Science in an Age of (Non)Reason

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Abstract In this chapter, we wish to reflect on some of the issues we see as affecting our work, how we see the ethos of our research institutions changing, the role of science in an age in which 'experts' are seen as an unnecessary luxury who stand in the way of popular and populist movements but in which, at the same time, people crave the products invented, developed and produced by such 'experts'. We take a structured approach that uses the norms of science defined by the social scientist Robert Merton (the so-called Mertonian norms) and examine how each of them is affected by the current climate for science. We also look at some cases—historical and current—to help specify the intrinsic and extrinsic challenges that a reason- and evidence-based approach to knowledge is now facing.

Keywords Mertonian norms · Scientific freedom and autonomy
Evidence-based facts · Fake news · Skepticism · Objectivity

Introduction

We are practising natural scientists who, in our daily work, are confronted with the issues facing our profession in 2017. We concern ourselves with plant sciences, food security and climate change and our interests run from basic understanding of biological processes at all levels of organisation from cells to (agro-) ecosystems. We often use mathematical descriptions and dynamic computer models of processes to help understand, give counter-intuitive insights into our theories and experiments, predict outcomes for new situations such as a changed climate and suggest

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phenotypes of crops that would be either higher yielding or have improved qualities, in terms of protein levels.

What are current threats to science? To answer this, we try to answer three questions:

1. What are the function(s) of the Mertonian norms?
2. How do the norms of society affect the Mertonian norms either in defining them or implementing them?
3. Do the Mertonian norms still have a role in the increasingly 'post-academic' science?

Our general conclusion is in some agreement with the postmodernist self-evident view that science is a socially constructed human process—it cannot be anything else as it is a human activity that simply reflects the way that humans think. This psychological fact is the main reason why science will survive and thrive in the future. However, we do not argue, as many constructivists do, that 'opinions' without evidence are as convincing or correct as evidence-based experimentation or unifying theories of natural phenomena.

The logical conclusion of 'science as a social construction' is that facts as objective truths do not exist and *ipso facto* the assertion that 'there is no such thing as a fact'; the problem being that this postulate is illogically circular as a fact is being stated in making such a statement and terminates logically in solipsism—since the only thing one can really be sure of is that something only exists in a personal context. There is a delightful story of an eminent logician, Mrs. Christine Ladd-Franklin, writing to the British philosopher Sir Bertrand Russell postulating the benefits of solipsism and concluding her letter with the comment that she was surprised that there were not more people who agreed with her view (Russell 1948).

So, what we do mean is that science will survive because drawing conclusions on the basis of knowledge and evidence is intrinsic to the way that human beings think—in other words science cannot be anything else but a 'constructed human process' but not in the trivial way meant by social constructivists.

Extrinsic Constraints to Science—The Changing Role of Society

Science can be defined as organised knowledge production by investigating phenomena via systematic observation and experiment, and the formulation, testing and modification of hypotheses, thereby acquiring new, or modifying existing, understanding. Science as organised knowledge is rational (communicated unambiguously), reliable (because it is based on reason) and specialised (based on empirical evidence from expert studies). Science is authoritative because it is evaluated by well-organised societal systems dedicated to knowledge production (institutions). Science nowadays is vital to health, wealth and human happiness and is a major element of the economy and has adapted more and more to the requirements of policy (Ziman 2008a). Whether this realignment is beneficial in the long run is open to question.

Different societies have and have had different political agendas for science (Ziman 2008b)—from *traditional societies* as hunter-gatherers to agricultural empires, where production of knowledge was not an organised social activity; to *theocratic* societies, where the role of science was to sustain the authority of religious beliefs; and *totalitarian* societies in which scientific activity was and is incorporated into the credo of the state apparatus so as not to conflict with the state's ideology (Roll-Hansen 2015). Finally, in *technocratic* societies, scientific research is linked to technological innovation and undertaken by companies and public research organisations seeking to profit economically from the knowledge produced (Ziman 2008b).

Changing cultures over the last hundred years or so have had a large impact on the institutions pursuing science as well as on the nature of research. Thus, academic science as pure *basic* research at universities has been facing competition from post-academic science in the form of *strategic* research mainly done in government labs and *applied* research with and within the industry. Thus, what science gets done is nowadays largely driven and shaped by governmental, financial, industrial, military and legal demands for knowledge and products. Public perception and science policy are both questioning increasingly the trustworthiness of science and dividing resources between 'theoretical' and 'practical' science, often under the rubric of 'societal problem solving'. This last definition would be the one that resonates most closely with a western public's view of the reason—more the need for—science. In this way, society is defining ever more a role for science that is consistent with predominating political agendas, as exemplified by the move from politically, but perhaps not culturally, neutral 'theoretical' science for the common good to 'practical' science dealing with specific technological problems.

