Science, Capitalism & Catastrophe

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> *I had a dream, which was not all a dream.*
> *The bright sun was extinguish'd, and the stars*
> *Did wander darkling in the eternal space,*
> *Rayless, and pathless, and the icy earth*
> *Swung blind and blackening in the moonless air;*
> *Morn came and went—and came, and brought no day,*
> *And men forgot their passions in the dread*
> *Of this their desolation; and all hearts*
> *Were chill'd into a selfish prayer for light.* Byron

Thus begins *The Darkness*, Lord Byron's terrifying description of the last days of a dying world. Written in the summer of 1816, while Byron (along with friends including Percy Shelley and his wife Mary Wollstonecraft-Shelley) vacationed near Lake Geneva, the poem is partly inspired by an event which took place a year earlier on the other side of the world. In April 1815, Mount Tambora, a volcano in the Indonesian archipelago, erupted. Estimated to be the largest volcanic blast in recorded history, its ferocity was such that the top 1.5 kilometers of the mountain was completely obliterated. Tens of millions of tons of ash (mostly sulphur) were sent high into the atmosphere. At such altitudes, dust can take years to dissipate forming what scientists call a "persistent stratospheric sulphate aerosol veil".[1] The effect of this was to restrict the sunlight reaching the Earth's surface, leading to global crop failures, hunger, and disease.

While likely unaware of the cause, Byron and his friends were struck by the bleak atmospheric conditions: thunderstorms, icy winds, constant rainfall, and a dearth of sunlight.

The disquieting darkness led 1816 to be known as the "year without a summer" and led Byron's party, eager to enjoy outdoor pursuits, to instead seek refuge in the more cerebral activity of writing ghost stories. Two great literary works emerged from that grim vacation which are frighteningly relevant today. The less famous of these was Byron's *The Darkness*. The other, far more famous and written by the eighteen-year-old Mary Wollstonecraft-Shelley, was the beautiful and moving gothic novel, *Frankenstein.* Wollstonecraft-Shelley's novel tells the story of scientist Dr Victor Frankenstein's creation of a sentient life form. The creature has human traits but is freakishly large and Dr Frankenstein soon loses control of the powerful beast, to terrible effect. Though dealing with a variety of deep questions concerning consciousness and love, *Frankenstein* is mostly remembered as a cautionary tale. The full title of the book was '*Frankenstein or The Modern Prometheus'*, an allusion to the Titan, Prometheus, in Greek mythology who created humans so that Zeus could bequeath them with a life force. Prometheus comes to a rather sticky end when, having stolen the secret of fire from Zeus as a gift for humanity, Zeus chains him to a rock in the Caucuses and sets an eagle to forever peck out his immortal liver. In the case of Dr Victor Frankenstein, the death and destruction unleashed by his 'monster' present a stark warning to the title character's "*unquestioned belief that the products of science and technology are an unqualified blessing for mankind*".[2]

A great paradox

Given the precarious place our species occupies, Byron's deathly vision and Wollstonecraft-Shelley's caution against scientific hubris feel alarmingly apposite. We face extinction threats on multiple fronts: from catastrophic climate change to nuclear annihilation. Indeed, the world Byron describes bears an uncanny resemblance to that predicted by scientific models of nuclear winter.[3] There is good reason for this. Scientists have applied the lessons of volcanic eruptions, like Mount Tambora, to model the likely climactic effects of nuclear war. It is now well understood that even a relatively small nuclear exchange (a regional conflict between India and Pakistan, say) involving only about 0.03 percent of the world's nuclear weapons, would send enough soot hurtling into the stratosphere to cause global crop failures and cataclysmic famine.[4] This is without even considering the blasts themselves or the effects of radioactivity.

We are confronted with the greatest of paradoxes. In parallel to our deepening understanding of nature and our ever-growing ability to harness its power, our world is becoming dangerously inhospitable. Technological revolutions in industry and agriculture have given us productive capacities undreamt of by any previous generation. And yet these very capacities allow our world to be filled with junk and our atmosphere with greenhouses gasses which threaten to cook us. We can produce lifesaving medicines and yet our use of antibiotics, along with our modern farming methods, creates resistant superbugs which endanger us all.[5] Most extraordinary, the culmination of centuries of incremental toil and profound thought in physics and mathematics, leading, for example, to the splitting of the atom, has resulted in a collection of weapons that could realise Byron's lifeless world in a matter of minutes.

