist

The modern patent system, in a sense, draws inspiration from Galileo Galilei (1564 – 1642), the father of modern physics, who in 1594, came up with an invention, a machine for raising water and irrigating land for which he sought a "privilege" (in modern parlance, a patent) on the condition that it had never before been thought of or made by others. In his petition he said, "it not being fit that this invention, which is my own, discovered by me with great labour and expense, be made the common property of

[50] Bera (2015).
[51] Popper (1963).

everyone." He added that if he were granted the privilege, "I shall the more attentively apply myself to new inventions for universal benefit."[52] His concern: the invention, once divulged, would be copied by others for free exploitation. He, therefore, wanted to reserve some benefits for himself as just compensation for his inventive efforts. The Venetian Council saw merit in Galileo's petition and granted him a "privilege" for 21 years. Since then, his reasoning pervades the patent system.

In 1623, the same Galileo wrote,

> Philosophy [*i.e.* physics] is written in this grand book, the universe, which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language and interpret the characters in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures, without which it is humanly impossible to understand a single word of it; without these, one is wandering around in a dark labyrinth.[53]

In 1637 René Descartes (1596 – 1650) published his masterwork, *Discourse on the Method of Reasoning Well and Seeking Truth in the Sciences.*[54] In that he unified geometry and algebra for the first time into what we now call coordinate geometry. Descartes invented coordinate geometry by assigning number-pairs to the points of plane Euclidean geometry, and proved geometrical theorems about points by proving algebraic theorems about numbers. Euclidean geometry was thus reduced to a branch of algebra. Its remarkable advantage was that one "could borrow all that was best both in geometrical analysis and in algebra, and correct all the defects of the one by help of the other." A few centuries later, computer graphics became possible with ease because geometric figures could be equivalently expressed in algebraic form and plotted on a computer screen pixel-by-pixel. Descartes, unintentionally, had enabled the future of modern computer graphics.

While Descartes was alive, in the year Galileo died, an intellectual colossus, Isaac Newton (1642 – 1727), was born, who put physics on a sound mathematical footing. His book *Philosophiæ Naturalis Principia Mathematica*[55] ("Mathematical Principles of Natural Philosophy"), first published in 1687, laid the foundations for classical mechanics. He also shares credit with Gottfried Leibniz for the development of calculus. For the first time, one could get a feel for the Universe in precise mathematical language that described the action of forces on matter and its motion rather than from divinity.

While Newton pinned down the mathematical description of the gravitational force acting between masses, James Clerk Maxwell (1831–1879) nearly two centuries later provided the mathematical description of the electromagnetic force[56] (1864). Newton's equations of motion and his law of gravitation complemented by Maxwell's equations of electromagnetism pretty much made up the *force* and *motion* knowledge required to deal with the engineering and technology of the time. During Maxwell's lifetime, the laws of thermodynamics were also discovered with a central role played by Léonard Sadi Carnot (1824)[57] and Rudolf Clausius (1850)[58]. In 1854, Lord Kelvin gave a definition of thermodynamics as follows:

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[52] Inkster (2006).
[53] Galileo (1623). The only modern scientist known by his first name.
[54] Descartes (1637).
[55] Newton (1687).
[56] Maxwell (1865).
[57] Carnot (1824). Carnot introduced the first modern definition of *work* as weight lifted through a height.
[58] Clausius (1850). Clausius defined the term *entropy* as the heat lost or turned into waste.

Thermo-dynamics is the subject of the relation of heat to forces acting between contiguous parts of bodies, and the relation of heat to electrical agency.[59]

The laws of thermodynamics establish fundamental mathematical relations between *work*, *energy*, and *temperature*, along with certain general constraints[60] that are common to all materials. In particular, it established the crucial notion of *entropy*, which essentially is a measure of the number of specific ways in which a thermodynamic system may be arranged. So, this is where the best of scientific knowledge, with precise mathematical descriptions, was when the industrial revolution (1760-1840) ushered in the industrial economy. The French Revolution began in 1789. Notable inventions made during the industrial era include: steam engine (James Watt, 1769; it became a major driver of the industrial revolution); sewing machine (Thomas Saint, 1790); vaccination (Edward Jenner, 1796); the telegraph (Samuel Morse, 1837); rubber vulcanization (Charles Goodyear, 1839); internal combustion engine (Jean Lenoir, 1858); typewriter (1860s); the telephone (Alexander Graham Bell, 1876); the electric bulb (Thomas Alva Edison, 1879); first practical automobile powered by an internal combustion engine (Karl Benz, 1885); AC motor and transformer (Nikola Tesla, 1888); first human-controlled, powered and sustained flight of a heavier-than-air airplane (Wright brothers, 1903); etc.[61] Gradually, the artisan was receding into the background and the STEM professional was coming to the fore. The industrial stage lasted only a few centuries and thus acted as a transitory phase before ushering in the post-industrial stage where we now stand.[62] The transition essentially reflected a fundamental change in the motive power driving economies – from brawn power augmented by industrial machines to brain power augmented by computing machines, and with it the source of innovation – from the artisan to the university educated knowledge professional.

6.2 Knowledge explosion since the 20th century

By 1900, scientific knowledge had advanced so much, or so it seemed, that Lord Kelvin (William Thomson, 1824-1907) told an assemblage of physicists at the British Association for the advancement of Science in 1900, "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement."[63] A similar statement is attributed to the American physicist Albert Michelson made in 1894, "The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote . . . Our future discoveries must be looked for in the sixth place of decimals.".[64] In 1895, Kelvin had confidently said, "heavier-than-air flying machines are impossible" (Australian Institute of Physics), and in 1896 he said, "I have not the smallest molecule of faith in aerial navigation other than ballooning...I would not care to be a member of the Aeronautical Society."[65] How wrong he would prove to be within a few years!

Almost immediately, starting 1900, some breathtaking advances in physics (quantum mechanics (1900-1926), and theory of relativity (1905, 1916)), heavier than air flying machines (Wright brothers, 1903), a deep understanding of mathematics (Gödel's theorem, 1931), mathematical algorithms and computing (the abstract Universal Turing Machine, 1936), the discovery of the structure of the genetic information carrying DNA molecule (the double helix, 1953), the microchip (1958), and men stepping

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59 Thomson (1854). In this paper, William Thomson (Lord Kelvin) first coined the term *thermo-dynamics*.
60 For example, it forbids the existence of a perpetual motion machine in Nature.
61 "In science credit goes to the man who convinces the world, not the man to whom the idea first occurs." (Francis Galton)
62 In comparison, the agricultural economy preceding it spanned about 12,000 years. *See*, *e.g.*, Bernstein (2004).
63 Cited from: Kelvin, Lord William Thomson (1824-1907). Wolfram Research. http://scienceworld.wolfram.com/biography/Kelvin.html
64 Cited from http://www.phy.davidson.edu/FacHome/thg/320_files/physics-is-dead.htm.
65 Quotes of Kelvin as they appear in: Kelvin, Lord William Thomson (1824-1907), Wolfram Research, http://scienceworld.wolfram.com/biography/Kelvin.html.

on the surface of the Moon and safely returning to Earth (1969) would be accomplished before 1970. This explosion of knowledge in STEM, and its application was phenomenal. By 1934, it had become clear to Karl Popper (and many scientists) that "The game of science is, in principle, without end. He who decides one day that scientific statements do not call for any further test, and that they can be regarded as finally verified, retires from the game."[66]

That game took a new turn in 1936 when Alan Turing, in trying to answer a deep mathematical question, described how one could mechanize the human act of computing. He essentially created an abstract mathematical model (the Universal Turing Machine, UTM) of a human-computer[67] (*e.g.*, a human trained to accurately follow instructions without applying his mind using an unlimited supply of paper, pencil, and erasure – a human robot). It is now well established that Turing machines, recursive functions, λ-definable functions, cellular automata, pointer machines, bouncing billiard balls, Conway's Game of Life, etc. are equivalent in terms of what they can and cannot compute. Thus, the set of computable problems does not depend on the computational model. The abstract UTM thus serves as a generic written description of all classical physical computers.

Then, Claude Shannon in 1948 lucidly provided a mathematical theory of information and connected it with physics (Shannon entropy) and discovered fundamental limits on signal processing operations such as data compression and the reliability of communicating and storing data.[68] In 1953, the remarkable discovery by James Watson and Francis Crick of the double-helix structure of cellular DNA (deoxyribonucleic acid)[69] and that the DNA molecule encodes within it all the genetic information needed to replicate itself[70] turned out to be the biggest discovery in biology since Darwin's theory of evolution (1859).[71] In 1961, Rolf Landauer complemented this with the deep insight that "information is physical" and provided the lower theoretical limit of energy consumption in computation.[72]

These path-breaking events in mid-20th century brought about a far greater understanding of nature in mathematical terms than ever before. "Now the language of information is pervasive in molecular biology—genes are linear sequences of bases (like letters of an alphabet) that carry information (like words) for the production of proteins (like sentences). The process of going from DNA sequences to proteins is described by words like "transcription" and "translation", and we talk of passing genetic "information" from one generation to another. It is rather uncanny that molecular biology can be understood by ignoring chemistry and treating the DNA as a computer program (with enough input data included) in stored memory residing in a computer (the cellular machinery). It is this aspect that bioinformatics exploits in deciphering the information carried by the DNA. It is analogous to viewing Euclidean geometry not in terms of drawings but in terms of algebra. In our current understanding, DNA is an informational polymer. It is a vast chemical information database that *inter alia* carries the complete set of instructions for making all the proteins a cell will ever need."[73]

Albert Lehninger lyrically put it: understanding the DNA is the study of "the molecular logic of the living state."[74] Indeed organisms are defined by the information encoded in their genomes. DNA is Nature's digital recording medium. Researchers are now close to anticipating and pre-empting

[66] Popper (1934).
[67] Turing (1936).
[68] Shannon (1948).
[69] Watson & Crick (1953a).
[70] Watson & Crick (1953b).
[71] Darwin (1859).
[72] Landauer (1991).
[73] See, e.g., Bera (2015b).
[74] Nelson & Cox (2006).

evolutionary events that left to themselves would perhaps take a few million years to occur, and even resurrecting extinct species.