The autonomy of science (and of liberal democracy) can be undermined as exemplified, perhaps *in extremis*, by the regimes in Nazi Germany and in Stalinist Soviet Russia (Graham 1992; Soyfer 2001; Roll-Hansen 2015). In response, scientific freedom and autonomy were defended *inter alia* by the philosophers Karl Popper and Thomas Kuhn, although with different aims (Fuller 2003). Robert K. Merton contributed importantly to this debate by introducing four regulated principles or norms for the ethos of science (Merton 1942). As science is not only knowledge in itself but the product of society, these epistemic norms have been also linked to social norms. They can be summarised as CUDOS: Communality: All scientists should have common ownership of scientific knowledge because scientific findings are always a product of collaborative efforts and 'constitute a common heritage in which the equity of the individual producer is severely limited'. Universalism: Scientific work should be evaluated on the basis of 'pre-established impersonal criteria: consonance with observation and with previously confirmed knowledge' because scientific validity should be independent of the sociopolitical status and person. Disinterestedness: Scientific work should remain uncorrupted by self-interested motivations. It is defined by objectivity, reliability and credibility; its results as facts and theories lead to paradigms and models of the working of the world and wider and act for the benefit of a common scientific enterprise, rather than for the personal gain of individuals within them. Organised Scepticism: Scientific facts and results need to be tested and justified, and should be exposed to 'detached scrutiny of beliefs in terms of empirical and logical criteria' before being accepted. This means that scientific findings are presented transparently so that they can be assessed and judged by society according to accepted standards and criteria. An important question to ask however is whether these Mertonian norms still have a role in post-academic science.

Do the Mertonian Norms Still Have a Role in 'Post-Academic Science'?

Although creating knowledge, post-academic science does not fully conform to Merton's norms (Ziman 2008b). In academic science, the norm of Communality requires scientists to produce evidence for a specific hypothesis. References are limited to accepted and cited literature. In post-academic science, the norm of Communality is extended and replaced by 'Communication'. The need to get the latest information via alternative means of communication such as preprints frequently enables the availability of results before being assessed completely by reviewers. This increase in popularisation of science comes with the danger of misinterpretation and can lead to compromised credibility. In addition, scientists are increasingly pressed by politicians/industry for so-called quantitative assessments of their careers and output known as 'bean-counting' via, *inter alia*, H-index, impact factors, number of patents. In fact, the scientific role played by such indices is illusory because hiding within the comfort zone of quantification does not necessarily furnish any strategic usefulness. The established peer review system for scientific manuscripts has increasingly been questioned but without satisfactory suggestions as to its replacement (Schroter et al. 2008; Siebert et al. 2015).

Academic freedom is constrained as contracts with companies who finance research frequently demanding that all research activities must be recorded systematically and be kept secret. The argument that is often made is that companies have invested large resources in developing the scientific products demanded by society such that they earn the right in law to patent and restrict the divulgence of research results. Two comments are relevant here—the first is that among the legal criteria for patents are that they are rewards for particular types of invention and not for the amount of effort needed to develop the products of research; the second is that for many years Switzerland had a strict no-patent policy in an attempt to foster the development of fledgling chemical and later pharmaceutical industries (Vatiero 2016)—the message here being that start-ups are not likely to benefit from strict intellectual property agreements and it is mainly more mature concerns looking to protect their market share that finds them especially useful.

While in academic science the norm of Universalism applies, in post-academic science, Universalism is replaced by Utilitarianism. Researchers are constantly reminded that their work is sponsored and that the application of research results, therefore, must be profitable in a narrow sense. In academic science, the norm of Disinterestedness applies. In post-academic science, it is dismissed because of funding constraints and disclosure agreements by the industry which could lead to conflict of interests (Ziman 2008a).

A sceptical view of research, which has been performed, is an important norm in academic science. It is instantiated by asking the questions to be researched (falsification of hypotheses sensu Popper) and setting the answers obtained into a context (i.e. paradigms sensu Kuhn). Post-academic science does not apply this norm fully as it is too dependent on funding agencies and politics such that proposals are based on work to be done. Thus, contract research is ordered by funding bodies who request proposals which still have to present their originality but limit possibilities for creativity because these proposals have to fit into politically defined programs. Often nothing new can be started until a grant for a specific project is obtained. Fierce competition for funding and evaluation of these proposals can lead to nepotism, plagiarism and conflicts of interest. The reproducibility of scientific investigations is an integrated part of the scientific method. There has been increased awareness that some experiments cannot be replicated (Baker 2016) and efforts to overcome the 'replication crisis' have been discussed (Schooler 2014).

