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Article

The Progress of Science—Past, Present and Future

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Abstract: Scientific orthodoxy based on the acquired authority of some scientists has seriously hampered the progress of the natural sciences in the past and continues to do so today because of new societal influences, such as directive funding and political interference in the setting of research objectives. Enhancing the progress of science must continue to be an important priority in order to meet the future needs of mankind. Yet priority setting between different branches of research is currently controversial because of the limited availability of funds and the political interference. For sound priority setting, an adequate level of scientific literacy is required among policy makers, a subject that will attract attention throughout this paper. The "introduction" gives an overview of the issues at stake. Prevailing pessimistic views of the future of our complex society are viewed as being similar to a medieval doomsday syndrome. Pathways to a new renaissance and age of reason are suggested. Three major recommendations are made: (i) Freedom of inquiry must be protected; (ii) The political misuse of potential environmental scares needs to be investigated before doomsday predictions alarm public perceptions and hence shape policies; (iii) The search for excellence in the leadership of science should be emphasized because it should not be based largely on acquired authority. The current controversy over possible impacts of rising levels of CO_2 in the atmosphere on climate is analyzed as a case study.

Keywords: scientific orthodoxy; directive funding power; political interference; scientific illiteracy; history of the natural science

1. Introduction

Over its long history, progress in the natural sciences has at various times accelerated and decelerated and has not always been consistent across its different fields. This essay attempts to analyze the major causes of this phenomenon in the past and to investigate the arguments made more recently that even today, progress might be retarded in some disciplines by specific poor practices. This is in contrast to other disciplines, such as physics, astronomy, geology, molecular biology and chemistry, which are forging ahead, with spectacular results bringing wide public awareness of developments in those fields.

Deficiencies in the application of science in furthering society have been noted in modern times by several writers. Some have gone so far as to express pessimism about the future of our Western society as a whole. A leading, and perhaps prophetic, voice is Aldous Huxley, who is best known for his book "Brave New World" (1932) and, in our own times, a kind of doomsday syndrome emerges. Writers such as Umberto Eco (1986) and Roberto Vacca (2000) like us to believe that we are entering a new "dark age", taking a backward step from what they see as an age of science and empirical observation. (See Section 9).

This essay will present a comparison between today's scientific approaches and those which produced the major discoveries of the Enlightenment and earlier history. In this context it will go on to discuss the main issues that threaten the progress of science.

The ensuing sections in part I contain a short historical report on how science matured before and shortly after the Industrial Revolution, with specific reference to the second half of the19th and first half of the 20th centuries, identifying the emergent scientific priorities, philosophies and impulses.

Part II (beginning Section 5) will discuss problems that arise from the complex structure of society today in which the scientific community has to function. Roughly two different kinds of problems can be distinguished: (a) Those which are observed to arise from inside the scientific community itself, comprising such problems as maintenance of quality of scientific performance and imposed authority by schools and individuals and (b) those that arise from the functioning of the scientific community in society as a whole and are accompanied by political interference.

The root of the second problem is very much *competition for public funds*, between fundamental research, with the exploration of the unknown as its main goal, and applied research, with the goal to establish or at least maintain a sustainable development in worldwide society. The current political and scientific debate on expected climate change as presented by the UN Intergovernmental Panel on Climate Change (IPCC) is examined as an important example of the newly emerged philosophy of science indicated as post-normal science.

Finally part III (beginning Section 10) will present the prospects for a new Renaissance in science, not with much confidence that this is likely to happen any time soon, but rather to suggest the kind of future that science and mankind might have if observed impediments to good science can be removed. Wrong directions in scientific practices which occurred in the past were eventually corrected, so it is optimistically suggested that today's can likewise be overcome.

Part I. The History of Science and Impediments in the Past

It is not within the scope of this essay to attempt a full account of the history of science and of the development of science philosophy in the historical period. Consideration will be limited to some specific characteristics of four major episodes that are significant to scientific practice today.

To study the history of science in conjunction with its philosophy is greatly more important than just antiquarian curiosity. It makes us understand the various lines of thought and reasoning which drove the hypotheses and discoveries of the great contributors to progress and makes them worthy of application today and reconsideration in the light of the more recent discoveries.