The following quotes show the power of mathematics as a descriptive language.

1. "Mathematics is a language plus reasoning; it is like a language plus logic. Mathematics is a tool for reasoning. … [I]t is impossible to explain honestly the beauties of the laws of nature in a way that people can feel, without their having some deep understanding of mathematics."[75] (Richard Feynman)

2. "The Unreasonable Effectiveness of Mathematics in the Natural Sciences"[76]. (Eugene Wigner)

3. "Our reality isn't just described by mathematics – it is mathematics … Not just aspects of it, but all of it, including you." In other words, "our external physical reality is a mathematical structure".[77] (Max Tegmark)

Mathematicians did not create mathematics with the aim that one day physicists would find it useful. John von Neumann noted:

> A large part of mathematics which becomes useful developed with absolutely no desire to be useful, and in a situation where nobody could possibly know in what area it would become useful; and there were no general indications that it ever would be so. By and large it is uniformly true in mathematics that there is a time lapse between a mathematical discovery and the moment when it is useful ….[78]

Douglas Hofstadter, in a remarkable book,[79] showed how Gödel's theorem can be understood by analogy with Bach's musical compositions and Escher's paintings thereby showing that even those who revel in the arts can find tremendous beauty in mathematics. The modern computer scientist is not surprised. After all he encodes music and paintings in abstract binary strings (just as easily as he encodes mathematical algorithms) which a computer (using appropriate software and input-output hardware) decodes into music and painting at will.

One might thus conclude that the Universe itself is a computer ceaselessly performing mathematical calculations of the laws of nature. We have traversed far from when Galileo famously said that the universe is written in the language of mathematics to Max Tegmark saying that the universe IS mathematics. If Tegmark's conjecture is right (there is no convincing refutation of it yet), his thesis represents a paradigm shift in the relationship between physics and mathematics. *Ipso facto*, it fundamentally affects how we define patent-eligible subject matter; an invention's utility, novelty and non-obviousness; how an invention is described; and the expansive scope of the doctrine of equivalents in patent law.

The twentieth century began by dazzling us with aeroplanes, automobiles, and radio and ended with spaceships, computers, cell phones, the Internet, and genetic engineering.[80] In just a century they dramatically changed the industrial economy into a post-industrial economy that is global, heavily

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[75] Feynman (1965).
[76] Wigner (1960).
[77] Tegmark (2014).
[78] Neumann (1954).
[79] Hofstadter (1979).
[80] For a timeline of inventions, see, *e.g.*, http://inventors.about.com/od/timelines/a/twentieth.htm. *See also*: Olson (2015) and Cooke & Hilton (2015). "The past half-century has witnessed a dramatic increase in the scale and complexity of scientific research. The growing scale of science has been accompanied by a shift toward collaborative research". "The size of authoring teams has expanded as individual scientists, funders, and universities have sought to increase research productivity and investigate multifaceted problems by engaging more individuals. Most articles are now written by 6 to 10 individuals from more than one institution."

consumer-oriented, talent-hungry, knowledge-centered, dependent on a university-educated and globally-mobile workforce, and above all driven by innovation as never before.[81] In Fig. 2 (top left), we are at the knee of a curve, advancing at an exponential rate in developing new technologies, very much in line with Kurzweil's predictions. The STEM knowledge required to keep pace with this rate of advancement is beyond the intellectual capacity of most people armed with a PhD in STEM. The time to start reforming the patent system was when Neil Armstrong stepped on the surface of the Moon! We are half-a-century behind schedule.

6.3 Algorithmically designed biological inventions

In 1973, the pioneering work of Cohen and Boyer in recombinant DNA technology[82] gave birth to genetic engineering and the biotechnology industry. The related Cohen-Boyer patents (U.S. Patent Nos. 4,237,224; 4,468,464; and 4,740,470) that protected the technology played a stellar role in the rapid rise of the biotechnology industry.[83] The next landmark was the creation of a bacterial cell controlled by a chemically synthesized genome by Craig Venter and his group in 2010.[84] Then in 2014, Floyd Romesberg and colleagues[85] reported the creation of a semisynthetic organism with an expanded genetic alphabet. The new letters in the alphabet were artificially created nucleotides not found in Nature. Along with these breakthroughs, the great promise of CRISPR (clustered regularly interspaced short palindromic repeats), and in particular CRISPR-Cas9 gene editing technology pioneered by Feng Zhang[86], Emmanuelle Charpentier, and Jennifer Doudna[87] in 2012 as a new way of making precise, targeted changes to the genome of a cell or an organism has set the stage for major advances in synthetic biology. The achievable aim is to design and construct new biological parts, novel artificial biological pathways, organisms or devices and systems including the re-design of existing natural biological systems for useful purposes. Thus, the focus is on developing tools and methods that would enable researchers to encode, in artificially created or natural DNA, basic genetic functions in novel combinations by design. The aim is to artificially create biological systems of increasing size, complexity, and tailored functionality. Currently, synthesis capabilities far exceed design capabilities in the sense that we know how to build but not yet with clarity what to build.[88] Synthesis capabilities are developing at a pace where DNA synthesis can be automated, and the desired DNA produced once the sequence is provided to vendors.

Biologists now have tools for manipulating DNA in a manner similar to manipulating character strings in a text. For example, they can copy DNA fragments using the polymerase chain reaction (PCR) or clone it using a cloning vector; cut DNA using molecular scissors called restriction enzymes; join two complementary DNA strands into a double-stranded molecule in a process called hybridization; and measure the size of DNA fragments without sequencing them using a technique called gel-electrophoresis. This complex integration of biology and traditional engineering driven by information processing and computing technologies, and algorithm design is moving so rapidly that a couple of decades hence, researchers may begin producing synthetic organisms designed to produce not only pharmaceutical products but also industrial products such as biofuels on a commercial scale. Possible socio-economic benefits from synthetic biology research are thus enormous.

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[81] *See*, *e.g.*, Palmisano (2003). *See also*: Bera (2015a).
[82] Cohen, et al (1973).
[83] *See*, *e.g.*, Bera (2009, 2012).
[84] Gibson, et al (2010).
[85] Malyshev, et al (2014).
[86] Cong, *et al* (2013).
[87] Sharlach (2014).
[88] Prather (2010).

The CRISPR genome editing technology allows one to precisely insert DNA into a cell *in vivo* or snip out mutated DNA and replace it with the correct sequence. It thus offers possible means of treating many genetic disorders.[89] The key to success will lie in encoding and embedding mathematically structured and manipulated information in DNA strings and in interpreting it or activating it in a given chemical context. A 2012 book, *Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century*, from the National Academies explains how mathematics is fuelling innovation and discovery. It notes,

> The mathematical sciences are part of everyday life. Modern communication, transportation, science, engineering, technology, medicine, manufacturing, security, and finance all depend on the mathematical sciences. Fueling Innovation and Discovery describes recent advances in the mathematical sciences and advances enabled by mathematical sciences research. It is geared toward general readers who would like to know more about ongoing advances in the mathematical sciences and how these advances are changing our understanding of the world, creating new technologies, and transforming industries.[90]

Creating public awareness about mathematical sciences in the post-industrial economy is now a critically felt need. It is widely believed that the twenty-first century belongs to advances in life sciences. The century has already begun creatively by creating and editing novel and non-obvious DNA sequences which speak for and describe themselves in a language that those skilled in the art understand with precision, as to the invention the sequences stand for. These are self-describing inventions just as mathematical algorithms are when interpreted in a well-defined context.

6.4 Molecular biology is mathematical

We define the information content of an object as the size of the set of instructions that we need to be able to reconstruct the object, or better, the state of the object. Implicit here is that information can be encoded in physical systems. Indeed, without a physical device we cannot store, transmit, process, or receive information. Moreover, the laws of physics dictate the properties of these devices and therefore they limit our capabilities for information processing. Hence, it is clear that information theory cannot be a purely mathematical concept but that the laws of physics dictate the properties of its basic units. This rather obvious fact became obvious to information theorists only in 1961 with the publication of a landmark paper by Rolf Landauer,[91] who realizing that physical devices are needed to encode information, showed that there is a fundamental asymmetry in the way Nature allows us to process information. In fact, he proved the surprising result that all but one operation required in computation could be performed in a reversible manner. For example, copying classical information can be done reversibly and without wasting any energy, but when information is erased there is a minimum energy cost involved per classical bit to be paid. That is, the erasure of information is inevitably accompanied by the generation of heat (i.e., there is friction and resistance and creation of randomness). Indeed, Landauer's principle provides a bridge between information theory and physics via thermodynamics. That insight has brought about a sea-change in the way we look at information and computation as the following quote from the quantum physicist David Deutsch shows:

> The theory of computation has traditionally been studied almost entirely in the abstract, as a topic in pure mathematics. This is to miss the point of it. Computers are physical objects, and computations are physical processes. What computers can or cannot compute is determined by the laws of physics alone, and not by pure mathematics. One of the most important concepts of the

[89] Yin, *et al* (2014).
[90] NRC (2012).
[91] Landauer (1961, 1991).

theory of computation is *universality*. A *universal computer* is usually defined as an abstract machine that can mimic the computations of any other abstract machine in a certain well-defined class. However, the significance of universality lies in the fact that universal computers, or at least good approximations to them, can actually be built, and can be used to compute not just each other's but the behaviour of interesting physical and abstract entities.[92]

Modern biologists view the DNA (deoxyribonucleic acid) as a string of encoded information, something in the nature of a long tape containing both program and data for a Universal Turing Machine. The DNA's interaction with the rest of the cell's machinery is nothing but a series of computational steps. Not surprisingly, bioinformatics as a discipline has so many computer scientists in its ranks, many of them holding joint academic appointments in the departments of biology and of computer science.