Some people are tempted by a certain misanthropic fatalism at this point. Humanity, the argument goes, cannot be trusted with such profound knowledge or powerful technology. Perhaps we would be better off in a state of pre-scientific ignorance? That way we would be less likely to destroy ourselves and the life-forms we share the planet with. While this view is deeply pessimistic (and wrong), it is certainly understandable. For every scientific advance, there seems to be a dangerous downside. The airplane can be used to connect loved ones who live oceans apart. At the same time, air travel is a notorious contributor to global warming. Ever more efficient machines that save us from back-breaking toil threaten our ecosystem with a seemingly unbounded ability to flood our world with 'stuff'. Then there are the lost livelihoods of the workers they replace. Indeed, in the case of so-called artificial intelligence, (and without even considering some of the apocalyptic forecasts made by some in this field) it is not just menial tasks but the creative labour of artists and writers that may be usurped.[6]

Worst of all, there are examples, such as the construction of weapons, where scientific knowledge is put intentionally to nefarious purposes. Albert Einstein, on learning that atomic bombs had been used on the civilian populations of Hiroshima and Nagasaki is reported to have exclaimed 'If I had known they were going to do this, I would have become a shoemaker'. While Einstein was not directly involved in the Manhattan Project to build an atomic bomb, his contributions to physics formed a significant part of the theoretical background to the endeavour. Faced with the prospect of one's explorations into nature's fundamental structure giving rise to world-destroying technology, one can surely sympathise with Einstein's sentiment. In the end, Einstein did not quit science although he did dedicate much of his later years to campaigning for nuclear disarmament.

Disillusionment in science

The universe is mysterious and human intuition (also known as common sense) is often a poor guide to understanding it. After all, common sense suggested to many that the Earth is flat! The scientific method of carefully testing hypotheses, along with an unsentimental willingness to reform or even replace ideas which are contradicted by experiment, is humanity's way of compensating. Science, ideally, should be a humble, questioning, self-critical search for understanding and its fruits should nurture humanity as a whole. Yet despite its undoubted achievements, there is a glaring contradiction between what science ought to deliver, and the reality of life for much of our species and indeed our biosphere.

The gap between the promise science holds and what it delivers is reflected, partly, in the growth of pseudo-science as well as suspicion and cynicism of scientific expertise. The sale of homeopathic treatments and dubious dietary supplements is a multi-billion-euro industry. So called 'gurus' like Deepak Chopra make fortunes selling books and 'quack' remedies, hijacking the language of real scientific theories like quantum mechanics to give intellectual validity to what is nothing more than new-age hokum.[7] Ironically, while this sort of grifting has a long history, it is the advent of communication technologies, precisely based on scientific theories such as quantum mechanics, that has greatly extended the reach of such charlatans.

Another form of pseudo-science is so-called 'scientific racism' and the baseless claims, couched in scientific language, that superficial differences like skin colour are connected to differences in mental ability. This has its origins in the need to dehumanise swathes of humanity in order to justify slavery, at a time when the language of liberty and emancipation (for some) was invoked in the struggle by a rising merchant class to cast off the old feudal system. Such falsehoods though utterly debunked (in, for example, classic texts like *The Mismeasure of Man* by Stephen J. Gould and *Not in Our Genes* by Stephen Rose, Leon Kamin and Richard Lewontin or the recently published "Superior" by Angela Saini) were (and still are) often promulgated by respectable scientists.

Scientific ignorance costs lives, as the recent pandemic has taught us. The National Institute of Health in the United States estimates that well over 200,000 American adults died from Covid 19 because of their refusal to be vaccinated.[8] Mistrust of vaccines more generally (arising from the spread of misinformation) has meant a resurgence in diseases like measles, pertussis, and polio.[9] Social media algorithms and the ease with which misinformation can spread are no doubt major factors in all of this. It is certainly true that the role of scientific education (preferably based on empathy and an understanding of where people are coming from) as a counter to this is an essential one. But this alone is insufficient and misses a crucial point.

Consider the case of Covid 19 and the suspicion around vaccination. Naomi Klein in her recent book, *Doppelganger,* argues that, when considering concerns about the effects of vaccines on pregnant women, "rather than commentators summarily shutting down questions as frivolous or nutty, there should have been ample room in public debates and reliable media for concerns about how vaccines would impact reproductive health."[10] Klein goes on to say that for many, these concerns were based much more on suspicion of the pharmaceutical industry, governments, and perceived elites, than they were on skepticism of the philosophical underpinnings of science. When one considers the role played by companies like Johnson and Johnson in perpetuating a deadly opioid crisis in the United States, or the astonishing wealth that companies like Pfizer accumulated during the pandemic, the anti-vaccination attitude, while mistaken, becomes more understandable.