2. Science Matures

2.1. The Greeks; the Harbingers

Between 600 and 300 BC Ancient Greece harbored many philosophers fundamental to the development of what we know as our western philosophy and this period also saw the early flowering of several branches of natural sciences such as astronomy, mathematics and biology. Science history of course goes even further back to ancient Egypt (and later Alexandria). The study of the sciences at this time went hand-in-hand with the growth of art and aesthetics, principally literature, theatre and pottery. It is the combination of these very varied cultural activities that makes us refer to the Greek as the harbingers of our western civilization.

In the context of this essay the concurrent development of science and philosophy is of interest and in particular the development of methodologies to manage dialogue about controversial issues. There were many disputes in Ancient Greek society, not at least about state affairs (Plato) and the value of democracy. The last chapter of this treatise will examine Plato's ideals in detail but here he will be quoted only as reporter on the dialogues of Socrates and commentator on the so-called sophists.

Socrates was not much of a natural scientist like Euclid, Democritus or Archimedes in later times. His concerns were mainly religion and virtue. It is, however, the style of his conversations that makes the dialogues relevant for scientific issues. It is of course known as investigation by Socratic questioning. The technique is to make an amiable approach to your counterparty with a series of ostensibly naïve questions, present yourself as being rather ignorant and praise him for his answers but persist with the interrogation until a kind of embarrassment emerges. This technique attempts to create doubts about your interlocutor's largely biased convictions and invites further investigation of issues from a new angle. It is a way of "teaching" that is very different from indoctrination, amounting rather to a method which induces 'learning' through self reflection.

As an example of a Socratic interrogation, see Plato's version of a discussion with Euthyphro on piety [1].

Euthyphro was a sophist and practiced a form of teaching which both Plato and Socrates despised. The sophists in both Ancient Greece and in the Roman Empire specialized in the application of the tools of philosophy and rhetoric, though mathematics was also taught. In general, they claimed to teach "excellence" predominantly to young statesmen and aristocrats. Their rhetorical techniques were found to be extremely useful for young noblemen looking for public office. Their teachings, although controversial, had a profound influence on the direction of thought in the fifth century B.C. They turned away from the theoretical natural science to practical examination of human affairs and the betterment and success of human life. They had great impact on the early development of law and, indeed, were the world's first lawyers. Their status resulted from extremely developed argumentation skills. In this respect it should be noted that the search for judicial truth is not equivalent to that for scientific truth. The first is based on the opinion of the 'judges', the second on the evidence that Nature provides.

The modern usage of the term sophist describes a person who reasons with clever but fallacious and deceptive arguments and sophism as a false argument to mislead someone. Today therefore the term is sometimes more loosely applied by critical scientists to colleagues who inflict their own very strong convictions on the public and politicians on the importance of anthropogenic impact, for example on the physical environment.

2.2. The Middle Ages

The medieval period is frequently referred to as the "Dark Ages". This is, in a sense, a retrospective view on the intermediate period between the ancient Greek republics and Roman Empire and the onset of the Renaissance. The latter was followed by a period named The Enlightenment, the "Age of Reason", which revived the spirit of the ancient thinkers and reconsidered the established convictions of the whole of the historical period. Today's historians are, however, of the opinion that these Middle Ages are not as gloomy and sterile as previously thought. The Dark Ages are felt to deserve our study because there is irrefutable evidence that several fields of the arts flourished and interesting discoveries were made in sciences such as chemistry, transmitted to Europe from old Alexandria through the Arabs in the 13th century. At that time also the oldest universities were established (Oxford 1167, Cambridge 1209, Montpellier 1220, Padua 1222, Sorbonne 1253, Valladolid 1292).

The spiritual world in Europe was however dominated by the Roman Catholic Church, and it is easy to summarize its influence: obedience to the Church's enforced doctrines without questioning. This, of course, impacted on science, as Galileo Galilei still experienced in 1616 when he presented the evidence that the Earth was circling the Sun, instead of the other way round, and that sunrise and sunset are caused by the planet's rotation around its axis. Even in 1636, Galileo had to have his last work, *Discorsi*, smuggled for publication to The Netherlands, where the scientific age of reason had found acceptance. An advantage of this national situation was that Leiden University (founded in 1575), in particular, profited from being viewed as a haven for many learned men from other European countries, reflected in the image of its coat of arms as 'Presidium Libertatis' (Stronghold of freedom).

