Science, Democracy and Relativism

Science, Democracy and Relativism: The Production and Dissemination of Scientific Knowledge from the Viewpoint of Communitarian Epistemology

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PUBLISHING

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This book first published 2014

Cambridge Scholars Publishing

12 Back Chapman Street, Newcastle upon Tyne, NE6 2XX, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-4438-5337-2, ISBN (13): 978-1-4438-5337-8

The present work is dedicated to †Anthi and Sofia, Yiannis and Ioannis.

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Acknowledgements

I wish to thank all the persons that made it so that this work has reached the printing press. My Parents and Family, my Teachers and Friends, you all know who you are and I will be eternally grateful to you All. Thanks for Everything!

I would like to specifically thank my supervisor, Professor Alexander Bird, and my mentor during my later years at Bristol, Professor Emeritus Ken Binmore, for, dare I say, appearing (at least) to have shown some faith in me.

PREFACE TO THE READER

The present work is the result of the blending of many pre-sentiments rather than ideas that I have gathered since I began observing the world. In this brief introduction I will attempt to lay out some of these, in the hope that the reader will better understand the argument laid down.

A first guiding impression was the cacophony of languages encountered at the European School in Brussels, when one may learn to swear in most of the languages of the European Union before they reach puberty. At such a young age, the live encounters with children from different countries provided me with an appreciation of community diversity that has motivated me ever since and to which I sometimes think is akin to the methodological relativism employed by some anthropologists. Much later, this led me to a conversion to the idea of language relativity, which is roughly the idea that the structure of a language affects the way we conceive of the world, that is it affects our world-view. Hence the idea of communities that I advance here has linguistic communities as its progenitor. An advancement of this view may be of course to conceive of scientific communities as akin to linguistic communities and of their activities as forms of language games in a Wittgensteinian sense.

Puberty in a rather conservative, predominantly Christian Orthodox society such as urban Cyprus twisted my teenage rebellion into one against all forms of power and domination, rather than as one purely against God. In the dilemma between Jean-Paul Sartre and Albert Camus I chose to read the latter, whose portrayal of the absurdity of life somehow meshed with my local priest's message (at an age when my football-playing friends were reprimanding me for not identifying with Che Guevara and the Sunday-school kids were fed up with me asking questions all the time, I was lucky that my parish priest had the patience to listen to my questions and engage with me) of the imperfect nature of humans. This interplay between a good-natured religion and teenage rebellion helped me much later, when it gave me the power to question science's (or any institution's, for that matter, including religion) superiority in leading to the Truth in a predominantly positivist University of Bristol Department of Philosophy. Hence I became sceptical of the Truth and began supporting truths, and finally, in order to eradicate power-games (call it mistimed teenage romanticism), of truths constructed through consensus.

Unfortunately so far I have been unable to rid my life of power-games, indeed sometimes they seem to be the only spice of life. However, as many a postgraduate writing their magnum opus, I have found solace, as well as the will to continue my quest in communities such as the open-source software communities and projects like Ubuntu and Wikipedia. Such co-operative, well-structured communities have shown me that co-operation may be a genuine alternative. The mobilisation of students in Britain in 2013 showed me that this approach can be fruitfully carried through to the way politics is conducted, something which brings me to the final pre-sentiment, that of democracy.

As a teenager being fed with the past glories of Hellenism, I was given through my schooling a deeply distorted yet deeply utopian vision of democracy, drawing on the ancient Athenians for inspiration (ignoring for a moment other bits of our education, such as Thucidides, that portrayed Athenians as brute imperialists during the Peloponesian Wars). This, after a belated rebellion against monarchy during my first years in the UK, translated into the conviction that debate on societal issues, or in any case debate about issues that affect the well-being of the whole or a part of a society ought to be simple enough to be within the grasp of the well-informed lay-person, and that the lay-person ought to participate in the deliberation process as directly as possible. And that this should include issues that have a scientific element embedded. Otherwise one need not bother with democracy, instead preferring the rule of the experts, which, among other things, may prove to be more efficient and better in many respects. Somehow, in a manner which until today I fail to articulate clearly, this seems to me rather paternalistic and in any case not democratic, at least not democratic in the original sense of the word as rule by the people; hence the clash with the whole edifice of modern liberal democracy.