Molecular-biology-rooted biotechnology inventions are expected to dominate 21st century commerce because of biotechnology's tremendous potential to contribute to human health, food security, and the environment in which humans live. These inventions are clearly patentable subject matter. All players involved in creating and commercialising this knowledge-and-capital intensive emerging technology are obviously deeply interested in knowing how they would gain or lose from the intellectual property (IP) system in place and whether that system needs to be changed, replaced, or abolished from their respective perspective.[93] The patent system must address their concerns in a comprehensive way as to subject matter eligibility in patent law. [94]

7 Quantum physics

Quantum mechanics, the most successful branch of scientific knowledge, deals with the world inhabited by photons, electrons, protons, atoms, molecules, *etc*. and how they interact among themselves to create larger matter entities in terms of chemical bonds of various strengths. It does so using the abstract language of mathematics and it is only in that language that we understand it.

> Quantum mechanics is an immensely successful theory. Not only have all its predictions been experimentally confirmed to an unprecedented level of accuracy, allowing for a detailed understanding of the atomic and subatomic aspects of matter; the theory also lies at the heart of many of the technological advances shaping modern society – not least the transistor and therefore all of the electronic equipment that surrounds us.[95]

Quantum mechanics is expected to play an important role in synthetic biology, inter alia, in understanding the myriad chemical reactions that take place inside a cell and the chemical means a cell uses in information transfer within itself and the external world. The patent system is not geared to deal with a flood of quantum mechanics-based inventions.

We now have reasons to believe that these "biological" computations are not completely based on classical logic but also on quantum logic. It turns out that quantum computers can do what classical computers do plus some more[96]. The surprises and breakthroughs will most likely come from the exclusively quantum part of the logic. It is a realm of logic where our normal human reasoning fails. It is a branch of knowledge, which is understood with difficulty even by the experts in the field! No one has yet claimed to have developed any intuition for it. The new fields of quantum computing and quantum information have already accumulated some breathtaking results in teleportation,

[92] Deutsch (1998), p. 98.
[93] Bera (2015b).
[94] See, e.g., Bera (2016), Bera (2015c), and Bera (2015).
[95] Zinkernagel (2015). Zinkernagel (2016).
[96] Nielsen & Chuang (2000).

encryption and code breaking, parallel computing, etc. What disruptive technologies they will spawn are difficult to foretell. That there will be more stunning results coming out of quantum mechanics with technological implications seems obvious. That it will eventually encompass biology, as it did astronomy some decades ago, appears inevitable. Interestingly, the abstract mathematical representation of quantum mechanics captures several interpretations of the Universe.[97]

8 Confluence of AI, synthetic biology, and quantum computing

Patent systems around the world were designed to deal with inventions created in siloed disciplines. Thus there are mechanical, electrical, chemical, biological, etc. inventions dealt by patent examiners specialized in these disciplines. Today, the most interesting examples come from teams that juxtapose concepts from multiple disciplines and the most advanced teams include elements of AI into their work. Their inventions are more easily understood in conceptual terms which emphasize an invention's functionalities rather than in terms of their physical representation. This is increasingly true where the functionalities are carried out by embedded computer chips running algorithms to provide functionalities. When abstract concepts are captured in mathematics, mathematics is captured in software, and software is hardwired in computer chips or some other material form, how the invention is captured becomes irrelevant because the forms are interchangeable. Abstract concepts and their material representation are two sides of the same coin; they define each other. If one side is patentable, then the other side must be too. Abstraction cannot be treated differently from material representation. Further, by invoking the doctrine of equivalents a vast number of inventions can be nullified, e.g., by citing an old, outdated patent and tying it to an abstract concept to claim that the concept covers all conceivable form of its material representation and hence any later patent that can be tied to that concept either belongs to prior art or is infringing a prior patent. Is this ridiculous? No, because future AI machines can make this claim using a human intermediary! The relationship between a PHOSITA and prior art is that a PHOSITA can always improve his knowledge and application of that knowledge by making a diligent study of the prior art. A human PHOSITA in today's competitive world should be assumed to be a person who is alert, inquisitive, and willing to imbibe the prior art if called upon to do so in solving a problem. In an increasing number of situations, AI machines are being programmed to do so; the AI machine is the PHOSITA.

Thus, we are forced to redefine what is patentable subject matter, the relevance of granting patents to human inventors, the criteria to be used to define the legally enforceable boundary of a patent to detect infringement, and above all who is a PHOSITA. Without knowing who the PHOSITA is related to a patent application, it is no longer possible to even decide if the patent applicant is an inventor.

8.1 Knowledge integration by concepts

Computing technology has now advanced to a stage where quantum computers can mimic a Universal Turing Machine (UTM) and beyond. A quantum computer's phenomenal computing power comes from the extraordinary laws of quantum mechanics that include such esoteric concepts as superposition of quantum states, entanglement ('spooky action at a distance' as Albert Einstein once quipped) and tunneling through insulating walls, which though highly counter-intuitive, play extremely useful roles in understanding Nature at sub-atomic levels. It appears that these concepts cannot be ignored in biology and living processes in the way they are ignored, say, in the design of cars and airplanes. There are areas in biology where quantum effects have been found, *e.g.*, in protein–pigment (or ligand) complex systems.[98] Thus, while the role of quantum mechanics is clear in

[97] *See*, *e.g.*, Bera & Menon (2009).
[98] Brookes(2017).

quantum computing and hence in advancing both AI and synthetic biology research, it is not yet known if in the design of DNA, knowledge of quantum mechanics is required or that natural selection favors quantum-optimized processes. Essentially, we do not know if any cellular DNA maintains or can maintain sustained entangled quantum states between different parts of the DNA (even if it involves only atoms in a nucleotide). But we cannot rule out the possibility that sporadic random entanglements do occur that result in biological mutations or that researchers will not be able to achieve it in the laboratory and find novel uses for it in synthetic biology.[99] For example, in principle, it is possible to design molecular quantum computers, insert them in cells that can observe cellular activity and activate select chemical pathways in the cell in a programmed manner. There is increasing speculation that some brain activity, *e.g.*, cognition, may be quantum mechanical.[100]

The role of computer simulation in developing modern inventions is barely understood by patent examiners, mainly because it rests on mathematics, its digitization for calculation, and inspired interpretation of mathematical models in different branches of science, engineering and technology.

The fundamental role of mathematical simulation is to capture the abstract essence of algorithmic changes that define a system's dynamics or structure without attaching meanings to it. In mathematics symbols have no meaning other than those implied by their relationships to one another. It therefore lends itself to automation via the isomorphism shown in Table 1. It is the most powerful means by which we generalize, that is, we identify the parts of a whole, as belonging to a much larger whole at a conceptual level. This means that the expansive use of the doctrine of equivalents from the standpoint of concepts can create havoc by (1) allowing a patentee to claim an ever-expanding scope for his claims, and (2) an alleged infringer to counterclaim that the patent in suit is invalid because it belongs to the prior art as it falls into the expanded scope of one or more earlier patents that fall in the same conceptual category. Conceptual bases is what well-qualified STEM researchers routinely use in simulation, e.g., studying mechanical systems by studying their exact analogous electrical systems because they share a common mathematical model. Since mathematics is mechanizable (Turing 1937)[101], and AI wholly depends on mathematics and computers to execute it without any application of the mind, the doctrine of equivalents by itself would be enough to completely demolish the patent system of any country.

Table 1 Isomorphism between formal and computational systems

Formal system	**Computational system**
Axioms	Program input or initial state
Rules of inference	Program interpreter
Theorem(s)	Program output
Derivation	Computation

Ref: Lewis, J. P., Large limits to software estimation, ACM Software Engineering Notes, Vol. 26, No. 4, July 2001, pp. 54-59.

8.2 Integrating the triad: mechanization of speciation

A combination of emerging technologies such as clustered regularly interspaced short palindromic repeats (CRISPR), artificial intelligence (AI), and quantum computing (QC); new delivery models for products and services that form the core around which *Homo sapiens* organize themselves through

[99] Brooks (2015).
[100] Fisher (2015).
[101] Turing (1936).

collaborative division of labor; and talent migration, driven not by rote education but by innate creativity and global opportunities for employment open to them, is disrupting and changing the character of the global talent pool that society needs today. Globalization has created opportunities for the talented to reach for the skies but in a resource constrained world it also means that many others must be or feel deprived.[102]

This social dynamics is captured very well in terms of a remarkable result in graph theory[103] and the logistic map in chaos theory[104] because the related mathematical models are equally valid for both animate and inanimate systems. The models show that in a resource constrained world very rapid progress provides ample scope for swift and fluctuating adversarial social dynamics to occur in which some turn predators and others become preys depending on current circumstance. Globalization has accentuated the problem at all levels of social structure, and since speciation is triggered by a changing environment, it affects the DNA. This has imposed survivability demands on the *Homo sapiens*.

As this pressure mounts beyond endurance, *Homo sapiens* will face speciation by natural selection with uncertain outcomes. However, in the case of *Homo sapiens* in their present state of STEM knowledge, this process too may face a disruptive change because the highly intelligent among them may boldly initiate speciation using upcoming advances in synthetic biology, perhaps after perfecting their techniques by creating humanoids (a hybrid creation of life with embedded intelligent machinery). This will be a watershed event where a species takes on the task of speciation on itself.

This remarkable possibility arises because *Homo sapiens* created and mastered mathematics, rational thought, computing machinery, and eventually deep data analytics so that life could be designed by them in the laboratory to create superior species. This will also permit us, at all levels of the hierarchy of biological structures (molecules, cells, tissues and organisms), to redesign existing natural biological systems and may even help us recreate certain extinct species (if we can also recreate the environment they had adapted to). It is not surprising that an extinct species has never revived itself since speciation and environment go together. Successes of synthetic biology will change the face of human civilization and almost certainly bring in new elements into play when *Homo sapiens* eventually speciate by playing an active role in it. The present patent system cannot control inventions arising from this development.