2.3. A Side-Track to Ancient China

All historians, however, are in agreement that Ancient China made no backward step during the medieval period. The state of science and technology in the Eastern world was very much advanced over that which prevailed in Europe. In this respect the grand question raised by Joseph Needham (1900–1995) is why China was later overtaken by the West despite its earlier successes [2] at the start of our Renaissance.

The author met Needham during his post-doctoral period (1959) in Cambridge (England), became fascinated by this question and was encouraged to take an interest in China's history and language.

Later (1995) he met others of similar interests at the University at Sheng Du (Sishuan) when lecturing on Darwinian evolution theory at a time when China was still recovering from its ‘Cultural Revolution’ and becoming prepared to distance itself from the Russian Lysenko doctrine. (See Section 4.5).

In the opinion of the author a major difference in approaches between East and West (which will never meet?) stems from a fundamentally different attitude to the acceptance of uncertainties in life: Yin and Yang in contrast to the certainty sought for in Western religions. This belief system must also have a bearing on how surprising phenomena are investigated in each culture. This, however, does not explain convincingly why, during one of the most prosperous periods in China’s history, the Ming dynasty (1368–1644), science progressed less than at the same time in the West. An explanation might well be the contemporaneous emergence of the increased central bureaucracy of the “Forbidden City” in Beijing which was imposed on local mandarins, as also happened later during the Manchu Qing dynasty, not to mention the modern analogy of the “red Tsar” Stalin in Soviet Russia.

2.4. The Renaissance and the Enlightenment

Certainly at the beginning of the European “age of reason” centrally-executed authoritative powers began to diminish in favor of a civilian class which became interested in the activities of such individual scientists and independent philosophers as Descartes and Spinoza. At a later stage (in the 18th century) science even became a kind of fashion, in the sense that people gathered in “salons” to see the wonders of nature demonstrated through experimental performance. In short, science aspired to a position as an expression of civilization in every way equal to the arts.

The driving force was as yet not the expectation that scientific knowledge could be exploited to the benefit of mankind, but nevertheless some useful applications emerged. Critically, these related to progress in navigation and warfare that allowed Britain (and Spain, Portugal and the Netherlands) to “rule the waves” and colonize the rest of the known world. The great advances of the time occurred in geography, astronomy, chemistry, physics, mathematics, biological taxonomy, practice of medicine, manufacturing and engineering, and fresh understanding of magnetism and electricity.

As the role of universities in institutionalized science began to diminish, learned societies became the cornerstone of organized science. After 1700, a tremendous number of official academies and societies were founded in Europe, and by 1789 there were over seventy official scientific societies. The 18th century might well merit the epithet of “the Age of Academies”.

While that period might be personified by the names of the famous scientists who made great contributions to the progress of science (e.g., Laplace, Lomonosov, Newton, Priestley, Volta), we would do well to remember the essential spirit of the age as embodied in the motto of the Royal Society of London (1660), “Nullius in verba” (Takes nobody’s word for it). This is the signature of the Fellows’ determination to establish facts only via experimentation.

2.5. Modern Science after the Industrial Revolution

If we accept the growing authority of experimentation then but also into today’s science, it undeniably took increased momentum during the Industrial Revolution at the end of the 18th century. Concurrently with industrialization the application of scientific knowledge for practical purposes took on a new velocity.

This transition was essentially the change from manual production to machinery. It led to increased chemical manufacturing and iron production processes, enabled by the increasing use of steam power as an energy source produced by the burning of coal.

The working of the steam engine is based on two laws of thermodynamics relating to the transformation and conservation of energy and the amount of work that can be delivered by a heat transfer process. Rather remarkably, these laws were shaped (e.g., the second law by Clausius 1865) long after the first workable engines were constructed (James Watt 1781). Clausius restated Carnot's principle (1824) as the Carnot cycle that helped early engineers tremendously to improve the efficiency of the steam engine. On the other hand it is also noteworthy to consider how far such discoveries go back in our modern times but yet are still of the greatest importance for many branches of modern science.