With these considerations in mind, I am now ready to offer this work to you, the reader. Keeping in line with the last paragraph, I hope that my argument is simple enough to be easily understood. Roughly, I argue that democracy dictates that no man's opinion matter more than anybody else's on a topic of societal concern – including experts (Chapter One). I then proceed to argue that current studies of perceptions of science favour a view of science favouring the formation of scientific elites, along with science communication efforts and popular science books (Chapter Two). Keeping in line with the democracy strand of the argument laid down in Chapter One, in Chapter Three I argue that education for citizenship and science education can reinforce each other in producing citizens well-enough informed to be able to adjudicate and exert control over technicallyladen decisions. Furthermore, I begin to explore some of the philosophical implications of the epistemological view that I am proposing. In Chapter Four I venture into a lengthy defence of communitarian epistemology, the theory of knowledge that I am advocating, as one accurately describing both the production and the dissemination of scientific knowledge. Chapter Five consists of an original defence of a philosophical view on meaning associated with communitarian epistemology. Finally, Chapter Six marks a return into more practical territory, by sketching how a "communitarian" field of science would look like, through the example of sustainability science.

I hope the above is helpful enough to lead to a thought-provoking reading of the book.

Nicosia, July 2013

CHAPTER ONE

SCIENCE AND DEMOCRACY

1.1 Introduction

The topic of the present work is the relationship between science, democracy and epistemology. I offer a philosophical defence of communitarian epistemology as appropriate and conducive to a society which is truly democratic, and where scientists involved in policy are held in check from forming unelected and unaccountable elites.

In this chapter, by way of introduction, I will delineate the domain of my thesis and sketch the main motivations behind it. I will do this first by presenting a picture of science emerging from remarks by science popularisers and some standard rebuttals from the consensus among philosophers and sociologists of science. The topic is what science cannot be, thus highlighting the difficulties of providing a definition of the term "science". I will then show how science is indispensable to the modern state, by highlighting its role both as sustaining the economy and on policy-making. Following this I will move onto a discussion of democracy. Through the examination of different notions of democracy I aim to show the sheer contestedness of the whole domain, before moving back to examine the interface between science and democracy. I will look into different models of this interface, before hinting at my preference for a model in which the lay public is inextricably involved. I will lay down the foundations for an egalitarian model of democracy before finally elaborating on the role that scientists will play in such a model. This will lead me into a first consideration and linking together of communitarian epistemology, scientific knowledge and society and suggesting a look at lay perceptions of science and their origins, something which will be the topic of the second chapter.

1.2 Remarks by science popularisers and the consensus in philosophy of science

In this section I will contrast a picture of science emerging from assertions by practising scientists and popularisers with rebuttals from the fields of the sociology of science and the philosophy of science, thus showing how difficult it is to define “science”.

1.2.1 Remarks by science popularisers

I will begin presenting a popular picture of science through two quotes from Lewis Wolpert's 1998 Medawar Lecture, in which he lays down a demarcation between science and technology. Wolpert asserts that “[...] science provides the best way of understanding the world in a reliable, logical, quantitative, testable and elegant manner. Science is at the core of our culture, almost the main mode of thought that characterizes our age.” (Wolpert 2005, 1253)

Furthermore, in drawing the distinction with technology, he asserts that

> The distinction between science and technology, between knowledge and understanding on the one hand, and the application of that knowledge to making something, or using it in some practical way, is fundamental. (...) Technology is much older than anything one could regard as science and unaided by any science, technology gave rise to the crafts of early humans, like agriculture and metalworking. Science made virtually no contribution to technology until the nineteenth century (Basalla 1988). (Wolpert 2005, 1254)

Another remark comes from an introduction of a book celebrating science, entitled “The new optimists” (Richards 2010). In his introduction the editor, Keith Richards, notes that