Since the discovery of the double helix structure of cellular DNA by James Watson and Francis Crick in 1953[105] and its significance that the "precise sequence of the bases is the *code* which carries the genetical *information* …" (emphasis added)[106], the jargon and theory of information has invaded molecular biology. This enriched biotechnology and computational biology with nomenclature, definitions, concepts and meanings, which facilitates integration of synthetic biology with AI and QC. DNA is an information carrying polymer. It is an organized chemical information database that *inter alia* carries the complete set of instructions for making all the proteins a cell will ever need.[107]

DNA synthesis services are now commercially available. The time is ripe for the wholesale integration of synthetic biology with AI via mathematics to enable seamless communication among them, connect with and discover conceptual similarities for consistent integration of subsystems and validation of the whole system. The added benefit is that it can be used to also communicate between humans and

[102] Bera (2019).
[103] Erdős & Rényi (1960).
[104] May (1976).
[105] Watson & Crick (1953a).
[106] Watson & Crick (1953b).
[107] For a more elaborate explanation see, e.g., Bera (2019).

machines. It is fortuitous that the DNA serves as the "Book of Life" that appears to have structure and grammar amenable to translation into mathematics. Once translated, biologists will discover some amazing patterns that have a direct bearing on life at the molecular level.

9 When machines invent, are patents relevant?

Patent law allows useful, novel, non-obvious, and well-articulated inventions to be patented subject to certain other statutory requirements being fulfilled, *i.e.*, the inventor is given a limited period property-like monopoly ownership of the invention. The principal feature of this ownership is the statutory right to sue those who infringe the patent, but not necessarily the right to practice the invention. The heart of any patent is its set of claims which delineate the boundary of the protected territory of the invention's novel and non-obvious aspects with respect to the related technological prior art as statutorily defined. Claims are required to fulfil two important functions: (1) to give notice to the examiner at the U.S. Patent and Trademark Office (USPTO) during prosecution as to what is being claimed for limited period monopoly privileges, and (2) to the public at large, including potential competitors, after the patent has issued, what is not to be infringed during the term of the patent. Once the patent expires, it is dedicated to the public.

The Supreme Court of the United States (SCOTUS) has held that claims define the scope of patent protection: "[T]he claims made in the patent are the sole measure of the grant …"[108]. The courts also hold that 'subject matter disclosed but not claimed in a patent application is dedicated to the public'.[109] In reality, most patent claims, due to inadequacies of natural languages in which they are written, and inadvertent omissions and inclusions during drafting become prone to contentious ambiguity as to the scope of the claims. Later, if the patent's validity is contested, failure to establish the boundary would make the claim at issue unpatentable, invalid, and unenforceable under the doctrine of indefiniteness.[110] While literal infringement of a patent is usually obvious and easily dealt with, the grant of a patent also gives the invention additional protection from the judicially created doctrine of equivalents which serves to expand patent protection beyond the literal language of the claim. That is,

> A patentee may invoke this doctrine to proceed against the producer of a device "if it performs substantially the same function in substantially the same way to obtain the same result."[111]

This immediately raises two questions: (1) "What if a device performs substantially the same function in a substantially different way to obtain the same result?" And, (2), "What happens, if during patent prosecution, the inventor surrenders or dilutes some of his claims, can he reclaim them once the patent is granted under the doctrine of equivalents?" Mathematicians resolve such complex issues by ensuring that their language does not allow such ambiguities to occur in the first place. We shall see that this fact has major implications in the development of AI and its introduction in any discipline of knowledge. Presently courts deal with such questions in ambiguous and highly unsatisfactory and tortuous ways, e.g., the reverse doctrine of equivalents[112] to deal with the first question and prosecution history estoppel[113] to deal with the second. The fact is that the manner and the language in which claims are written compounded by the fact that judges are not trained in STEM precludes a satisfactory solution to be ever developed. The most damaging aspect of the situation is that the

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[108] SCOTUS (1961)
[109] See*, e.g.*, CAFC (2002).
[110] SCOTUS (2014).
[111] SCOTUS (1950).
[112] SCOTUS (1950).
[113] SCOTUS (2002).

doctrine of equivalents de facto redefines the scope of the claims and ignores the public's right to know in advance the precise legal limits of patent protection without recourse to judicial ruling. By redefining the scope, moving boundaries of ownership get created where knowing what was and who infringed becomes unusually complicated to the extent that chaos may prevail making a judicial decision impossible. The SCOTUS, if it anticipates such a situation, can, of course, wriggle out by not hearing the case at all without assigning any reason! In many other cases, either ignorance or uninformed heroism leads judges to resort to Markman hearing[114] where the interpretation of claims are handled by the judge while questions of validity are handled by the jury. Unfortunately, both lack the STEM expertise required for their respective jobs. These tasks really belong to the Patent Validation Board (see Section 10.1).

Any mathematician would see that the questions are ill-posed in the patent system in which it is raised. The problem is with the language in which the Patent Act and patent applications are written. The present style and legalese used in claim writing hinders the smooth flow of thoughts. It needs a change. Just as arithmetic (indeed any branch of mathematics) cannot be done comfortably using Roman numerals, mathematicians came up with Arabic numerals and augmented it with other symbols and a set of precise, formal rules for manipulating those symbols to produce permissible words, sentences, etc. so that there is no ambiguity about the legitimacy of the mathematical structures that are built and the way or the multiple ways they are understood. The U.S. courts have further vitiated the already troubled waters by functioning both as courts of law and courts of equity. Oil and water don't mix well.

Further, the patent system failed to note what Harding had already observed in 1941:

> Originally industry relied on the chance discoveries of gifted individuals working at random, their choice of problems being guided by their interests, backgrounds, abilities and the prospect they saw of making a profit from their activities. Modern research is planned to fit specific needs. A large element of unpredictability and discovery and in the value of discoveries in monetary terms, can no longer be permitted. [The so-called discovery and invention of serendipity.] In the 20th century industry saw that it could no longer rely on random discoveries and it turned to the accumulation of new knowledge. The science of invention was perfected and research discoveries were largely tailored to specific business or industrial requirements.[115]

The need for and reliance on patents has dramatically changed over time. In such circumstances, a court of law must tread with caution when injecting issues related to equity in its judgements. For example, unclaimed subject matter in patent claims should strictly be considered as dedicated to the public and not surreptitiously reclaimed under the doctrine of equivalents or equity considerations.

As STEM knowledge advances, it increases the possibility that certain inventions are quite likely to sprout spontaneously and hence such inventions, if patented, only hinders the public's access to such inventions. The essence of the patent system is to strike a balance between private incentives and protection of public interest, not indiscriminate distribution of private incentives. It is therefore necessary to assess if the invention may have arisen without the incentives.

All these issues become irrelevant when an AI machine invents. In reality, an AI machine does not invent, it merely reproduces "theorems" in a mechanized way that are implicit in the axiomatic system that is programmed into it or it becomes a means of generating axiomatic systems. All inventions (theorems) produced using AI reside in an abstract world from which innumerable specific instances

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[114] SCOTUS (1996).
[115] Harding (1941).

to satisfy present patent acts in the world can be created. This means the PHOSITA has no place in an AI-driven world. Any AI machine is a PHOSITA and an inventor. AI-machines can churn out inventions on demand and spontaneously.

> The way in which the building blocks of a body of thought are designated profoundly affects the development of that discipline. — H. C. von Baeyer, a noted physicist.

AI is now at a stage where it influences the way we solve problems, especially, how we solve problems rationally. Logic is the foundation of rational human thought. It deals with the terms "and", "or", "not", "if", "then". Reasoning (or propositional calculus) is built around our notions of the correct usage of the words *if* ... *then* ... (or *implies*), *or*, *and*, *not*. It has a vocabulary, rules that tell us how to construct correctly formatted statements, and inference rules for deriving new statements from a given set of correctly formatted statements. The inference rules are chosen such that if the statements in a given set represent true statements, then subsequently derived statements will also represent true statements.

Logic underpins mathematics, and the natural sciences, especially, physics. The great advances in mathematics and the sciences were made possible because mathematicians, in particular, meticulously developed a symbolic system to express their concepts, axioms, theorems, and proofs. When physicists adopted mathematics as their lingua franca, it began to advance rapidly, as have chemistry, biology, and engineering since. With the publication of Isaac Newton's *Philosophiae Naturalis Principia Mathematica* in 1686, scientists and later engineers have gone from strength to strength using the power of mathematics. Jurisprudence, although founded on logic, took a different route; it continued to rely on natural languages (with its built-in ambiguities) for communication. Thus, courts cannot always interpret the law literally but must try to divine the intent behind the law. Literalist interpreters see it as subverting the statutes. When ambiguity rules, decisions end up as 5-4, leaving a feeling that it may well have been decided by tossing a coin. In interpreting mathematical rules or laws of nature, intent is irrelevant.

Modern technologies have deep roots in science, and science has deep roots in mathematics. The immense power of AI, tapped and untapped, lies in the expressive power of mathematics and the computing power of computers which has yet to reach its limits. Language powers intelligence.

So there are unavoidable impediments in interpreting patent law. As Benjamin Whorf said, "Language shapes the way we think, and determines what we can think about." And Ludwig Wittgenstein noted, "The limits of my language mean the limits of my world."[116] Nevertheless, the law requires that it must be clear from the written description that the applicant was indeed in possession of the claimed invention at the time of filing but it does not provide unambiguous means to assert what exactly is being claimed.

9.1 Fundamental tests of patentability

The base reference for measuring human ingenuity is obviously a world in which no humans exist. Therefore the very first test of patentable subject matter is: Could the invention under consideration possibly have occurred or likely to occur in our planet in the absence of intelligent and thinking humans? (*Yes means not patentable.*) For example, it is inconceivable that a modern jetliner could have ever occurred in the absence of intelligent and thinking humans. The second test is: If the invention could occur in the future in our planet devoid of humans, would the presence of intelligent and thinking humans accelerate the process of bringing forth that invention not by their mere

[116] The original statement was in German ("Die Grenzen meiner Sprache bedeuten die Grenzen meiner Welt.")

presence but by observation, analysis, and deliberate human intervention. (*No means not patentable.*) The third test is that if the problem the invention solves was posed to other humans would several of them (in a statistical sense) have come up with the invention or a similar invention or a superior invention, say, within a specified 'short' period of each other. (*Yes means not patentable.*) Finally, if a computer, such as IBM's *Watson*, was given the task of solving the problem, would it solve the problem in a few years. (*Yes means not patentable.*) Note that a mathematical solution to the problem is a valid solution. An algorithmic solution is, by definition, implementable on a Universal Turing Machine (UTM) and hence on a sufficiently powerful physical computer. The invention is not patentable if the answer is *not patentable* to any of the four questions.