Science and Policy

Distinct scientific disciplines have merged with technological disciplines. The outcome is that basic and fundamental research (original investigation of phenomena without an application) has merged with strategic and applied research and development (R&D; knowledge towards a specific aim, products or practical gains) emphasising economic goals and achievements. 'Techno-science' (sensu Latour 1987) has become a substitute for science, signalling the view that the difference between science and technology is not important (Roll-Hansen 2015). As a result, society via science policy increasingly demands that science is extended by R&D and contributes to innovation and creation of wealth. In totalitarian states, it can become an instrument of oppression while in democratic countries it is often influenced by the competing interests of government policy and the industrial economy which in turn inhibits a vision of any other role of science in society. Thus, as research priorities and programmes are defined and the performance of scientists are evaluated, science has become identical with its usability and Merton's norms have been replaced by utilitarianism writ large. Academic freedom and autonomy, while dependent on liberal democracy, have become more and more obsolete as academic science is losing its institutional independence.

However, basic and fundamental science is still relevant and beneficial for society as a source of reliable, rational, unbiased and independent expertise. The norms of originality (novelty) and scepticism (appreciation of the strengths and weaknesses) of academic science still apply, as results need to be tested, justified and shared with others (communalism). For example, the impact of global warming was at first mostly overlooked, i.e. regarded as academic science, but the science of climate change has since become utilitarian and a highly political topic. Post-factual politics as typified by the recent Brexit campaign in Great Britain and the US presidential campaign are deeply disturbing (Hossenfelder 2017). Thus, the role of science in political decision making has changed, as science policy has become politicised science. This is exemplified by the disdain for 'so-called' experts on the evidence of anthropogenic sources of climate change. The New York Times environmental correspondent has postulated that we now live in a 'fact-less society' in which opinions carry as much weight as evidence and personal narratives and experiences are seen every day in social media and news programs—the personal has become the message of the media, to misquote McLuhan (1967).

On the other hand, evidence has come under attack from interest groups opposed to doing anything about issues such as climate change or the use and introduction of the products of biotechnology in Europe—on the basis that the evidence is either not strong enough or that actions to deal with these issues are not warranted. Such pressure from lobby groups have been seen many times before, as exemplified by Naomi Oreskes and Erik Conway who in their book 'The Merchants of Doubt' have shown how the public, on issues such as the link between tobacco and cancer, acid rain, the ozone hole and global warming, has been influenced using replays of the same tricks and methods to discredit scientific research that threatens private interests (Oreskes and Conway 2012). Thus, scientists were used to dispute findings of other scientists. Alternative 'facts' and explanations for observations were provided, thus creating the impression in mass media that there are more sides to every question.

The situation is fluid, however—the IPCC Fifth Assessment Report was met with little opposition from the fossil fuel lobby when compared with the Fourth Assessment Report, since one cannot really pull the same stunt twice. The case with biotechnology where medical biotechnology engenders almost no resistance in Europe, whereas agricultural biotechnology meets considerable resistance, shows again the two-eyed attitude of society towards science. Issues related to these two ends of the spectrum are the questions of who benefits, the status and use of patenting and a bucolic view of agriculture.

Intrinsic Constraints to Science—Agronomy and Food Production as an Example

Agronomy is the applied science of crop and plant production for food, fibre and energy. It is intrinsically multidisciplinary—it encompasses plant genetics, plant and crop physiology, climate and meteorology and soil science and expresses these interactions in terms of interactions between genotype (G), environment (E), management and technology (M).

Agronomy has to anticipate the contributions that can be made by novel developments in other disciplines, such as gene technology, remote sensing, systems theory, software developments as important for predictive simulation modelling. Agronomists need to have knowledge of biology, chemistry, ecology, climate, soils and genetics. Agronomy also has to move away from traditional approaches towards a more integrated focus on the multiple functions of agro systems rather than on short-term yield alone, while maintaining its primary focus on understanding, describing and predicting the consequences of sustainable primary production. A tangible and acute issue for agronomy is that of raising the productivity of cropping in the face of climate change and more variable conditions for crop growth. How might agronomy and how might other disciplines approach this issue?