There are good reasons why people should be suspicious of governments and powerful corporations (including corporate media). The legacy of the 2008 financial crash and the reckless greed of the financial establishment is still with us. History is replete with examples of governments lying to their people, often to justify wars. The falsehood about weapons of mass destruction used to justify the 2003 invasion of Iraq is just one example in a litany of such lies. Corporations lie all the time and often use quite sophisticated technology to do it. In 2017, for example, US prosecutors demonstrated that between 2009 and 2015, the Volkswagen Group had deliberately added devices to over 11 million of its cars to cheat an emissions test. After initial denials and claims that the discrepancies were mere technical glitches, pressure from the US Environmental Protection Agency (EPA) eventually lead to a complete admission of responsibility. The scandal was not, as Volkswagen had at one stage maintained "the work of a few software engineers" but went right to the top of the organisation.[11]

Research by scientists working at companies like Exxon and Shell has, since the late 1970s, predicted that the continued burning of fossil fuels would result in "potentially catastrophic events", "the disappearance of specific ecosystems and habitat destruction", and warned that many parts of the world, including the American Midwest could be turned to desert.[12] At the same time its own researchers were engaged in high quality scientific work endorsing the expert consensus on climate change, Exxon was simultaneously funding climate change denying think tanks doing precisely the opposite. Following the playbook of the tobacco industry before it, this included funding shoddy research based on cherry-picked data which contradicted the serious work of its own scientists!

It is here that we begin to see the role of science in a more meaningful context. While we may aspire towards an ideal, objective version of science which seeks only to benefit humanity, science takes place in a world where the benefit of humanity is often a low priority. The Exxon example is a particularly instructive one. On the one hand, to prosper in the marketplace, Exxon requires top quality scientific research, work which is as unbiased and objective as science can feasibly be. And yet the conclusions of that research are either hidden from the public, or to the extent that much of this research did end up in peer-reviewed journals, drowned out with aggressive campaigns of misinformation and enough seemingly serious contradictory research to sow doubt in the scientific consensus. As I will argue, this example is not an exception but represents a general tendency. While many, if not most, scientists strive toward a scientific ideal, and while wonderful results are often achieved, the economic and political structure of our society, namely capitalism, has a distorting effect. Put simply, science under capitalism is a warped version of what science could be.

The co-emergence of capitalism and science

The historian of science, Clifford D. Conner, argues that what we call science,

> …originated with the people closest to nature: hunter-gatherers, peasant farmers, sailors, miners, blacksmiths, folk healers, and others forced by the conditions of their lives to wrest the means of their survival from an encounter with nature on a daily basis.[13]

There are numerous examples of this: the domestication of plant and animal species by preliterate ancient peoples (virtually every fruit or vegetable you can purchase in a supermarket was cultivated this way); the development of chemistry, metallurgy and the materials sciences from the knowledge obtained by ancient miners, smiths and potters; the debt owed by mathematics to surveyors, merchants and mechanics. As Conner points out, when one considers the undoubtedly brilliant scientific contributions by figures like Newton or Einstein, one must remember that these contributions are built on a mountain of knowledge gathered incrementally over millennia by "massed ranks of labourers, craftsmen, miners, potters, artisans and low mechaniks".[14]

Over time, what we might call scientific knowledge was gained (often at great cost), shared, bought, sold, stolen, and sometimes lost. At various times and in different parts of the world, in classical Greece, in Baghdad or China during the Middle Ages, the scientific project flourished. Roughly speaking, what we call 'modern science' emerged during the 16th and 17th centuries as the old scholastic tradition (which was based on preserving and interpreting the knowledge of ancient classical scholars like Aristotle) was transcended through knowledge flowing from the practical workshop techniques of European artisans. The new scientific worldview was also deeply connected with a more general revolutionary process involving the rise of a new capitalist class and its eventual defeat of the old feudal order. Friedrich Engels, one of the most insightful thinkers on the role of science in human history, regarded this as:

> "the greatest progressive revolution that mankind has so far experienced. … Natural science developed in the midst of the general revolution and was itself thoroughly revolutionary".[15]

As the rising capitalist class expanded its wealth and power, it required understanding of the natural world, the better to exploit it. This was a powerful stimulus for scientific discovery, one which utterly transformed our understanding of the world and our place in it. One crucial early development in this transformation was the adoption in Europe of the Hindu-Arabic number system (the positional number system we use today). This arose from the interactions of European merchants with traders from the Arab world and the observation that their Arabic counterparts had far superior arithmetical techniques. The importance of this technological advance cannot be overstated - anyone who doubts this should try doing long division with Roman numerals.