It is a genetically coded property of the human mind that when it is inquisitive about the material world, it frames, tests, and revises hypotheses (conjectures and refutations) about patterns and correlations that fit what it observes and the knowledge and information it possesses about the world. When it finds satisfactory patterns or correlations, whether deterministic or statistical, it may use them to solve problems. When the solution leads to a material product, or a process or a correlation that can be executed or determined that includes using non-mental tools or machinery and which necessarily requires in some part human ingenuity then that product or process or correlation is patent eligible subject matter provided its patenting does not unreasonably interfere with or discourage developments or the further spread of useful knowledge itself (the constitutional requirement). This is a subjective decision to be generally decided by majority voting by a statutory body comprising members from the patent office, the national science academies, and other eminent STEM experts, since a bright line rule cannot be formulated. This statutory body therefore will have the enormous moral responsibility of deciding when the grant of a patent to a given invention would adversely affect the society at large based on parameters that cannot be objectively quantified. That is, this august body must deal with "the difficulty of drawing a line between the things which are worth to the public the embarrassment of an exclusive patent, and those which are not"[117]. Then and only then should the grant of a patent be decided on the basis of the patent act. It is at this stage that the USPTO has the great responsibility of ensuring that it does not grant overbroad and indefinite claims, which once admitted, would invite litigation.

9.2 The superfluous PHOSITA

When dealing with the doctrine of equivalents, it is a fallacy to bring in the PHOSITA into the analysis for infringement. Those who want to circumvent a valid patent and succeed must be deemed to be superior to a PHOSITA and in the class of inventors capable of conjuring patentable inventions. If a patent-in-suit is valid it is an advancement in technology by definition. Therefore circumscribing it would likely require another advancement. This is where modern researchers well-versed in mathematics are likely intermediaries who can find equivalents based on conceptual similarities rather than in terms of physical similarities. In engineering this is called computer simulation where, say, mechanical artefacts can be analyzed in digital simulation based entirely on mathematical calculations and reinterpreted into an equivalent electrical artefact which is another discipline in engineering. With 3D manufacturing and CAD/CAM technologies easily available and continuously advancing with embedded AI, an extremely wide range of granted patents may be assiduously converted into equivalent non-inventions, more-or-less, in a mechanizable way. No judiciary in the world has enough knowledge to deal with this situation, nor does any patent office in the world.

Although Albert Einstein failed in his quest to find a theory of everything, it does not follow that an AI machine will not find or make considerable advances toward it. Once it does, then a conceptual

[117] Jefferson (1813).

solution to a problem would more-or-less amount to finding equivalent solutions in a wide-range of engineering disciplines. We are approaching this stage rather rapidly, going by Kurzweil's forecast.

9.3 Drafting of patent applications

All patent systems around the world suffer from serious debilities. The first and foremost is its gross inability to move away from archaic legalese in drafting patent applications to describe an invention. It has shown no sign of rectifying this. This anachronistic system bears comparison with arithmetic which very sensibly switched over from using Roman numerals to Arabic numerals. Without the switch, human civilization would still be in the preindustrial era. With Roman numerals, even adding a grocery bill is an onerous and frustrating task. The primacy of language seems to have escaped the notice of the IP community in granting patents and in adjudicating disputes related to them.

A defining feature of a sophisticated society is how it communicates with humans, machines, and institutions. That is how humans control and coordinate strategy. But the relationship between language and power in intricate. Thoughts get communicated through language (speech, script, and sign) and emotion (body language). Thus, whoever speaks depends on language, but ultimately the power of language lies not with the speaker but with language itself.[118] Anyone can acquire the power of language, even AI machines.

The frustrating aspect of legalese in the patent system is that even judges must resort to Markman hearings (a common practice since the U.S. Supreme Court, in the 1996 case of *Markman v. Westview Instruments, Inc.*, 517 U.S. 370 (1996)) so that the patent can be understood in plainer English. One can imagine the fate of the jury (comprising mostly of ordinary people with very little or no education in STEM). That such a jury should even be involved in deciding the fate of inventions involving cutting edge technologies in patent trials is irrational. That both judge and jury are ignorant of STEM makes the entire set-up a mockery of rational reasoning. It provides ample opportunities for patent lawyers to game the system in a reckless manner.

The overhaul of the patent system must begin at its very foundations. While doing so one must bear in mind that AI-machines are already discovering novel and non-obvious inventions that do not belong to the prior art. Google's alpha-Go is a harbinger of such events occurring more frequently in the future. The AI-machine as a prolific source of inventions is no longer a fond dream but a reality so extraordinary that every AI-machine can be viewed as a PHOSITA that far surpasses highly intelligent *Homo sapiens*. The collapse of the patent system is near.

A deep question arise. If a machine reinvents and without conscious thought becomes instrumental in commercializing a patented invention during its term, taking directions from software (essentially mathematical algorithms), unsupervised by humans, does it qualify as infringement or should the patented invention be annulled on the grounds that machine implementable prior art existed which was overlooked by overworked patent examiners. If inventions can sprout from machines for the asking, then what and where is the need to protect, celebrate, and sanctify the rare individual who once in a while measures up to the inventive capability of a machine in terms of ingenuity, novelty, non-obviousness? Further, a fully documented disclosure of the invention always resides in the machine when the invention is in use which it can also share with other machines and human experts. Indeed, at any time we may not even know if it has already disclosed the invention to other machines and so has placed it in the public domain.

[118] Weiß & Schwietring (2018). See also: Bera (2018).

In Section 6 it was noted that the judiciary erred in the past when it declared that the "Laws of Nature" as discovered by humans are unpatentable because they are common property of all mankind.[119] However, it is prudent to deny patents to such conjectured "Laws of Nature" because otherwise the inventor will gain excessive monopoly rights that can be coercively used to stifle others from inventing further during the term of the patent. James Watt[120] and Rifkin[121] are notable examples of such actions, while the Cohen-Boyer patent is not.[122] The emerging situation is that AI machines work only according to the unknown laws of Nature that appear to be mathematically encodable in abstract form. The machines do not use any intelligence in the process; they only follow instructions. Under patent law, such machines cannot even apply for a patent since they are not humans. Thus all machine created inventions must automatically fall into the public domain unless protected as trade secrets.

We must also recognize that AI-driven, 3D printers and personal robots producing goods and services on demand in a customized manner will soon become ubiquitous in homes. Such machines can hardly be declared as infringing an active patent. Punitive action against hundreds of millions is impossible. Self-learning AI machines are advancing their ability to solve problems and invent based purely on mechanized implementation of conjectures programmed into them. In fact, they can even be programmed to make conjectures of their own. Eventually, the *Homo sapiens* will no longer be looking for a better patent system because they would be speciating themselves into extinction, possibly within a century. There is a new successor species waiting in the wings to displace us.

10 Recommendations for the immediate future

In the interim, while society is reorganizing itself to cope with AI, the courts should carefully consider the embarrassment of creating a judicial exception when deciding a patent case. A pragmatic two stage process would be to ask: (1) Is the invention patentable under the statutes? And in the process, pointing out anomalies in the statutes if a reasoned conclusion cannot be drawn. (2) If the invention is patentable, should it be denied a patent because it would be an "embarrassment" to society in its present state and rate of evolution or should it be granted a patent with obligatory social conditions (decided on a case-by-case basis) attached in consultation with the patentee? This question should be answered by a separate statutory body, e.g., PVB, and the answer should not be contestable in a court or any other forum.

The following should be taken into account when considering patent grant:

1. *Human ingenuity* criterion. The patent application must describe an invention that required human ingenuity for its creation, without which it is extremely unlikely that the invention would have occurred or might occur at some distant time in the future or occur spontaneously over which humans have no direct or indirect control on planet Earth.

2. *Quid pro quo* criterion. Establish a clearer equitable *quid pro quo* criterion for patent grant. This should be the first barrier a patent application must cross before provisions of the patent

[119] Bera (2016); Bera (2015c).
[120] Ashton (1955). James Watt deliberately refused to license certain steam engine related patents held by him to prevent others from bringing improvements into the market and compete against him. He actively discouraged use of steam at high pressure even though it was not covered by his patents. The authority he wielded at the time was sufficient to clog engineering enterprise for more than a generation.
[121] Heathcotte & Robert (2006). Stuart Newman and Jeremy Rifkin unsuccessfully sought a US patent in which they claimed a method for combining human and animal embryo cells to produce a single embryo, which could then be implanted in a human or animal surrogate mother, resulting in the birth of a "chimera". Their unusual objective was to secure the patent and then restrict the application of this technology for the life of the patent, during which they hoped to foster a social debate about moral boundaries in relation to biotechnology patents.
[122] Cohen, et al (1973). See also: Bera (2009) for the story of the magnanimity with which the patents were licensed.

act are applied. An invention is patent ineligible if it fails to meet an established *quid pro quo* criterion for patent grant. Any equitable criterion must bear in mind its effect on public health and safety, effect on human skill development, the functioning of global commerce, the freedom to practice technology and service standards, etc. The *quid pro quo* criterion must necessarily be a statistical criterion according to which some benefit, some do not, some are agnostic, and some are antagonistic, and it must be a dynamic criterion that is periodically reviewed in the “best interest” of humankind.

3. *Unenforceability* criterion. If a claimed element of a patented invention, in principle, can be performed wholly in the mind by any person, and this fact is known prior to patent grant, then the claim should not be allowed. If post-grant, it becomes known at any time that a claimed element of a patented invention can be performed wholly in the mind by a person, then the claim cannot thenceforth be infringed by any act that would otherwise have been considered infringing. For example, diagnostic tests may be patentable but not the mental diagnosis by a physician or anyone else or a similar diagnosis made by any other means. Since it is not possible to control peoples’ thoughts, infringement of such claims cannot be controlled without violating a person’s natural right to free thought. In this respect the patent is unenforceable.