> For professional scientists, living down the wilful distortions and extravagant promises made on their behalf by the popular press is an occupational necessity, but seeing science downgraded to just another belief system is harder to swallow. Scientists, like the rest of us, have plenty of beliefs, but the pursuit of science does not allow the luxury of indulging them at the expense of proper procedure.
>
> Science is a way of trying to understand and explain the way things work. It is driven by endless curiosity coupled with a determination not to be beguiled by easy answers.” (Richards 2010, xiii)

A further attempt to philosophically ground scientific theorising and practice comes from Stephen Hawking's and Leonard Mlodinow's hugely popular “A briefer history of time” . Hawking and Mlodinow, conclude their Chapter that has to do with the nature of scientific theorising by identifying curiosity and the thirst for explanation as the underlying motive of science:

> But ever the since the dawn of civilization, people have not been content to see events as unconnected and inexplicable. We have craved an understanding of the underlying order in the world. Today we still yearn to know why we are here and where we came from. Humanity's deepest desire for knowledge is justification enough for our continuing quest. And our goal is nothing less than a complete description of the universe we live in. (Hawking and Mlodinow 2010, 18)

Before addressing the argument from curiosity, however, I will look into two more attempts at a philosophical grounding of science by scientists themselves.

The first is an attempt by Brian Greene, in his popular book “The fabric of the cosmos”. Greene states:

> And physicists such as myself are acutely aware that the reality we observe – matter evolving on the stage of space and time – may have little to do with the reality, if any, that's out there. Nevertheless, because observations are all we have, we take them seriously. We choose hard data and the framework of mathematics as our guides, not unrestrained imagination or unrelenting skepticism, and seek the simplest yet most wide-reaching theories capable of explaining and predicting the outcome of today's and future experiments. This severely restricts the theories we pursue. (Greene 2004, ix)

The last quote comes from Alan Sokal and his book-length polemic against what he terms “the postmodernists of the left, the fundamentalists of the right, or the muddle-headed of all political and apolitical stripes” (Sokal, back cover). In his foray into defining a coherent philosophical position vis-a-vis scientific knowledge and scientific methods, he states that

> For us, the scientific method is not radically different from the rational attitude in everyday life or in other domains of human knowledge. Historians, detectives and plumbers – indeed, all human beings – use the same basic methods of induction, deduction and assessment of evidence as do physicists or biochemists. Modern science tries to carry out these operations in a more careful and systematic way, by using controls and

> statistical tests, insisting on replication, and so forth. Moreover, scientific measurements are often much more precise than everyday observations; they allow us to discover hitherto unknown phenomena; and they often conflict with "common sense". But the conflict is at the level of conclusions, not the basic approach. (Sokal 2008, p.178)

I will now contrast these remarks with the broad consensus in the philosophy, sociology and history of science.

1.2.2 Rebuttals from the history and philosophy of science

1.2.2.1 The "scientific method" and its characteristics

In what follows I will expose a well-known argument against progress in science, as well as two short arguments rebutting some of the quite naïve, philosophically speaking, assertions concerning the manner of science. These two arguments reflect the current consensus in the philosophy and sociology of science.

A first common thread in the above quotation is the view of science as consisting of some sort of method, or "procedure". However, the idea of defining science in terms of a methodology, in terms of criteria that would delimit this "mode of thought", has been largely discredited for philosophical reasons. The quest for fixed methodological criteria unique to science has largely fizzled out in recent years, thanks to the critiques of Feyerabend (1993) and Laudan (1978). A more radical extension of this view (from outside of philosophy, this time) may be found in Jenkins (2007) who argues that science as a unified enterprise and the scientific method are essentially 19th century political constructs and that school science is a misrepresentation in that it ignores important philosophical, conceptual, and methodological differences between the basic scientific disciplines. In the philosophical literature, the naïve unity of science project which gained momentum with Oppenheim's and Putnam's paper "The Unity of Science as a Working Hypothesis" (1958) has conceded a lot of ground to weaker methodological or heuristic theses of unity ([Fodor 1974], [Wimsatt 1976]). On the other hand, the mid-nineties have seen the emergence of arguments for the disunity in science being grounded in the fragmented nature of the natural world itself, such as the patchwork picture of the scientific universe described by Cartwright (1999) or the pluralist picture described by John Dupré (1993). These pluralist approaches however still insist on their realist credentials, as opposed to other anti-realist, non-realist or relativist epistemologies and ontologies.