It took one and a half centuries after Clausius before it was fully realized that the second law originally formulated for physical thermodynamic processes is also of huge significance to understand these same processes in chemical conversions and biochemical pathways in living cells. The appreciation of the "philosophy" behind these processes has led directly to the new function "entropy" as the general indicator for the limitation of the direction processes. This latter term was in fact originally coined by Clausius (from the Greek) as "transformation content".

Similar universal merit can be ascribed to biological evolution theory, the formulation of the action of environmental selection on natural spontaneous biological variation as proposed by Darwin in his treatise *On the Origin of Species*, published in 1859. It became the unifying theory of the life sciences, explaining the diversity of life.

The number of influential scientists and inventors during the second half of the 19th century is too large to honor them all in this essay. We name only a few, recognized by most people as those who have made outstanding contributions to the progress of science; in physics, Maxwell, Boltzmann, Planck, Kelvin, van der Waals, Fourier, and, in other disciplines, Pasteur and Curie.

It is said that the 19th century gave birth to the professional scientist, a title first used in 1833 by Whewell, fellow at Trinity College Cambridge, himself an *uomo universale*, mineralogist, science philosopher and historian. He was probably the first, long before Popper and Kuhn, to study the philosophy of discovery and the importance of the formulation of concepts.

The start of the 20th century was strongly marked by Einstein's formulation of the theory of relativity (1905) including the unifying concept of energy related to mass and the speed of light: $E = mc^2$. He made many more contributions, notably to statistical mechanics, and he provided a great inspiring influence for many other physicists.

The first half of the century saw many other physicists celebrated for breakthroughs in physics. Their pictures and names are well recorded during several Solvay Conferences in Belgium [3].

The foundations of modern physics were no doubt laid in the 19th century, but the field grew in the 20th into a primary discipline contributing to all today's basic natural sciences, astronomy, chemistry and biology. Although it took a hundred years since Clausius's time for it to be fully recognized that all biological processes have also to obey the laws of thermodynamics, the border between the origin of the living and the non-living worlds has now at last been blurred. The year 1953 was an important landmark for biology with the description by Crick and Watson of the structure of DNA, the carrier of genetic information.

If we give nicknames to the various ages of progress, then the 20th century deserves that of the "Physics and Information Age".

In the context of this essay some other features which came to be typical of the first half of the 20th century can be mentioned. First among them is the intensification of disputes among major scholars. "Conferences" became the stage where Academies and Schools did battle. The dispute between Einstein and Bohr on quantum theory was never ended, although both men had the greatest respect for each other's views. In passing, it is interesting to note that Einstein reached many disputable conclusions over the years that later were corrected by others. In 1921, Einstein was awarded the Nobel Prize for his explanation of the photoelectric effect, not for the theory of relativity, since that was probably considered still somewhat controversial. Some other disputes are presented in Section 4.

Also typical of the century is the evolution in the organization of scientific research, the general features of which will be dealt with in Section 5. What was new here, however, was the birth of large private enterprises (later multinationals) with their own laboratories and philosophies. Of course, they were strongly centered on the application of scientific knowledge, but they made also important contributions to fundamental research; Solvay, Shell and Unilever in chemistry, Philips and Bell in physics, Hoffmann-La Roche and Novo in pharmacy.

In the second half of the 20th century several branches of science continued to make great progress and we here list physics, chemistry, biology, geology and astronomy. For example, there was the development of the semi-conductor (transistor), followed by developments in nanotechnology that led to great advances in information technology. In nuclear physics the discovery of sub-atomic particles provided a great leap forward.

In biology, the deciphering of the genetic code and the regulatory mechanisms in living cells paved the way for "genetic engineering", the transfer of genes over the borders that separate the species and an increase in speed in sequencing genes in chromosomes, all combining to make great progress in understanding and treating carcinogenesis.

In astronomy, the borders of the universe came into the picture, the discovery of black holes and dark matter made visible by radio astronomy changed thinking, and lately the circulation of planets around other stars than the Sun pushed out the boundaries.