4. *Scientific discovery and algorithm* criterion. Laws of nature are universally pervasive. These are Nature’s prohibitory laws in that they will not allow any activity or creation that violate the laws. These laws primarily deal with matter; energy; space; time; motion; forces; transformations of matter and energy; and detection of natural phenomena by observers, sensors and detectors. They govern all human activity, including creating patentable inventions. Discovery of natural laws requires human ingenuity. However, humans can only know these laws not in their exact form but as guesses by making conjectures and refining them through diligent refutation of what has been discovered earlier. For this reason, discovery of a conjectured law of nature is patent eligible subject matter. Since laws of nature, as far as physicists can determine, are expressible in mathematical form (Tegmark), mathematical algorithms, whether known or newly discovered, when specifically interpreted (*i.e.*, given a specific meaning) by relating them to elements that constitute the universe or processes believed to be permitted to occur in the universe, are also patent eligible subject matter. A mathematical algorithm without an accompanying specific interpretation that connects it to the real world is not patentable subject matter for lack of utility. Interpretations not categorically claimed in a patent cannot be claimed under the doctrine of equivalents in patent enforcement.

10.1 Patent validation board

The legal validity of a granted patent’s claims, if challenged, should not be decided by the courts but by an independent statutory body, which we here call the *Patent Validation Board*. The Board’s decision shall not be contested in a court of law unless there is clear evidence of corrupt practices indulged by the Board that could have impacted the decision. On such evidence, the court shall have the patent re-examined by a new Board. The Board may ask the USPTO to re-examine and reissue an amended version of the patent, if feasible. A reissued patent shall be treated as a new patent for validation purposes. A patent needs to be validated only once by the Board; it can be done at any time during the patent’s life and the validation may be requested by anyone. It would be in the interest of the patentee to have his patent validated before engaging in any licensing or other commercial activity or litigation.

The Board should comprise experts in patent examination, STEM experts, experts in patent law and members from the National Academies, all suitably chosen keeping the patented invention in mind. The Board should be supported by an expert prior art search team. The Board may also crowd-source to find prior art. The Board shall *de novo* determine the relevant PHOSITA for the patent. The first question it should settle before anything else is the *quid pro quo* aspect of patent grant: "Would society have benefited more if the patent had not been granted?" If the answer is yes, the patent should be revoked. The Board must decide keeping in mind the words of Thomas Jefferson:

> Considering the exclusive right to invention as given not of natural right, but for the benefit of society, I know well the difficulty of drawing a line between the things which are worth to the public the embarrassment of an exclusive patent, and those which are not.[123]

In litigation, the validity of the patent-in-suit must first be established by a Patent Validation Board, if not already done. For a valid patent, issues related to expansion of claim scope under the doctrine of equivalents or the applicability of the reverse doctrine of equivalents should be referred to the Patent Validation Board by the courts. The Board's decision in this respect shall be final.

11 Conclusions

In the confines of these pages arguments have been presented that compel us to believe that it is not just the patent system but the fate of the entire human race is at stake. We the *Homo sapiens* may no longer exist a few centuries hence. The patent system encouraged and made it profitable for humans to use their ingenuity to innovate, share their innovations in a certain equitable way, and collectively improve the living conditions of fellow humans. Like all human constructed systems, it was never perfect, but it did wonders to give shape to our collective dreams and fantasies, e.g., visiting the planets, exploring space, global communication, flying in the air, and so on. Indeed, it has gone beyond our wildest dreams. It has now led to artificial intelligence, synthetic biology, and quantum computing. Collectively the trio have the unimaginable power to wipe us out of existence. The best the patent system can do is to adapt and reconfigure itself so that it can gracefully wind itself down before the *Homo sapiens* become extinct. There are many secrets about biological life that we do not know, e.g., there exist on Earth creatures with incredible superpowers of survival even after being frozen and suffocated, resist ageing, regrow organs, defy cancer, etc. Any new understanding of these could revolutionize medicine, space travel and even war.[124] It is likely that our successor species may find and build their own world with this kind of new knowledge.

AI inventions by their very nature cannot be granted patent rights or such rights protected. AI inventions at their core belong to abstract mathematics and their most complex applications are essentially controlled by algorithms that are mechanizable computations. In fact, we already know some of the tricks that would allow AI machines to develop and discover new algorithms in a mechanized way. Human ingenuity may be rare, AI ingenuity will be pervasive.

[123] Jefferson (1813).
[124] Ainsworth (2019).

References

Ainsworth (2019). Ainsworth, C. Want to regrow organs and defy cancer? Just copy these awesome animals. New Scientist, 09 October 2019.

Ashton (1955). Ashton, T.S. *An Economic History of England: The 18th Century*. Taylor & Francis, 1955, p. 107.

Bera (2009). Bera R. K. The Story of the Cohen-Boyer patents. Current Science, Vol. 96, No. 6, 25 March 2009, pp. 760-763. http://www.currentscience.ac.in/Downloads/article_id_096_06_0760_0763_0.pdf

Bera (2012). Bera R. K. *Biotechnology Patents: Safeguarding Human Health*, in Innovations in Biotechnology (Eddy C. Agbo, ed.). InTech, ISBN 978-953-51-0096-6, Chapter 15, pp. 349-376 (2012). http://www.intechopen.com/source/pdfs/28719/InTech-Biotechnology_patents_safeguarding_human_health.pdf. (Book is available at http://www.intechweb.org/books/show/title/innovations-in-biotechnology and can be downloaded for free.)

Bera (2015). Bera, R. K. How valid are judicial exceptions in subject matter eligibility in U.S. patent law? (May 10, 2015). Available at SSRN: https://ssrn.com/abstract=2604737 or http://dx.doi.org/10.2139/ssrn.2604737

Bera (2015a). Bera, R. K., Intellectual property rights: The new wealth of nations. (March 3, 2015). Available at SSRN: http://ssrn.com/abstract=2572850 or http://dx.doi.org/10.2139/ssrn.2572850.

Bera (2015b). Bera, R. K. *Synthetic Biology and Intellectual Property Rights*, in Biotechnology (Deniz Ekinci, ed), InTech, ISBN 978-953-51-2040-7, Chapter 9, pp. 195-232 (2015). http://www.intechopen.com/download/pdf/48297. (Book is available at http://www.intechopen.com/books/biotechnology).

Bera (2015c). Bera, R. K. Rethinking patentable subject matter and related issues. (December 4, 2015). Available at SSRN: https://ssrn.com/abstract=2699219 or http://dx.doi.org/10.2139/ssrn.2699219

Bera (2016). Bera, R. K. Patent subject matter eligibility. (December 11, 2016). Available at SSRN: https://ssrn.com/abstract=2883838 or http://dx.doi.org/10.2139/ssrn.2883838

Bera (2018). Bera, R. K. AI powered society. (September 28, 2018). Available at SSRN: https://ssrn.com/abstract=3256873. An updated version is available at Bera, R. K. AI powered society. Advanced Computing and Communications, March 2019, pp.59-85. https://acc.digital/aipowered-society/

Bera (2019). Bera, R. K. *Synthetic Biology, Artificial Intelligence, and Quantum Computing*. Book chapter in Genetic Engineering Technology and Synthetic Biology, Madan L. Nagpal (Ed.). IntechOpen, London, (to appear in 2019). Prepublication access to the chapter has been provided by InTech at https://www.intechopen.com/online-first/synthetic-biology-artificial-intelligence-and-quantum-computing; PDF at https://www.intechopen.com/chapter/pdf-download/65149

Bera(2019a). Bera, R.K. China: The Trump factor revisited. (October 05, 2019). Available at SSRN: https://papers.ssrn.com/sol3/cf_dev/AbsByAuth.cfm?per_id=1752696

Bera & Menon (2009). Bera, R. K., and Menon, V. A new interpretation of superposition, entanglement, and measurement in quantum mechanics, arXiv:0908.0957v1 [quant-ph], 07 August 2009, http://arxiv.org/abs/0908.0957

Bernstein (2004). Bernstein, W. J. *The Birth of Plenty: How the Modern World of Prosperity was Launched*. McGraw-Hill, 2004.

Best (2013). Best, J., IBM Watson: The inside story of how the Jeopardy-winning supercomputer was born, and what It wants to do next. TechRepublic, 10 September 2013. http://www.techrepublic.com/article/ibm-watson-the-inside-story-of-how-the-jeopardy-winning-supercomputer-was-born-and-what-it-wants-to-do-next/

Bloch (1990). Bloch, E. Can the U.S. compete? World Link, January-February 1990.