A second family of views reflected in the above quotations consists in describing science variously as reliable, logical, quantitative, testable and elegant. I will give a couple of arguments against these assertions, even though the sheer variety of practices adopted by paradigmatic natural sciences should be enough to deter knowledgeable people from making such generalisations.

I will focus on three arguments that counter two main claims referred to in the quotations above. The first argument that counters the assertion that the manner of science is reliable, in the sense that its results invariably drive us towards truth, is the sceptical argument of pessimistic meta-induction, which has been spelled out by Larry Laudan (1981). Laudan's argument roughly claims that we have no reason to believe that key terms of our best scientific theories genuinely refer, as the history of scientific ideas is full of entities which have been later dismissed as non-referring. Examples of this are entities such as the ether, caloric, humours, etc. As regards theories themselves, a similar argument may be run: the historical record is full of dead theories, so there's no good reason to claim that our current theories are on the right track as regards their claims of being genuine candidates for approaching the true fabric of the reality that surrounds us.

The second and third short arguments that I will now propose concern the assertions that science is somehow “elegant” and that this elegance proceeds in part from the harmony and logical character of their most cherished equations.

In order to answer the first part, one may derive a lot of material from physics, which is regarded by some as the most paradigmatic natural science. The laws of physics, as Cartwright (1983) points out, can be separated into phenomenological and explanatory ones, the first being more related with what really happens in experiments, whilst the latter are generalisations and abstractions designed for ideal conditions. As Cartwright claims, the former are usually the elegant ones which possess much explanatory power but apply only to idealised conditions and hence never explain experimental phenomena, whereas the latter are usually more “messy” and do not possess the elegant character of the former, but they have more success in assessing and predicting experimental data.

As concerns the logical part of science and the beauty derived from its explanatory laws and their “logic”, one may countenance the claim that perhaps logic is not so much a given embedded in scientific procedures but is rather an empirical discipline which co-evolves along with paradigmatic successful theories. For example, Wilce (2006) states that “Some have argued that the empirical success of quantum mechanics calls for a revolution in logic itself”, something which indicates that quantum mechanics may redefine how we see logic. Hence, a revision in some cherished laws of logic such as that of the excluded middle is required in order to be consistent with the results and theoretical baggage of quantum mechanics.

1.2.2.2 Aims of science

In his second quote, contrasting science with technology, Wolpert distinguishes between the aims of science and technology in the following way: science, according to Wolpert, has the aim of obtaining understanding and knowledge of how the world works, whereas the aim of technology is more practical and doesn't focus on systematic knowledge. The same train of thought is to be found in a more dramatic fashion in the Hawking quotation, whereas it is also a part of Richards' quotation. I will here argue that the two aims, the purely epistemic-curiosity driven one and the instrumental one, cannot be neatly separated, and that furthermore the claim that science is only concerned with knowledge is untenable. My argument will begin by the consideration that scientific inquiry has often been made possible by practical, or at least non-epistemic beliefs, needs and innovations. Through this I will show that considerations other than that of the quest for understanding and of knowledge of how the world works were necessary for science to even get off the ground. I will then argue that the position that science's sole aim is knowledge is untenable and also that there is no evidence that a quest for objective truth leads to progress, which seems to be the ultimate aim of the "knowledge as understanding of the world" view. Finally, I will present an argument that in any case the distinction between fundamental and applied research is relative to the given context. These considerations will serve to undermine the claim that a neat separation between the aims of science and technology can be made.