What is to be absolutely avoided in this debate is ideology, typified by the current conventional wisdom that '-omics' has the major part to play in improving yields as exemplified, for example, by the claim that improving Rubisco's carbon-dioxide-fixing capability by genetic engineering is able to enhance crop productivity significantly on its own (Ellis 2010). There is a current tendency towards genetic determinism in many areas. The 'gene-as-determinant' tendency is not driven by scientific principles but by large corporations that see both profit and market control in biotechnological products such as genetically modified organisms (GMOs). In order to claim originality, usefulness and thus patent rights require the establishment of the conventional wisdom and ideology that genes dictate nearly all properties of organisms and secondly that using biotechnological tools creates inventions. This 'gene-as-determinant' concept is also highly scale dependent; the notion that genes control processes may apply at the level of individual plants. However, the frequency with which genes appear at the level of a population depends on processes such as competition, symbiosis, parasitism that affect gene frequencies—in other words the field of population genetics.

Ideologically-based plant breeding can lead to disaster (Soyfer 2001). In the 1920s, the Russian botanist Nikolai Vavilov identified the historic centres of variation and origin of crop plants. For this, he was awarded the Order of Lenin. However, in 1940 he was imprisoned and later died on the pretext that he was an advocate of the 'bourgeois pseudo-science' of genetics (Janick 2015). The reason for such a human and scientific *volte-face* lies with the 'peasant scientist' Trofim Denisovich Lysenko, who was helped by Vavilov through the Soviet scientific hierarchy to become a Fellow of the Ukrainian Academy of Sciences, president of the Lenin Academy and thereby administrator of Soviet agricultural science under Joseph Stalin. Lysenko rejected genetics and the classical inheritance theory for which Vavilov was an exponent, for the almost 'occult' hybridization theory that approached Lamarckism; that the environment during a life cycle affects hereditary characteristics which are then passed on to subsequent generations (Soyfer 1989).

We know today that there is evidence that the perception of environmental stress induces signals that in turn induce changes in the activity and/or expression of epigenetic regulators. Epigenetics is 'the structural adaptation of chromosomal regions so as to register, signal, or perpetuate altered activity states' (Bird 2007). While the DNA sequence is mostly static and identical for essentially all cells of a given organism, chromatin structure is highly dynamic and cell-type specific. It has recently been shown that epigenetic regulation is based on the structure and confirmation properties of chromatin modulated by small RNA's, methylation of DNA and different modifications of histones. The accumulating knowledge on chromatin structure and dynamics resulted in the concept of a chromatin 'code' (Thellier and Lüttge 2013). It has been suggested that this code can store information as epigenetic memory (Eichten et al. 2014) while other changes can lead to transient acclimation responses (Chinnusamy and Zhu 2009). However, whether these epigenetic modifications are involved in intra- or even trans-generational responses in crops is an important question that needs further investigations. On the other hand, there may be cases where non-nuclear DNA, the structure of which can be changed during ontogeny, could lead to inherited phenology's giving a *sotto voce* of support for the theories of Lamarck.

Epigenetics provides a small potential for 'Lamarckism', but in the Soviet Union of the 1930s, Lysenkoism was the conventional wisdom because it was in agreement with Marxist theory that the environment was totally decisive for things as diverse as wheat yields and societal development. The deployment of Lysenko's theories contributed to famine in the Soviet Union in the 1930s. Lysenko has become an unpleasant footnote in the history of genetics but his story shows the danger of basing plant breeding on ideology, from whichever side of the political spectrum it comes (Roll-Hansen 2005). Nevertheless, inspired by the connection between epigenetics and inheritance there has been a recent rebirth of 'Lysenkoism' and calls for rehabilitation of Lamarck and Lysenko by many scientists in Russia as documented in a recent book by Loren Graham (Graham 2016). In addition, the conversion of spring wheat into winter wheat and vice versa has recently been discussed (Li and Liu 2010). Incidentally, biotechnology policy in the USA has been linked to the 'ghost of Lysenko' (Miller 1995). The same has been applied to global warming (Ollier 2009).

Improving global food security in the face or climate change and population growth is a many-faceted challenge that is not even restricted to the production of food, let alone the production of the basic food commodities like rice, wheat and maize. It encompasses the demand side of the equation (i.e. diet and animal feeds) as much as the supply side; it has to take account of demographic shifts from rural to urban living and how we could process and use waste. In the end, it requires a shift in values from food and its production being a private and commercial activity to becoming more of a public–private partnership. GMOs cannot solve the global problem of feeding people. This can only occur via an alliance between G, E and M brought about by more interdisciplinary than single-disciplinary research efforts.