Brookes(2017). Brookes, J.C. Quantum effects in biology: golden rule in enzymes, olfaction, photosynthesis and magnetodetection. Proceedings of the Royal Society A, Mathematical, Physical and Engineering Sciences, 2017; 473:20160822. DOI: http://dx.doi.org/10.1098/rspa.2016.0822

Brooks (2015). Brooks, M. Is quantum physics behind your brain's ability to think? New Scientist, 02 December 2015. Available from: https://www.newscientist.com/article/mg22830500-300-is-quantum-physics-behind-your-brains-ability-to-think/ Accessed: 2018-12-02

Burk & Lemley (2009). Burk, D. L., and Lemley, M. A., Fence posts or sign posts? Rethinking patent claim construction. University of Pennsylvania Law Review, Vol. 157, No. 6, Symposium: The Foundations of Intellectual Property Reform (June 2009), pp. 1743-1799, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1358460#

CAFC (2002). *Johnson & Johnston Associates, Inc.* v. *RE Service Co*., 285 F.3d 1046 (Fed. Cir. Mar. 28, 2002) (*en banc*, *per curiam*), http://digital-law-online.info/cases/62PQ2D1225.htm

Callaway (2017). Callaway, E. Oldest Homo sapiens fossil claim rewrites our species' history. Nature, 07 June 2017. (Corrected 08 June 2017). https://www.nature.com/news/oldest-homo-sapiens-fossil-claim-rewrites-our-species-history-1.22114

Carnot (1824). Carnot, S. *Reflections on the Motive Power of Fire and on Machines Fitted to Develop that Power*. Bachelier, Paris, 1824, http://www.thermohistory.org/carnot.pdf

Chaitin (2003). Chaitin, G. J. Leibniz, Information, Math and Physics. arXiv:math.HO/0306303 v2 21 Jun 2003. http://arxiv.org/abs/math/0306303

Clausius (1850). Clausius, R. Über die bewegende Kraft der Wärme, Part I, Part II, Annalen der Physik, Vol. 79, 1850, pp. 368–397, 500–524. *See* English Translation: On the moving force of heat, and the law regarding the nature of heat itself which are deducible therefrom, *Phil. Mag*. (1851), 2, pp. 1–21, 102–119, https://archive.org/details/londonedinburghd02lond

Cohen, et al (1973). Cohen S. N., Chang A. C. Y., Boyer H. W., and Helling R. B. Construction of biologically functional bacterial plasmids in vitro. Proc. National Academy of Sciences, USA 1973; 70(11) 3240-3244. http://www.pnas.org/content/70/11/3240.full.pdf

Cong, et al (2013). Cong L., et al. Multiplex genome engineering using CRISPR/Cas systems. Science, 339 (6121), 2013, pp. 819–823. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3795411/

Cooke & Hilton (2015). Cooke, N. J. and Hilton, M. L. (Editors). *Enhancing the Effectiveness of Team Science*. NAP, 2015. http://download.nap.edu/cart/download.cgi?&record_id=19007

Darwin (1859). Darwin, C. *On the Origin of Species by Means of Natural Selection*. First Edition. John Murray, London, 1859. http://darwin-online.org.uk/content/frameset?itemID=F373&viewtype=text&pageseq=1

Dawkins (2010). Dawkins, R. *The Greatest Show on Earth: The Evidence for Evolution*. Free Press; Reprint edition 2010.

Descartes (1637). Descartes, R. *Discourse on the Method of Reasoning Well and Seeking Truth in the Sciences*. 1637, http://www.earlymoderntexts.com/pdfs/descartes1637.pdf

Deutsch (1998). Deutsch, D. *The Fabric of Reality*. Penguin, 1998. Chapter 1, p. 2.

Economist (20190912a). Now the world will change as computers spread into everyday objects. The Economist, 12 September 2019. https://www.economist.com/leaders/2019/09/12/now-the-world-will-change-as-computers-spread-into-everyday-objects

Economist (20190912b). A singular opportunity. The Economist, 12 September 2019. https://www.economist.com/leaders/2019/09/12/a-singular-opportunity

Encyclopaedia Britannica (2019). The Editors of Encyclopaedia Britannica. Homo: hominin genus. Encyclopaedia Britannica. Last updated 09 January 2019. https://www.britannica.com/topic/Homo

Erdős & Rényi (1960). Erdős, P., and Rényi, A. On the evolution of random graphs. Publications of the Hungarian Academy of Sciences, 1960, 5(1), 1960, pp. 17-61. http://snap.stanford.edu/class/cs224w-readings/erdos60random.pdf

Feynman (1965). Feynman, R. *The Character of Physical Law*. Modern Library Edition, 1994, Originally published by BBC in 1965, and in paperback by MIT Press, 1967.

Fisher (2015). Fisher, M. P. A. Quantum cognition: The possibility of processing with nuclear spins in the brain. Annals of Physics. 2015; 362: 593-602. DOI: https://doi.org/10.1016/j.aop.2015.08.020

Fox News (2017). Ray Kurzweil predicts computers will be as smart as humans in 12 Years. Fox News. 2017. http://www.foxnews.com/tech/2017/03/16/ray-kurzweil-predicts-computers-willbe-as-smart-as-humans-in-12-years.html

Galileo (1623). Galileo Galilei, Il Saggiatore (in Italian) (Rome, 1623); *The Assayer*, English translation: Stillman Drake and C. D. O'Malley, in *The Controversy on the Comets of 1618* (University of Pennsylvania Press, 1960), http://www.princeton.edu/~hos/h291/assayer.htm

Gerstell (2019). Gerstell. G. S. I work for N.S.A. We cannot afford to lose the digital revolution. The New York Times, 10 September 2019. https://www.nytimes.com/2019/09/10/opinion/nsa-privacy.html

Gibson, et al (2010). Gibson D, et al. Creation of a bacterial cell controlled by a chemically synthesized genome. Science, 329(5987), 2010, pp. 52–56. http://adsabs.harvard.edu/abs/2010Sci...329...52G

Gödel (1931). Gödel, K. Über formal unentseheidbare Sätze der Principia Mathematica und verwandter Systeme I. Monatshefte für Mathematik und Physik, **38**, 1931, pp. 173-198. (On formally undecidable propositions of Principia Mathematica and related systems I.) (Visit http://jacqkrol.x10.mx/assets/articles/godel-1931.pdf for an English translation by B. Meltzer.)

Harding (1941). Harding, T. S. Exploitation of the creators. Philosophy of Science, Vol. 8, No. 3 (July 1941), pp. 385-390, at 386-387.

Headrick (1981). Headrick, D. R. *The Tools of Empire: Technology and European Imperialism in the Nineteenth Century*, Oxford University Press, New York, 1981.

Heathcotte & Robert (2006). Heathcotte, B., and Robert, J. S. The strange case of the humanzee patent quest. The National Catholic Bioethics Quarterly, Vol. 6, No. 1, Spring 2006. http://ncbcenter.metapress.com/app/home/contribution.asp?referrer=parent&backto=issue,4,9;journal,6,26;linkingpublicationresults,1:119988,1

Hirst (2019). Hirst, K. K. Top 10 inventions in ancient human history. ThoughtCo. 01 July 2019. https://www.thoughtco.com/top-inventions-in-ancient-human-history-172900

Hofstadter (1979). Hofstadter, D. Gödel, Escher, Bach: An Eternal Golden Braid, Basic Books, 1979.

Hublin, et al (2017). Hublin, J. et al. New fossils from Jebel Irhoud, Morocco and the pan-African origin of *Homo sapiens*. Nature, Vol. 546, 08 June 2017, pp. 289–292. https://www.nature.com/articles/nature22336

Inkster (2006). Inkster, I. Potentially global: A story of useful and reliable knowledge and material progress in Europe, circa 1474-1914. International History Review, XXVIII (2), June 2006. pp. 237-286. http://www.jstor.org/discover/10.2307/40109747. An earlier version is available at http://grammatikhilfe.com/economicHistory/Research/GEHN/GEHNPDF/conf4_IInkster.pdf.

ITU News (2019). 'The future is better than you think:' Predictions on AI and development from Ray Kurzweil. ITU News, 29 May 2019. https://news.itu.int/the-future-is-better-than-you-think-predictions-on-ai-and-development-from-ray-kurzweil/

Jefferson (1813). Jefferson T. Letter to Isaac McPherson. Monticello, August 13, 1813. In: The Letters of Thomas Jefferson. From Revolution to Reconstruction and Beyond. American History. http://www.let.rug.nl/usa/presidents/thomas-jefferson/letters-of-thomas-jefferson/jefl220.php

Kurzweil (1999). Kurzweil, R. *The Age of Spiritual Machines*: *When Computers Exceed Human Intelligence*. Viking Press, 1999.

Kurzweil (2005). Kurzweil, R. *The Singularity is Near: When Humans Transcend Biology*. Viking, 2005.

Kurzweil (2010). Kurzweil R. How my predictions are faring. Kurzweilai.net. 2010. http://www.kurzweilai.net/images/How-My-Predictions-Are-Faring.pdf

Kurzweil Network (2019). A breakthrough processor invented for AI. Kurzweilai.net, 20 August 2019. https://www.kurzweilai.net/making-headlines-a-breakthrough-processor-invented-for-ai

Landauer (1961). Landauer, R. Irreversibility and heat generation in the computing process. IBM Journal of Research and Development, **5** (3), 183-191, 1961. Reprinted in IBM Journal of Research and Development, **44** (1-2), 261-269**,** January/March 2000. http://www.pitt.edu/~jdnorton/lectures/Rotman_Summer_School_2013/thermo_computing_docs/Landauer_1961.pdf

Landauer (1991). Landauer, R. Information is physical. Physics Today, May 1991, pp. 23-29.

Lee (2012). Lee, T. B. How a rogue appeals court wrecked the patent system. Arstechnica, 01 October 2012, http://arstechnica.com/tech-policy/2012/09/how-a-rogue-appeals-court-wrecked-the-patent-system/2/

Li & Alon (2019). Li, S., and Alon, I. China's intellectual property rights provocation: A political economy view. Journal of International Business Policy. 03 September 2019 (online). https://link.springer.com/article/10.1057%2Fs42214-019-00032-x, and https://doi.org/10.1057/s42214-019-00032-x

Lynley (2011). Lynley, M. Watson supercomputer defeated in Jeopardy by lone physicist — long live humanity! VentureBeat.com, 07 March 2011. https://venturebeat.com/2011/03/07/humanity-wins-against-watson/

Malyshev, et al (2014). Malyshev D. A., et al. A semi-synthetic organism with an expanded genetic alphabet. Nature, 509 (7500), 2014, pp. 385-388, http://www.ncbi.nlm.nih.gov/pubmed/24805238

Markovits (2019). Markovits, D. How life became an endless, terrible competition. The Atlantic, September 2019. https://www.theatlantic.com/magazine/archive/2019/09/meritocracys-miserable-winners/594760/

Maxwell (1865). Maxwell, J. C. A dynamical theory of the electromagnetic field. Philosophical Transactions of the Royal Society of London, Vol. 155, 1865, pp. 459–512. http://rstl.royalsocietypublishing.org/content/155/459. (This article accompanied a December 8, 1864 presentation by Maxwell to the Royal Society.)