The first example of innovation being necessary for "science-as-understanding of the world" may be discerned by Cardwell's (1972) study of western science and technology. Whilst Cardwell locates the origins of science in the 17th century, (1972, 3), with the systematization and institutionalisation of scientific inquiry, he also hails the impact of two technological innovations (the weight-driven clock and the printing press) that form the "twin pillars of our modern civilisation" (1972, 12). He claims that the Newtonian notion of absolute mathematical time, and the dissemination of printed material that allowed the lively dialogue among scholars in fact enabled science to emerge. Another example of standardization as an important factor enabling scientific inquiry is given by Chang's (2004) study of thermometry, and the historical and other contingencies involved in finding the fundamental truth of the constancy of a boiling point for water, which in turn paved the way for thermometric scales. Finally, in a non-european context, Baber (1996) shows how the invention of the spinning wheel in England, which triggered the industrial revolution, as well as research into dyes in chemistry, were both a result of the British effort to displace India from its dominant position as the world's supplier of dyed textiles. Furthermore, Baber also gives an example of how in ancient India the development of mathematics and astronomy related intimately with the religious background and how mathematical problems were linked to practical problems such as constructing appropriate sacrificial sites. (Baber 1996, 27)

The relationship between "pure" scientific inquiry and technology may also stretch not only in the past, but also in the future. Kitcher (2001, 89) notes that

> we may look forward and recognize that there are readily envisageable ways of linking the results of inquiry (or the possible results if the inquiry develops in a particular foreseeable way) to practical projects that others could be expected to pursue.

A similar line of argument is often invoked in defences of projects such as the Large Hadron Collider, where defenders of the project being proposed often have to resort to past practical innovations that have been developed as a result of related spin-off technologies, in order to secure funding for research they would consider as "fundamental". In conclusion, the above examples show that the basis of the distinction that Wolpert makes, do not correspond either to the history of science nor to its current manifestations.

A further powerful set of arguments against the view that the aim of science is an overriding concern with knowledge and understanding of truths of the natural world comes from Kitcher's proposal of well-ordered science, whose aim is to uncover "significant truths" (Kitcher 2001, ch.7).

Kitcher explodes the view that the aim of scientific inquiry consists solely of context-independent epistemic considerations, by considering an analogy with cartography and showing that there is no such thing as an "ideal" map out of which all other maps emerge (2001, ch.5). Instead he develops the idea that science is concerned with uncovering significant truths, with significance being subject to pragmatic considerations, as well as contingent on decisions taken within science in the past.

Kitcher dedicates a whole chapter (2001, ch. 12) to the question whether the quest for truth as an aim of science ought to trump all other values. He links this idea to the Enlightenment secularization of the concepts of truth and rationality, which in turn build on older notions of truth as stemming from the Divine.[1] Kitcher explores different strategies that the defender of the objective value of knowledge-as-justified-true-belief could follow in order to convince their opponent, and finds them wanting. He objects to the argument from a natural disposition essential to humans towards knowledge by arguing that the concept of rationality that would have to be involved in such a defence would be so attenuated that it would scarcely lend any support to a method of systematic inquiry. Furthermore, an overwhelming portion of our everyday behaviour cannot be traced back to manifestations of rationality. He thus fails to find any good arguments for the claim that truth may lead to any progress in our values, concluding his exploration of this question with the claim that

> Behind the often evangelical rhetoric about the value of knowledge stands a serious theology, an unexamined faith that pursuing inquiry will be good for us, even when it transforms our schemes of values (2001, 166).

He thus urges us to dispense with this theological residue, claiming that "We need agnosticism all the way down".

Another way in which the debate about the relationship between science and technology has been framed is to be found in the distinction between "basic", or "fundamental" research on one hand, and "applied" research or science on the other. In practice, however, as Ziman (2000) shows, the complicated system of patronage which is currently in place makes the distinction meaningless, as one funding agency's basic research is another agency's applied research. Ziman further argues that whether some research is fundamental is always relative to some other research, and that being fundamental is not an objective property of scientific activity, but rather that it is a relational one (2000, 21).He states that "In appropriate circumstances, almost any research project might turn out to be 'fundamental' relative to some body of knowledge". (2000, 21)

I thus conclude this section by reiterating my conclusion that, contrary to the assertions of science popularisers, science cannot be separated from technology in terms of the aims of the two activities. Indeed, the term "technoscience" is being used by some authors to describe "ways of making knowledge that are also ways of making commodities, or such quasi-commodities as state- produced weapons." (Pickstone 2000, 113–114)

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[1] See Campbell (1992, ch. 5 and 8) for a discussion of the link between truth and the Divine in early Christian and Medieval philosophy.