One cannot move on without mentioning the feedback provided by engineering to science through improved instrumentation and metrics, especially after World War II. A laboratory or a medical hospital looks very different from even a few decades before. The spin-off of astronautics in many fields has been tremendous. For astronomy and climatology the use of satellite observations became very important. Equally in almost every branch of science sophisticated instruments became indispensable, not least in speeding up research, in facilitating data collection and interpretation and for model-building with computer programs. Some disadvantages of the latter have to be noted if models are not handled with care. However, it should be recognized that the speed by which computers produce output is not a guarantee of the quality of the conclusions.

2.6. Science Today

In the next sections several supposed unfavorable developments will be discussed despite the image that some people have of science being still on a triumphal procession in which hundred of thousands of scientists participate.

We have in the first instance to isolate the essence of the results of the progress that really has been made over the last centuries as it affects our improved understanding of the processes of Nature.

A crucial development has been cross-fertilization among particular disciplines, physics, biology, chemistry and mathematics. This does not just relate to multi-disciplinary approaches in studying phenomena but also, critically, to the recognition that discovered natural laws in a specific branch might have a bearing on others. We have already mentioned the general importance of thermodynamic laws and of the Darwinian principle of natural variation being applied to understand the force from the environment for selection of structures of increasing complexity. The two principles come together in what is today named “complexity theory”, formerly termed “chaos” or “catastrophe theory” and, in a sense, misnamed. At root, the theory concerns merely the recognition that chaos need not necessarily be a permanent state in non-equilibrium systems that show a natural tendency for self-organization. It is the philosophy that underpins observations on how things by evolution come into being that counts here. It helps to improve our current understanding how today natural processes function [4] is.

We have also to mention the phenomenon of serendipity, which has been of great importance over the whole history of science in achieving progress. This is the gift of discovering or recognizing or relating unexpected things. This simple principle was given a new dimension through the assumption of an approach which started with a highly improbable assumption within a current scope and working out its consequences. Most of these will inevitably be considered useless and even crazy, but the odd conclusion might in fact turn out to be something really unexpected and innovative. In anticipation of Section 8 on the current state of climatology, an example of this is the assumption that CO_2 need not function as what is called a “greenhouse gas”. It is obvious from the latest report of the UN Intergovernmental Panel on Climate Change (IPCC 2013) that it is too daring an assumption for some thousands of scientists working in this field to consider the possibility that the effect of CO_2 on climate is probably strongly exaggerated or might even be nil.

Some other examples of a conservative attitude among scientists will be given in Section 4, “The importance of skeptical voices”. The approaches mentioned above how to make science progress are not being fully exploited today. This is probably an inborn error in its advancements caused by the degree to which specialization is required to contribute to groundbreaking research. This fatally hampers the spiritual multidisciplinary approach. This is a quote from a popular book on complexity [4]:

> At a dinner party the hostess introduces the Great Man to her guests: “This is professor Hackensplacken. He is an authority on crocodiles.” The professor smiles modestly: “My dear lady,” he says, “you do me too much honour. It is on the crocodile’s eyelids that I am an expert.”
>
> The next section deals with various expected impacts of science philosophies on the progress of science.

3. Philosophies of Science

3.1. Relevance to Progress of Science

Philosophy has many branches. One speaks of the philosophy of biology, of economics, education, history, language, literature, logic, mathematics, psychology, law. According to the *Cambridge Dictionary of Philosophy* ([5], p. 611) "*the scientific* branch is centered on a critical examination of the sciences; their methods and their results. One branch, *methodology,* is closely related to the theory of knowledge. It explores the methods by which science arrives at its posited *truths* concerning the world and critically explores alleged rationales for these methods. Issues concerning the sense in which theories are accepted in science, the nature of the confirmation relation between evidence and hypothesis, the degree to which scientific claims can be falsified by observational data, and the like are the concern of methodology."

The *Dictionary* goes on to cite: "Concepts of the credibility of hypotheses, of the structure of hypothesis, the foundation of physical theories" and special subjects such as "Chaos theory and chaotic systems and randomness". ([5], pp. 614–15).