The dismantling of the old Aristotelian picture of an Earth-centered universe and its replacement with a heliocentric model, put forward by Nicolas Copernicus in 1543, is the most famous consequence of this revolution. The new model was later improved by Johannes Kepler, substituting circular planetary trajectories with elliptical ones. More upheaval was to follow when Galileo, with the newly invented telescope, showed that Jupiter (and not just the Earth) had moons while the supposedly pristine surface of the sun contained dark spots. Galileo was a revolutionary in another way. The idea of testing hypotheses through observable evidence, rather than simply interpreting the writings of the old masters, was itself a radical departure from the scholastic tradition which had held sway for centuries. Importantly, this practical approach had its origins in the craftsman's workshop. Galileo's experiments on motion tested, and often debunked, preconceived intuitive notions.

Following this, Issac Newton formulated a coherent set of laws concerning motion and gravitation. From these simple principles could be deduced everything from Kepler's elliptical planetary orbits to the movement of Earthly tides, to the falling of apples from trees. The crowning scientific achievement of this age was the invention by Newton (and independently by Gottfried Leibniz) of Calculus, a potent mathematical language for describing movement and change. Newton's laws concerning motion and gravity were enormously successful. So successful in fact, that many concluded that the universe was simply an enormous clockwork mechanism, regular, predictable, and unchanging.

Figures like Galileo and Newton were no doubt motivated by a deep curiosity about the natural world. It is difficult to imagine how anybody could gain such insights without this. However, it is important to remember that their interests and the problems they worked on were also motivated by the needs of the day. For example, much of Galileo's work on motion was based on the practical knowledge of ballistics accumulated by contemporary military experts. Galileo also made contributions to the study of the strength of materials, in part motivated by the challenges faced by the Venetian navy in building large galleys.[16] Newton was particularly interested in the problem of computing longitude at sea and the related problem of time keeping in navigation. This was a very serious problem for seafarers and epitomised the growing need for ever more precise measuring devices. Ocean navigation was now a primary route to claiming new colonies and making vast profits. The longitude problem was eventually solved not by Newton, but by the master clockmaker, John Harrison.[17]

While developments in science were enhancing the productive process, the reverse was also the case. New methods of production and the exploration (and exploitation) of new territories, were providing a powerful stimulus for scientific discovery. One beautiful example of this is the deduction that the Earth is not perfectly round but is slightly flattened at the poles, while bulging at the equator.[18] In 1672, the French astronomer Jean Richer, while travelling to the colony of Cayenne in South America, observed that near the equator a pendulum swings slightly more slowly. There seemed no obvious explanation for this unless the force of gravity varied at different points on the earth. Newton heard about Richer's observation and concluded that this radical suggestion is precisely the case, performing the relevant calculations in his Principia. Even more radical still, Newton concluded from this that the earth could not be perfectly round but rather was an oblate spheroid.

Examples like this illustrate the potency of careful observation (aided by increasingly sophisticated instruments) combined with deep theoretical understanding. This growing understanding, even if for many it remained hidden behind difficult mathematical language, instilled the rising merchant class with a tremendous confidence. The success of theories such as Newton's were confirmation of the views expressed by Francis Bacon almost a century earlier: that nature could be understood and controlled.[19] Thus, alongside its enhanced practical power over both the natural world, and consequently much of humanity, the scientific revolution provided the newly birthed capitalist class with significant intellectual and ideological power. This would prove crucial in the political revolutions (some of which were already in progress) which would see capitalism prevail over the old feudal order.