1.2.3 The difficulties of defining science

In the previous section I argued explicitly that neither the methods nor the aims of science are unique to it, and implicitly that the fact of diversity in the practices of science makes the task of defining science a very difficult one. A further difficulty in defining science is the issue of the institutionalization. Cardwell claims that the social institution of science only gains significance in the 17th century (1972, 3). However, this appears to be too rash a move with historical studies of the institutionalization of scientific disciplines showing that this process differed from country to country and from discipline to discipline; furthermore sociological, cultural and historical factors were involved and played a crucial role (Lenoir 1997). Again, it seems that the diversity of scientific practices makes it hard to talk of science as a single institution. Finally, it is worth considering the historical argument that the spread of science in Europe began to take place roughly at the end of the seventeenth century, and that widespread dissemination of scientific knowledge only began with compulsory mass education at the end of the nineteenth century. This was approximately two centuries after the Scientific Revolution. (Fuller 1997, 110)[2]

Finally, the social character of science must not be disregarded. Scientific knowledge often consists in claims in which there is consensus as regards their truth among scientists. Wolpert recognises this[3], stating that “Science, ultimately, is about consensus as to how the world works” (2005, 1257).

Given the above considerations and the sheer diversity of practices described as scientific, I will abandon for the time being the attempt to define science in terms of a conceptual analysis of what counts as scientific practice or as to what methods could be termed as scientific. Before moving on to examine the role of science in the 21st century, I will briefly entertain the thought that “science” may turn out to be a family resemblance concept, following Wittgenstein's use of the term. In this case, there is no characteristic common to all its instances, but rather uses

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[2] The sheer diversity of methods and ideas of science may risk including the whole history of ideas, as Feyerabend remarks from a realist perspective: “A science interested in finding truth must therefore retain all the ideas of mankind for possible use, or to put it differently: the history of ideas is an essential part of scientific method” (Feyerabend 1999, 214).

[3] Even though it may be argued that the insistence on consensus may render his hard-nosed realism incoherent, since an eternal mind-independent truth as an aim of scientific inquiry is independent of any consensus.

of the word display “a complicated network of similarities, overlapping and criss-crossing” ([Wittgenstein 1953] cited in [Biletzki and Matar 2011]). The idea that science may be a family resemblance concept, enables us to unite the diversity of scientific practice, however realist philosophers may be a bit coy in accepting the associate notion of language games, as that leads into a relativism about meanings.

I now shift my attention to the role science plays in modern liberal, capitalist societies, in order to bring forth its significance for democracy, which is my main motivation for the current work.

1.3 Science in the 21st Century

In this section I will briefly highlight the role that science plays in modern societies. I will focus on two aspects of science, the role that it plays for the economy, and the role that it plays in solving societal problems. By doing this I hope to show that science and its products are a constitutive element of the social, economic and political life in the 21st century, and that it is inconceivable for us to imagine anything like the modern state without at the same time mentioning science and its products. Of course, it may be claimed that, on a broad understanding of science, it has always been part of the organisation of state administration, however I will elaborate on the 21st century and life as experienced now. The claim that science is indispensable in the economy and in state decision-making will serve to introduce the discussion of democracy, which will in turn introduce the idea of scientists involved in state decision making as members of a ruling elite in modern states.

1.3.1 Science and economic growth

It has been noted above that at least some researchers claim that “pure” science made no significant contribution to technology before the mid-nineteenth century. Despite my rejection of this claim (and of the accompanying distinction between pure and applied science), I have to accept that “pure” science played essentially no role in the Industrial Revolution, which dramatically changed the history of mankind.

Kealey (1996) notes that the major technological innovations in the mechanisation of the textile industry, as well as the successive improvements on the steam engine which was used both in the extraction of coal and its transportation through trains were carried out by

> uneducated, often isolated, men who applied practical common sense and

intuition to address the mechanical problems that beset them, and whose solutions would yield obvious economic reward (1996, 68).