This essay has no pretensions to go into great depth on every kind of philosophical thought. It will largely restrict itself to subjects related to disputes among scientists on controversial issues. For example, how does one cope with *uncertainties* which demand an answer, which is a variant of "how do we know?" that is to so say "what do we *not* know?" That question is an important component part of the quantum of scientific literacy (see Section 11.2) needed to judge the results and, indeed, the consequences of research. So is the understanding of the philosophy behind *chaos theory* which will be particularly relevant to the case study in Sections 7 and 8 on the progress made in the environmental sciences. However, firstly we turn to a more general controversial subject—respect for objectivity—which has kept many philosophers busy over the last century. This is fundamental to an understanding of the different attitudes of scientists when they approach in practice the exploration of the unknown, especially when motivated by the goal of contributing to the progress of science.

Most professional investigators of the philosophy and sociology of science assess the progress of science through the lenses of their own individual philosophical thought. (For a controversial example see Section 6 on post-normal science). Their findings are also strongly filtered through the fundamental convictions current among the scientific community at large. These two factors constantly provoke a profound discussion among philosophers on the value of what is defined as the *scientific truth*. This debate inevitably has to embrace the concept of uncertainties which might, in the final analysis, make the accepted "truth" questionable. Scientists whose prime aim is to be regarded as convincing, and therefore celebrated, would do well to remember this essential fact.

Fame, in any of its forms, is however not necessarily the primary drive of the more modest scientist, who is largely motivated by curiosity and who draws attention to his insights in order to stimulate further discussion in the service of the progress of science. He is not so much occupied with his own view on what he considers to be the scientific truth as with further truth-*finding* through dialogue with colleagues. He is at the same time open to cross-fertilization by new ideas which breach the borders of specific disciplines such as physics, chemistry and biology, a development mentioned in Section 2.6 as a recent achievement in science.

3.2. Positivism versus Relativism and Idealism

This controversy finds a basis in a dispute that among science philosophers has already been going on for quite a long time. It concerns different approaches to the nature of truth-finding. These are dealt with in many textbooks [6] and defined by Bem and Looren de Jong as follows [7].

> *Logical positivism.* Positivism in general refers to philosophical positions that emphasize empirical data and scientific methods. Logical positivism (or neo-positivism) is mostly associated with the so called Wiener Kreis (1920s–1930s), a group of philosophers, physicists and logicians who claimed that legitimate knowledge consists exclusively of observation sentences and logical connections between them. Statements that are not (empirically) verifiable are meaningless nonsense or metaphysics.
>
> *Relativism* holds that theories, concepts and categories are not absolutely true or valid, but are irredeemably dependent on subjective views, social context and historical processes: there is no such thing as objective knowledge, no knowable world independent from knowing subjects; neither are there objective criteria to assess whether one of the many possible perspectives is more warranted than others. Informally speaking, truth is in the eye of the beholder, it all depends on how you see things. Relativists challenge realism and the correspondence theory of truth.
>
> This theory of truth states that truth consists of the correspondence between thought and reality. Relativism is related to idealism.
>
> Idealism is a philosophical doctrine holding that reality is essential mental, consisting in something like the World Spirit (Hegel): this is called objective idealism. Idealism is usually considered a subjective epistemology, implying that knowledge is first and foremost a product of the activity of the knowing subject, and there is no way of finding out whether knowledge corresponds with, or refers to, something like an external reality. The idealist—and the relativist—view of truth is coherence, which states that the more beliefs are coherent, the truer they are.

Since the 19th century most orthodox scientists subscribed to the concept of positivism, and this is still probably true, but a degree of relativism was certainly not foreign to them. Otherwise the "scientific dispute" among scientists, with its mutual respect for different views, would not have grown as it did in importance for the improvement of truth-finding and the progress of science.

3.3. The Handling of Uncertainties

When reading the most recent IPCC reports on the scientific base of climate change one gets the impression that this notion of uncertainties has undergone some devaluation. These assessment reports rank confidence in particular conclusions as "likelihoods" on a simple scale which ranges between "unlikely" and "very likely", based on the expert knowledge of those who are invited to judge the findings. In this subtle way, the notion of an uncertainty seems to become restricted merely to a straw poll of the degree to which a pre-formulated theory can be trusted by those who are expected to make political decisions based on the particular theory. In this sense, the assessment of "likelihood" probably does embrace some vestige of the test question "what is the evidence for…?" However, it can hardly be considered as anything more than a watered-down invitation to use the level of uncertainty or likelihood to indicate the existence of an alternative theory other than the pre-formulated one and to open the way to the further research which rigor demands.