Scientific development now proceeded at a tremendous pace, in tandem with the rapidly expanding capitalist system. The scientific revolution had witnessed a flourishing of ever more sophisticated tools and mechanical instruments. By the late 18th and early 19th century, the industrial revolution was in full swing, spawning a host of new sciences. Capitalist competition meant the need for ever more efficient machines that could control the forces of nature and control the forces of human labour too. The development of steam engines led to the study of heat (thermodynamics). The pioneering work of Michael Faraday (the son of a blacksmith with no formal mathematical training) in understanding electromagnetic force through ingenious experimentation and geometric intuition paved the way for a sequence of astonishing inventions: the electric motor, the coil dynamo (generator) and the incandescent lightbulb. As understanding of these physical phenomena grew, scientists began to see deep connections between them. Different forms of energy could be turned into one another and what united them all was a principle called the Conservation of Energy.

Marx's Dialectical Approach to Science

One philosopher who kept abreast of the new scientific developments was Karl Marx. Seeking to understand the new capitalist society that was growing up around him, Marx was struck by the extreme disparities that were arising as scientific knowledge of the world was growing. At the heart of this was the fact that workers are alienated both from the means, and the fruits, of the production they carry out. The human experience of mechanisation (which in today's world includes robotics and so-called artificial intelligence) illustrated to Marx quite clearly the 'inverted world' that capitalism was shaping. While the productive capacities of humanity were exponentially improving, both in quality and quantity, people were forced to work ever harder. Or they could be told their creative talents were obsolete and face the loss of their livelihoods. In 1844, Marx wrote:

> The more the worker produces, the less he has to consume. The more value he creates, the more valueless, the more unworthy he becomes. Capitalism replaces labour by machines, but it throws one section of workers back to a barbarous kind of labour, and it turns the other section into a machine.[20]

The fact that the machines were (and still are) owned by a capitalist class, locked into a competitive struggle for profits that necessitated continued growth, created an absurd dynamic. Instead of technological and scientific progress being the servant of humanity, for many of us, and in the most meaningful ways, capitalism reverses this. In a rational society, mechanisation and the productive benefits that ensue, should mean we all work less without any material loss. The term 'luddite' is used in common parlance as a derogatory term referring to one with an aversion to new technology. In the context of the alienated form of labour Marx describes, one cannot but feel sympathy for the textile workers who, seeing their livelihoods ruined by new mechanised looms, adopted the name 'luddite' (follower of legendary weaver, Ned Ludd) and launched a revolt. This involved., among other things, the destruction of factory machines in clandestine raids.[21]

The philosophical and economic theories developed by Marx, and his collaborator Friedrich Engels (whose contributions to these matters were substantial), were deeply influenced by the new scientific theories emerging in the 19th century. These sciences differed in an important way from Newtonian mechanics. Newton's universe was a static clockwork mechanism consisting of discrete well-defined parts. The new sciences, like thermodynamics and electromagnetism, were all about transformation and flow. This is something which harked back to the intuition of the Greek atomist philosophers like Heraclitus and

Epicurus. It was becoming increasingly clear that previously disjointed categories, such as organic and inorganic matter, could no longer be so easily separated; developments in chemistry showed that living things were composed of the same sort of matter as non-living things.

The most spectacular example of this was the theory, due to Alfred Russel Wallace and Charles Darwin, that all species had evolved incrementally from common ancestors through the process of natural selection. Combined with the new subject of geology it was now clear that the world had a history. Entities emerged, disappeared, or transformed into other entities. What were once thought of as fixed permanent categories (of the sort Aristotle once grappled with): a mountain, a man, or a dog, were now being understood in a much fuzzier way. A mountain today may have once (a very long time ago) been a plain. The clear distinction between man and dog becomes blurry when one considers that both organisms have a common ancestor in the distant past. We are all cousins on the tree of life.

The view that reality should be regarded as consisting of disjoint components which needed to be studied in isolation, an approach known as reductionism, had yielded great success, culminating in Newton's powerful theories. Indeed, given the complexity of the world, a certain amount of reductionism is unavoidable. However, as scientific developments in the 19th century were demonstrating, this can blind us to a much richer emergent structure when individual entities are considered as part of a whole. One can see this clearly if one considers how difficult it would be to deduce the myriad emergent properties of an ocean wave from examination of a single water molecule. These problems become only more difficult when one tries to understand human society.

Marx adopted what is called a dialectical approach in his work, seeking to understand the way different aspects of the world around us, such as the material, the economic, political, and cultural spheres, interacted with each other in dynamic and mutually transforming ways. He saw that the political and economic structures of our society were not permanent fixtures. Instead, they had a history. Different social structures came and went. Capitalism was just the latest one, emerging from the decaying feudal order.