May (1976). May, R. M. Simple mathematical models with very complicated dynamics. Nature, 261, 1976, pp. 459–467. http://abel.harvard.edu/archive/118r_spring_05/docs/may.pdf

Metz (2019). Metz, C. To power AI, start-up creates a giant computer chip. The New York Times, 19 August 2019. https://www.nytimes.com/2019/08/19/technology/artificial-intelligence-chip-cerebras.html

Moore (1965). Moore, G. M. Cramming more components on to integrated circuits. Electronics, Vol. 38, No. 8, 19 April 1965. https://drive.google.com/file/d/0By83v5TWkGjvQkpBcXJKT1I1TTA/view

Moye (1996). Moye, W. T. ENIAC: The Army-Sponsored Revolution. 1996. https://web.archive.org/web/20170521072638/http://ftp.arl.mil/~mike/comphist/96summary/index.html

NAP (2014). National Research Council. *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond*. Division on Earth and Life Studies; Board on Life Sciences;

Committee on Key Challenge Areas for Convergence and Health. The National Academies Press, Washington D. C. 2014. https://www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering

Nelson & Cox (2006). Nelson D. L., and Cox M. M. *Lehninger Principles of Biochemistry*. 4th edn. 2006. https://www.academia.edu/4622632/Lehninger_Principles_of_Biochemistry_Fourth_Edition_-_David_L._Nelson_Michael_M._Cox

Neumann (1954). von Neumann, J. The role of mathematics in the sciences and in society (1954) an address to Princeton alumni, published in John von Neumann: Collected Works (1963), A. H. Taub (Ed.).

Newton (1687). Newton, I. *Philosophiæ Naturalis Principia Mathematica*. 1687, https://www.gutenberg.org/files/28233/28233-pdf.pdf

Nielsen & Chuang (2000). Nielsen, M. A., and Chuang, I. L. *Quantum Computation and Quantum Information*. Cambridge University Press, 2000. [Errata at http://www.squint.org/qci/]

NRC (2012). Committee on the Mathematical Sciences in 2025; Board on Mathematical Sciences And Their Applications; Division on Engineering and Physical Sciences; National Research Council. *Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century*. NAP, 2012. http://nap.us4.list-manage.com/track/click?u=eaea39b6442dc4e0d08e6aa4a&id=5ce538bec4&e=2d772d24ed

Ogle (2007). Ogle, R. *Smart World: Breakthrough Creativity and the New Science of Ideas*. Harvard Business School Press, May 2007.

Olson (2015). Olson, S. (Ed.) *The Past Half Century of Engineering—And a Look Forward*. NAP, 2015. https://doi.org/10.17226/21702.

Palmisano (2003). Palmisano, S. J. The globally integrated enterprise. Foreign Affairs, Vol. 85, No. 3. May/June 2003, pp. 127-136. http://www.oecd.org/sti/ieconomy/37998124.pdf

Popper (1934). Popper, K. *The Logic of Scientific Discovery*. Routledge, 1959. (Originally published in German: Logik der Forschung, Mohr Siebeck, 1934.)

Popper (1963). Popper, K. *Conjectures and Refutations: The Growth of Scientific Knowledge* (Reprinted Ed., 2004). (First published, 1963), Routledge.

Prather (2010). Prather K. L. J. Applications of synthetic biology. Presidential Commission for the Study of Bioethical Issues, 8 July 2010, http://bioethics.gov/sites/default/files/Applications-of-Synthetic-Biology.ppt

Reedy (2017). Reedy C. Kurzweil claims that the singularity will happen by 2045. Futurism. 2017. https://futurism.com/kurzweil-claims-thatthe-singularity-will-happen-by-2045/

Richter, et al (2017). Richter, D. et al. The age of the hominin fossils from Jebel Irhoud, Morocco, and the origins of the Middle Stone Age. Nature, Vol. 546, 08 June 2017, pp. 293–296 (2017). https://www.nature.com/articles/nature22335

Roser & Ortiz-Ospina (2017). Roser, M. and Ortiz-Ospina, E. World population growth. (Updated May 2019). Published online at OurWorldInData.org. https://ourworldindata.org/world-population-growth

SCOTUS (1950). *Graver Tank & Mfg. Co.* v. *Linde Air Products*, 339 U.S. 605 (1950), http://supreme.justia.com/us/339/605/case.html

SCOTUS (1961). *Aro Mfg. v. Convertible Top Replacement Co.*, 365 U.S. 336, 339 (1961), http://supreme.justia.com/us/365/336/case.html

SCOTUS (1996). *Markman* v. *Westview Instruments, Inc*., 517 U.S. 370, 371-73 (1996), http://straylight.law.cornell.edu/supct/html/95-26.ZO.html

SCOTUS (2002). *Festo Corp.* v. *Shoketsu Kinzoku Kogyokabushiki Co.*, 535 U.S. 722 (2002), http://www.law.cornell.edu/supct/pdf/00-1543P.ZO (vacated and remanded)

SCOTUS (2013). *Ass'n for Molecular Pathology* v. *Myriad Genetics, Inc*., 133 S. Ct. 2107, 2111 (2013), http://www.supremecourt.gov/opinions/12pdf/12-398_1b7d.pdf

SCOTUS (2014). *Nautilus, Inc.* v. *BioSig Instruments, Inc*., 572 U.S. ___ (2014), https://supreme.justia.com/cases/federal/us/572/13-369/

Shapiro (2015). Shapiro, Z., Patent law, expertise, and the Court of Appeals for the Federal Circuit. Harvard Law, 14 July 2015, http://blogs.law.harvard.edu/billofhealth/2015/07/14/patent-law-expertise-and-the-court-of-appeals-for-the-federal-circuit/

Shannon (1948). Shannon, C.E. A mathematical theory of communication. Bell System Technical Journal, 27, pp. 379–423 & 623–656, July & October, 1948, http://cm.bell-labs.com/cm/ms/what/shannonday/shannon1948.pdf

Sharlach (2014). Sharlach, M. CRISPR pioneers honored. The Scientist, 18 November 2014, http://www.the-scientist.com/?articles.view/articleNo/41455/title/CRISPR-Pioneers-Honored/

Stone (2016). Stone, P, *et al*. Artificial intelligence and life in 2030. One Hundred Year Study on Artificial Intelligence: Report of the 2015–2016 Study Panel (2016). 01 August 2016. https://ai100.stanford.edu/sites/default/files/ai_100_report_0831fnl.pdf

Tegmark (2014). Tegmark, M. *Our Mathematical Universe: My Quest for the Ultimate Nature of Reality*. Knopf, 2014.

Thomson (1854). Thomson, W. (Lord Kelvin). On the dynamical theory of heat. Part V. Thermo-electric currents, Transactions of the Royal Society of Edinburgh 21 (part I): 123, 1854, http://www.biodiversitylibrary.org/item/126375#page/147/mode/1up

Turing (1936). Turing, A. M. On computable numbers, with an application to the *Entscheidungsproblem*. Proceedings of the London Mathematical Society, **S2-42** (1), 230-265, 1936-1937. https://www.cs.virginia.edu/~robins/Turing_Paper_1936.pdf Correction at: Turing, A. M., On computable numbers, with an application to the Entscheidungsproblem. A correction. **S2-43** (1), 544–546, 1938. http://www.turingarchive.org/viewer/?id=466&title=02

UNPF (2017). World population dashboard. United Nations Population Fund, 2017. http://www.unfpa.org/pds/trends.htm

Warshofsky (1994). Warshofsky, F. *The Patent Wars*. John Wiley, 1994.

Watson & Crick (1953a). Watson J. D., and Crick F. H. C., Molecular structure of nucleic acids. Nature, 171 (4356), 1953, pp. 737-738. http://www.nature.com/scitable/content/molecular-structure-of-nucleic-acids-a-structure-13997975

Watson & Crick (1953b). Watson J. D., and Crick F. H. C. Genetical implications of the structure of deoxyribonucleic acid. Nature, 171(4361), 1953, pp. 964–967. http://www.nature.com/nature/dna50/watsoncrick2.pdf

Weiß & Schwietring (2018). Weiß, J., and Schwietring, T. The power of language: A philosophical-sociological reflection. Goethe-Institut, 2018. http://www.goethe.de/lhr/prj/mac/msp/en1253450.htm

Wigner (1960). Wigner, E. P. The unreasonable effectiveness of mathematics in the natural sciences. Richard Courant lecture in mathematical sciences delivered at New York University, May 11, 1959; published Communications on Pure and Applied Mathematics 13(1): 1–14, February 1960. http://www.maths.ed.ac.uk/~aar/papers/wigner.pdf

Yin, et al (2014). Yin H, et al. Genome editing with Cas9 in adult mice corrects a disease mutation and phenotype. Nature Biotechnology. Published online 30 March 2014 (Corrected 31 March 2014). http://www.nature.com/nbt/journal/vaop/ncurrent/full/nbt.2884.html

Yong (2016). Yong, E. A new origin story for dogs. The Atlantic Daily, 02 June 2016, https://www.theatlantic.com/science/archive/2016/06/the-origin-of-dogs/484976/

Zabala & Luria (2019). Zabala, C., and Luria, D. New gilded age or old normal? American Affairs, September 2019. https://americanaffairsjournal.org/2019/08/new-gilded-age-or-old-normal/

Zinkernagel (2015). Zinkernagel, H. Are we living in a quantum world? Bohr and quantum fundamentalism. In: Aaserud F, Kragh H, editors. One hundred years of the Bohr atom: Proceedings from a conference. Scientia Danica. Series M: Mathematica et physica, vol. 1. Copenhagen: Royal Danish Academy of Sciences and Letters; 2015. p. 419-434. http://philsci-archive.pitt.edu/11785/1/BohrQuantumWorld.pdf

Zinkernagel (2016). Zinkernagel, H. Niels Bohr on the wave function and the classical/quantum divide. Studies in History and Philosophy of Modern Physics. 2016; 53:9-19. https://arxiv.org/abs/1603.00353