4. The Importance of Skeptical Voices

> *"Authorities", "disciples", and "schools" are the curse of science; and do more to interfere with the work of the scientific spirit than all its enemies*. (Thomas Henry Huxley, 1825–1895) [8].

4.1. Controversial Views in Science

Modern science proceeds through theories that are tested by observations. If these do not fit the assumptions, new theories are developed to replace the former ones [9]. In the history of science there have been several long periods when two conflicting theories were proposed and, because no decisive observations could be made, the alternative concepts remained subject to debate among scientists. These were very interesting periods in the field concerned. The debate stimulated the development of new ideas with the result that these periods were among the most productive in the history of science. However, the "law" that science advances well through conflict cannot be generalized. In several historical cases we see that the debate went beyond the logic of scientific argumentation and became emotional. New ideas, conflicting with reigning views, affected the authority of the ruling class of scientists in the field.

In the next Sections 4.2 to 4.7 are presented many examples how orthodoxy or political interference hampered the progress of science in the past.

4.2. Phlogiston. The Substance with a Negative Weight

The theory of phlogiston was developed in the 17th century to explain the processes of oxidation and reduction. A flame is observed when carbon, sulphur, phosphorus or certain metals burn and Becher (1635–1682) and Stahl (1659–1734) postulated that this was due to the emission of a substance they named phlogiston. The flammability of a substance, it was argued, was related to its phlogiston content, and when this was released into the air during the combustion process, an inflammable product remained. Upon reduction, a substance would take up phlogiston. This remained the ruling theory in chemistry throughout the whole of the 18th century.

This is of course the world upside down. When a substance burns the primary process is of oxygen being taken up and it follows that the weight of the substance will increase. The phlogistonists were already familiar with weighing and did not neglect the increase, but explained it by attributing a negative weight to phlogiston. Despite the uptake of oxygen being proven by Lavoisier (1743–1794), the theory of phlogiston continued into the first part of the 19th century owing to a claim by Guyton de Morveau (1737–1816) that the specific weight of phlogiston was simply lower than that of air and thus the lower weight of material + phlogiston than that of the ash resulting from combustion was analogous to a heavy object that moves upwards with the aid of a balloon.

The author came upon on this remarkable part of science history when he studied the work of Johann Tobias Lowitz, (1757–1804) a chemist in St Petersburg who was a contemporary of Guyton [10]. Lowitz is a rather unknown but nevertheless creditable chemist. He synthesized acetic acid anhydride and discovered the absorption capacity of charcoal, an important factor in keeping fresh drinking water during long sea travels. Nevertheless, for 10 years after Lavoisier, he remained a convinced phlogistonist.

4.3. The Discovery of Continental Drift

The long lasting resistance against the explanation for the coming into being of the current earth's continental structure is a well known example of shown scientific orthodoxy of a whole discipline.

Alfred Wegener presented in 1912 for the first time the fundamental Continental Drift concept. At that time, this novel concept was, however, considered as highly speculative. Therefore, it had to wait for general acceptance until the 1950s, when new data and methods, such as paleomagnetism, provided strong support for Wegener's concept that lies at the base of the modern Plate Tectonics paradigm [11,12].

Wegener's theory was based in part on what appeared to him to be the remarkable fit of the South American and African continents, first noted by Abraham Ortelius three centuries earlier. Wegener was also intrigued by the occurrences of unusual geologic structures and of plant and animal fossils found on the matching coastlines of South America and Africa, which are now widely separated by the Atlantic Ocean. He reasoned that it was physically impossible for most of these organisms to have swum or have been transported across the vast oceans. To him, the presence of identical fossil species along the coastal parts of Africa and South America was the most compelling evidence that the two continents were once joined.

A great weakness in Wegener's theory was that it could not satisfactorily answer the most fundamental question raised by his critics: what kind of forces could be strong enough to move such large masses of solid rock over such great distances? Wegener suggested that the continents simply ploughed through the ocean floor, but Harold Jeffreys, a noted English geophysicist, argued correctly that it was physically impossible for a large mass of solid rock to plough through the ocean floor without breaking up. Magnetic surveys carried out in the 1950s by Bruce Heezen and Maurice Ewing (Lamont Geological Observatory) on ocean floor magnetism on both sides of the mid-Atlantic spreading ridge provided the deciding evidence for the actual mechanism.