Various naive idealistic explanations existed for this development - that this was part of a divine plan or an upward march of reason. Just as Darwin's theory had dispensed with these sorts of teleological explanations of the history of the natural world, Marx sought to do likewise at the level of human society.

Consequently, Marx realised that human society could not be understood in isolation from nature. This contrasts with most of mainstream economic theory which sees the economic sphere as existing independently of the natural sphere and unconstrained by scientific laws. This artificial separation allows many economists to regard economic growth as inconsequential to the external world, treating the economy as a sort of 'perpetual motion machine' and flouting fundamental physical principles such as the laws of thermodynamics.[22]

Marx grounded his theory in the material world, realising that before humans could pursue politics, art, literature or anything we would call culture, they must first interact with nature to provide food, shelter, clothing etc. From the outset, Marx argued:

> The first premise of all human history is, of course, the existence of living human individuals. Thus, the first fact to be established is the physical organisation of these individuals and their consequent relation to the rest of nature.[23]

One of Marx's concerns was the way the new capitalist system with its increasingly exploitative and extractive practices was distorting humanity's relationship with the rest of the natural world. In this, Marx was especially influenced by the organic chemist, Justus von Liebig. In the middle of the 19th century, Liebig had worked on the very serious problem of declining rates of soil fertility in Europe. He demonstrated that as the urban populations of Europe grew, the ever-increasing transfer of food from country to city was steadily robbing the soil of its nutritional content - minerals like potassium, nitrogen, and phosphorus).

This was a simple consequence of the resulting waste products ending up as pollutants in urban rivers or the sea. An ancient cycle was being interrupted in what Marx went on to call a 'metabolic rift'. An analogous rift in the carbon cycle (which regulates our atmospheric temperature) is responsible for global warming. The notion that capitalist modes of production can strain to the point of rupture, natural cycles that are essential to life, formed a key plank in Marx' analysis. In Capital, Marx wrote:

Capitalist agriculture produces conditions that provoke an irreparable rift in the interdependent process of social metabolism, a metabolism prescribed by the natural laws of life itself.[24]

Incidentally, the development of artificial fertilisers (following the Haber-Bosch process of taking nitrogen from the air to produce ammonia) has allowed humanity to postpone the problem of a rift in the soil cycle, without ever healing it. In fact, excessive use of nitrogen fertiliser reduces the soil's fertility, leading to a vicious cycle of ever-increasing need and setting off another sort of metabolic rift, one which we are grappling with today. Thus, capitalism, having set in motion the greatest impetus for scientific understanding the world had ever seen, is in its application to nature, simultaneously degrading the earth at a faster rate then ever before.

The end of the 19th century also saw a significant crisis in scientific theory. Various new theories, hugely successful in their own right, contradicted each other. This led to further scientific revolutions in the early twentieth century. The resulting new theories, Relativity and Quantum Mechanics, provided challenges to our intuition the like of which we had never seen. Space and time were no longer separate phenomena forming a fixed absolute backdrop on which life played out. Instead, they formed a unified whole, space-time, which could be warped and stretched by matter and motion. Moreover, objects can behave like both particles and waves (something which seems impossible) and there are fundamental uncertainties built into our universe at the subatomic scale. Despite defying common sense, these theories are enormously well verified, and, especially in the case of quantum mechanics, underlie much of the technology we depend on today.

Science today - the great distortion

What Marx recognised more than anyone else, was that science, and the productive forces unleashed by capitalism, have always existed in a dialectical relationship. Throughout its history, developments in scientific understanding (sometimes based only on curiosity) allowed for more powerful and efficient forms of extraction from nature. On the other hand, the needs of capitalism played a significant role in influencing the direction of research. There is an important nuance here. Scientific research, like any creative process, thrives in an environment where researchers are given freedom to ask questions and pursue interesting ideas. This is especially true of scientific education. Thus, it was and is, in the interest of capital (although not all capitalists realise this) that space be made for fundamental research without any obvious practical or profit-making motive.