As further evidence, Kealey contrasts the fortunes of France and the United Kingdom in the 19th century. Whereas France had instituted science and was producing great theoreticians, it was the United Kingdom that rose to become the major economic power.

The major changes in the economy may have started in the household; it witnessed in the mid-19th century, according to Mokyr (Mokyr 2002, 151–157), not one but three Scientific Revolutions, which had as a result what may be labelled "the greatest demographic shock to Western demographic history (at least since the Black Death), namely the decline in infectious disease in the industrialised West after 1870 or so" (2002, 167).

Mokyr labels the three Revolutions as follows: the sanitarian and hygienic movement which began in 1815 and was correlated with the statistical revolution that led to the development of epidemiology in the 19th century, the germ theory of disease, which, although not new (Mokyr [2002, 184] claims that it was proposed in the sixteenth century), became widely accepted after the successes of Pasteur and Koch from 1865 onwards, and finally the knowledge that trace elements of certain substances were crucial to human health, and that these need to be supplied through diet, which became more widespread in the beginning of the 20th century after experimental work reporting the inducement of scurvy to guinea-pigs treated with a particular diet. These revolutions had as a result the dramatic reduction of mortality and the accompanying improvement in the quality of life of the population.

However, during that time, which was earlier identified as the heyday of academic science, a more significant revolution was taking place in the economics of scientific and technological change. In 1851, Queen Victoria opened the Great Exhibition of the Industry of all Nations, an event that signalled the rising importance of technological artefacts and commodities. By the 1870s the first corporate research and development laboratories were being set up in Germany, and by the inter-war period in the 20th century R & D laboratories had become institutionalised within firms, especially in the electrical and chemical industries (Coombs, Saviotti, and Walsh 1987, 9). It was also in the second half of the nineteenth century, that the organisation of industrial enterprises in the most industrialised countries began to change, with small family enterprises being increasingly replaced by larger firms which focussed on more than one activity and in which the division of labour played an important role. It is important to notice that technological change as embodied by the mechanisation of the processes of production and other aspects of trade such as refrigeration and transport technologies, was one of the factors that helped bring about organisational changes in the firm (Coombs, Saviotti, and Walsh 1987, 8).

Three final points are worth making on technological innovation as related to the economy. The first is that whereas earlier economists and economic historians regarded technological innovation as exogenous to the economic system, in that innovation was regarded as independent of economic factors, Coombs et al. (1987, 6) argue that common features of economic processes of innovation arise because technological innovation is regarded as endogenous to the socio-economic system. Secondly, and as a consequence of the first point, progressive division of labour and the systematisation of technological change result in an increasing instability and dynamism of the socio-economic system (Clark 1985, 39–40). In a way, technology breeds technology. This brings me to the final point, which is to point out the failure of the old Baconian "linear" model linking academic science to economic growth through new technology. Kealey (1996, 216) cites extensive evidence that in fact most technological innovations that make it to the market are improvements on older technology, and that only ten percent of such innovations are a direct result of basic science. Coombs et al. (1987, 4) concur with this view, claiming that studies have shown that there is "no direct correlation between R&D spending and national rates of economic growth". However, the importance of science, both basic and applied, is undisputed, and it is increasingly been seen as a source of solutions for societal problems. To this, the relation between state policy and science, I now turn my attention.

1.3.2 Science and the State

We live in a technoscientific world in which the products of science are the cornerstones of any society, from the provision of electricity and running water to the internet and linear accelerators for the treatment of cancer. As technoscience is so pervasive in daily life, it is perhaps unavoidable that it is increasingly being consulted for the solution of perceived social problems. Primary examples of this are the environmental crisis, the obesity crisis and the fight against various diseases, for which the solutions sought are invariably from the technoscientific domain. As technoscientific solutions are increasingly sought for by policy-makers, questions of public participation in, accountability and responsibility for social action are induced. As Nelkin remarks on these issues,

> Science policy has always involved such dilemmas, but the pervasive influence of science and technology – the visibility of their social impacts

> – has brought growing public concern about technological development and declining confidence in the bureaucracies responsible for technical decisions (Nelkin 1977, 11).