Interdisciplinary projects are seen as unconventional and are often not funded. The authors have argued for the need for more multidisciplinary research approaches to tackle the study of climate change on crop yield and quality (Wollenweber et al. 2005). This is important because, as scientific disciplines have become increasingly diversified, a more complete understanding of the mechanisms by which genetic and environmental variation modify grain yield and composition is needed. Despite recent achievements in conventional plant breeding and genomics, the rate of increase of crop yields is declining. There has been recent progress in individual scientific disciplines, but future paradigms need to be characterised by multidisciplinary 'joint' efforts in order to achieving sufficient grain yield in the future as advances within a single scientific discipline cannot solve these challenges. Genomics, proteomics and metabolomics may increase our understanding of the regulation of different physiological processes and mechanisms of resistance to stress, but they do not show us the bigger picture.

The capital-driven focus on '-omics' and genes has led to losing two generations of young researchers who know about how whole plants grow and develop in populations in the field—where the best agricultural research has always and always will be performed. It is always easy to allow areas of science to go into decline but it requires much more effort to rebuild disciplines of science once they have gone. The situation with molecular biology in agriculture is that there have been 30 years of 'promises and more promises' but with no tangible outcomes to date, except for herbicide resistance and single gene pest resistance. And there will not be major breakthroughs in the areas that really matter such as adaptation to climate change because the methods being employed are, in the words of Wallace and Gromit 'the wrong trousers to be wearing'. A recognition of the balance and interactions between genotype, environment and management is the intelligent solution to feeding the growing global population (Porter and Wollenweber 2010).

Conclusions

The culture for science in an age verging on the equivalence of opinion and evidence-based knowledge is not good now but it has been much worse in the past and in the end science wins because humans use evidence-based thinking in their daily lives and that is what science is. It is humanly constructivist in the largest sense. We have asked three questions:

1. What are the function(s) of the Mertonian norms?
2. How do the norms of society affect the Mertonian norms either in defining them or implementing them?
3. Do the Mertonian norms still have a role in 'post-academic science'?

Our answers are:

Current science is increasingly driven by a number of extrinsic and intrinsic constraints to its norms and methods. Scientists, at least the most productive of the tribe, are principally driven by curiosity and a desire to be 'the first' to discover or describe and publish a phenomenon (Communality, Universalism). They are generally not much interested in huge sums of money as reward (Disinterestedness) and thus have an ambivalent attitude to the 'corporate culture' that has come to be the driving *leitmotif* of many faculties of post-academic science in those universities who depend on a combination of public and private resources to keep their organisations afloat. The fact is that large organisations, be they public or private, are extremely bureaucratic and many universities have moved far from the original Mertonian norms.

It is probably possible to harvest the industrial interest on previous intellectual capital generated from a 'curiosity culture' for a certain length of time. However, many research funding organisations have essentially started to use university researchers as contract consultants to deal with the problems and issues that are short term and frankly mostly boring for research scientists, with success rates for research applications in many cases below 10%. No industrial concern could tolerate such a waste of talented human resources. The fact is that the notion of 'corporate culture' as practised in universities is in our view one-eyed. It has implemented the competitive aspect *in extremis* in terms of making extremely talented people compete constantly for the limited available funds that often have to cover their own salaries whilst at the same time ignoring the intellectual waste, over-management and burdensome bureaucracy that now characterise many institutions of higher learning.

This situation has led to a culture among scientists to give as little output for as much funding as possible and then use the money to do things they think of as interesting; the moral quandary for scientists is how little they can get away with in using short-term funding yet still do some interesting work—this loss of innocence is a direct result of politicians and industry not understanding or even ignoring the Mertonian norms. This tendency, in the end, is intellectually corrosive and ultimately short-sighted in its application of a 'corporate culture' in extremis in universities—the 'tail wagging the dog syndrome'.

Science has to draw lessons from the past and has to identify and criticise evident pseudo-scientific claims related to faith and religion such as climate change denial, biodynamic agriculture, Lysenkoism, scientific creationism and Intelligent Design. The age of enlightenment (coined by the German philosopher Emanuel Kant), also called the age of reason, brought about by the scientific revolution replaced superstition and religious doctrine in the seventeenth century. If significant advancements in science are to be maintained in the twenty-first century, a new age of dispassionate reason has to include a better dialogue and understanding between science and society. The way ahead is that society, the public and their leaders, have to understand and accept that science provides reasonable, evidence-based facts and not 'fake news'. Global warming has placed scientists in the forefront of the political debate. The power of scientific reasoning lies in its ability to make accurate and precise predictions on basis of systematically acquired evidence. Scientific controversy and organised skepticism are intrinsic norms of scientific endeavours. Threats to the objectivity of science have to be acknowledged and dealt with. A better awareness of scientific pitfalls and balance between academic and post-academic science has to be implemented, more long-term funding for interdisciplinary research efforts and for gifted scientists have to be implemented.

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