What arose, and continues to the present day, is a world where scientific research takes place on a sort of spectrum. At one end, there is research directed to practical problems, some of which require urgent solutions: for example, finding a vaccine for a deadly virus. At the other end, there is research into questions which are simply interesting or even profound, but which have no obvious practical application. Subjects like Theoretical Physics and Mathematics are full of such questions. And there is a whole range of research which is a sort of hybrid of the two. These so-called pure and applied ends of the research spectrum are both essential and in fact reinforce each other, something which many modern university executives and funding bodies seem not to understand.[25]

From the mid-19th century on there was a move to professionalise science.[26] The importance of the scientific project both to capitalism, and to society more generally, was such that it could no longer be mainly the domain of 'Victorian gentleman scientists' or amateur enthusiasts. Today, we live in a world dominated by what is sometimes called Big Science: massive research projects involving vast numbers of scientists. The first serious example of this was the Manhattan Project where, under the direction of the brilliant theoretical physicist, Robert Oppenheimer, tens of thousands of scientists worked for three years to create the first atomic bombs. While an enormous amount of scientific research is publicly funded, science is increasingly dominated by private corporations. It is also important to bear in mind that public or state spending on science often takes place in partnership with private industry, and that, such is the nature of the state under capitalism, that the priorities of governments themselves are heavily skewed by private interests. These interests, which are based on short-term profit making and an inherent need to grow, have a hugely distorting effect and are at the heart of the paradox outlined earlier.

The distortion of science by capitalism takes many forms. One concerns the prioritisation of certain kinds of research over others. Since the end of the Vietnam War, the United States has spent about $3 trillion on scientific research.[27] More than half of this has been for military projects, maintaining the United States' position as the world's foremost imperial power. Some of this has gone toward replenishing and enhancing US nuclear capabilities. It is worth noting that, despite winning a Nobel Peace Prize after campaigning for a world free of nuclear weapons, Barack Obama and his administration pledged about $300 billion to upgrade and replenish the US nuclear arsenal, setting in motion a $1 trillion dollar commitment over the next two decades.[28] Apart from the horrific consequences we all face should these weapons ever be used, there is also the astounding waste of resources and scientific talent.

Another form of this distortion arises in the commodification of science and the withholding of vital scientific research to protect the profits of shareholders. Never was this problem more evident than during the recent pandemic. If ever there was an event that required a combined international approach, based on cooperation and human need, and a foregoing of profiteering, it was the Covid 19 pandemic. And yet, the profiteering proceeded with gusto, while companies like Pfizer and Moderna used so-called intellectual property rights to justify their refusal to share the vaccine recipe so that inexpensive generic versions could be distributed. This is particularly sickening when one considers that the development of Covid 19 vaccines was overwhelmingly funded by states, not the private pharmaceutical companies. More than this, the scientific principles behind these vaccines, such as the concept of modification of RNA (from which the name Moderna comes) was based on decades of research at publicly funded institutions.[29]

There have always been scientists who have fought hard to resist this distortion. Sometimes they work alone, other times, as part of organisations like the Union of Concerned Scientists. Most university academics maintain a tradition of openness and cooperation in their research, making their results publicly available. This is something that is becoming more difficult as funding for research is increasingly linked to the interests of private capital. There are also scientists like Jonas Salk, who developed a vaccine for polio and refused to seek a patent or make any profit from his discovery. Seeing his discovery as a 'people's vaccine', Salk famously compared the notion of patenting such an entity with 'patenting the sun'.[30]

A part of Salk's motivation here must surely be the realisation that all of us owe an enormous debt to the countless generations who through their curiosity, toil, and inspiration, amassed a mountain of knowledge about the natural world. This knowledge is the common treasury of humankind. It is highly interconnected and every new scientific idea today, irrespective of the brilliance of the scientists involved, relies on it. The idea that private firms have a right to ignore this debt, to own scientific knowledge and profit from monopoly privileges arising from the intellectual property legislation they formulated is a moral outrage.

Of course, the warping of science to satisfy the needs of capital has consequences far beyond the corporate accumulation of wealth. The rapidly growing rift in humanity's metabolic relationship with nature and the prospect of destruction at the hands of technologies we have created should sound alarm calls to us all. The prospects that we may find ourselves in the world of Byron's, The Darkness, is a very real one. Fatalism, or a rejection of the scientific project, will not help us here.

There is always the danger of unintended consequences to any new technology. And we must, of course, guard against the sort of hubris Mary Wollestonecraft-Shelley warns us about in her classic novel. But right now, we need science more than ever. We cannot allow the inhuman priorities of a system based on individual greed and unbounded extraction to control our scientific capabilities. Instead, we need to fight against the distortion, salvaging the best of the scientific tradition to create a form of science which serves humanity.

Endnotes

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