Furthermore, on the muddling of the boundaries between political and technical decisions, Nelkin remarks that

> the increased reliance upon technical expertise has helped to obscure responsibility for major social decisions, weakening the system of checks and balances. And policies, framed in technical language, are often difficult to comprehend or to control (1977, 12).

Before moving into a more detailed discussion of the role science should play in a democratic society, I will briefly address the question whether science can indeed solve social problems. In order to do this I will sketch two contrasting opinions on the subject, and trace the underlying notions of science that motivate these two opinions.

The first answer that I will sketch is the negative one. I will trace two routes towards this answer, the first exemplified by Weinberg's (1972) discussion of science and trans-science, the second by Sarewitz's (2004) discussion on what he labels "the excess of objectivity".

Weinberg claims that a whole class of questions which seem prima facie to be legitimate questions to ask of science, in that they are questions of fact and couched in scientific language, cannot find their answer from within science. Weinberg labels this sort of questions "trans-scientific" and gives as examples cases where science could provide in principle the right answer, given enough time and money for an experiment according to the experimental standards recognised as paradigmatic by science, however such a possibility would be blocked by considerations of practicality, or of very long time-scales, or even ethical considerations. Two other example classes of questions that Weinberg labels as trans-scientific are questions from the social sciences, where the objects of study are too complex and variable to be submitted to any sort of generalisations, and questions whose answers involve aesthetic and moral judgements. Two actual examples referred to by Weinberg, which I will modify slightly here, are the following; firstly, the effect of low dose radiation directly on humans, instead of experimentation using mice. The data that exists actually is derived from data gathered following the explosion of the two nuclear bombs in Nagasaki and Hiroshima, as ethical issues prevent direct experimentation using humans.

A second example comes from the calculation of very low risks but which, when actualised, cause major disturbances or catastrophes. Such events are the recent tsunami case that caused the destruction of the Fukushima nuclear plant, the eruption of the Eyjafjallajökull volcano in Iceland, which caused major disruption to airline travel and led to an interesting re-negotiation of allowed levels of dust within aeroplane engines. The answer to both questions posed transcends science and is firmly in the domain of trans-science.

Weinberg does claim, in a positive note, that although science cannot answer trans-scientific questions such as questions of risk, it can, however, limit their scope by minimising the risk through the improvement of the existing technologies and of current scientific knowledge. Hence, such questions would lose their pressing nature. However, other commentators in the field of science policy are less optimistic, some claiming that the most interesting questions in science are in fact trans-scientific (Barker and Peters 1993, 4).

A different route towards the same conclusion, namely that science cannot answer questions of policy, comes through Sarewitz's claim that science provides "an excess of objectivity". By this, Sarewitz defines the idea that the inability of science to prescribe human action is down to "not a lack of scientific knowledge so much as the contrary – a huge body of knowledge whose components can be legitimately assembled and interpreted in different ways to yield competing views of the 'problem' and of how society should respond" (Sarewitz 2004, 389).

Sarewitz claims that this phenomenon explains why, for example in debates about the environment, additional scientific evidence makes the debates harder, rather than easier to resolve. Sarewitz backs this claim up using the philosophical literature on the disunity of science, as mentioned above. Hence, his claim is that given the multiplicity of world-views within science, factual evidence may support any of a number of different positions on a decision prescribing human action.

However, the same move of linking the aims of science with contingent values, interests and choices of the people practising it can be used to promote the contrary claim that science can and does in fact prescribe social action (Kitcher 2001). A look at the historical record will show that both on a broad definition of science, and on a narrower (as the institutionalised activity that has become prominent in the last two centuries), technoscience has often been used to decide social, political and economic issues. Nonetheless, it ought to be recognised, as the historical record shows, that technoscience is by no means the only way of solving such disputes, and that furthermore it may not even be in a privileged position to prescribe good solutions. Some of the solutions given by technoscience are judged in retrospect to be good and useful,