4.4. The Deciphering of the Maya Script—The Thompson Affair

The deciphering of ancient and unused languages was an established area of research by the 19th century. In particular the spectacular decoding of the Egyptian hieroglyphs (J.F. Champollion, 1790–1832) was followed by the translation of the linear B form of Mycenaean Greek by M. Ventris (1922–1956).

At the same time the Mayan script was the subject of much attention although limited progress. The identification of the Mayan calendar was achieved through knowledge of astronomy (E. Förstermann, 1822–1906) and because certain hieroglyphs for numeric had accompanying characters the glyphs were assumed to represent geographic positioning (L. de Rosny, 1837–1914), but for many years this was the limit to the deciphering.

A new school was developed (E. Seler, 1849–1922 and C. Thomas, 1825–1910), which searched for a solution by investigating supposed phonetic relationships. The symbolic script was variously interpreted, but while this led to some interesting disputes, no clear path was evident until Eric Thompson (1898–1975), an Englishman attached to the Carnegie Institute in Washington, entered the scene.

Thompson's interpretation of the scripts was incorrect, as were the interpretations of several other researchers, but he managed to impose his view with great conviction on other Mayan scholars and was scathing of those who dared challenge his authority, in particular of Russian Y.V. Knorosov (born 1922), who worked on the Maya script behind the Iron Curtain.

Knorosov's first article, published in a Russian journal in 1952, is now generally accepted as the correct deciphering, but when Knorosov's ideas first reached the West, Thompson was furious "Has Knorosov any scientific honour? Certainly not. This is a Marxist hoax."

It was not until after Thompson's death in 1975 that the theories of Knorosov received wide attention and acceptance, which led of course to a rapid acceleration in the deciphering of the glyphs.

According to the analysis of M.C. Coe [13], Thompson had, through his authority and disdain of others, retarded developments in this field for some 50 years. His excessive self-esteem and stubborn belief had meant that most Mayan scholars had blindly accepted what was nothing more than pseudo-science and sophistry.

4.5. The Lysenko Indoctrination in Russia

To the deciphering of the Maya script—The Thompson affair—the phrase "Marxist ideology and science" will bring to mind one word: *Lysenko* [14]. It is frequently considered the most important of the various controversies concerning dialectical materialism and the truth finding in natural sciences in the Western world. It has been discussed in hundreds of articles and dozens of books. It suffices here to mention that the Lysenko doctrine was a challenge to Darwinian evolution theory. He claimed that crops could adapt to environmental circumstances not according to the concept of random variation followed by genetic stable change.

The Lysenko doctrine appears to have been disastrous for the development of agriculture in Russia [15].

4.6. The Lomborg Case

Bjørn Lomborg wrote a controversial book [16] in which he opposes the pessimistic view of a number of scientists and environmental organizations on the state of our physical, chemical and biological environment. Throughout the work he propagated the thesis that "Things are going better instead of worse". Some environmental researchers (S. Schneider, J.P. Holdren, J. Bogaarts, T. Lovely) raised opposition against many issues in the book in reviews and on web sites. Some others who praised the book (Ridley, Gleditsch, Wolpert, Hirshleifer), however are less directly involved in environmental research than the opponents. After an unsettled debate (largely outside the scientific journals) several opponents lodged a complaint of scientific misconduct to the Danish disciplinary body on scientific integrity (DCSD). In January 2003 this body evaluated the book as "dishonest" which raised a second wave of controversial statements from all over the world.

Lomborg asked for an “appeal” at the Danish Ministry of Science. In January 2004 it dismissed the ruling by the DCSD on procedural grounds and requested in a 60-page report a reinvestigation in the case. In March 2004 the DCSD produced a press release in which it considered this reinvestigation useless. Consequently, Lomborg felt himself exonerated.

4.7. The Causes for Persistent Views: Scientists Are Not Infallible

Science history does document many more mistakes and misbelieves that were perpetuated by the professional standing of certain individuals. Isaac Newton adversely influenced researchers for 50 years with his theory on the transmission of sound.

Common to the examples above is a persistently conservative attitude of the established scientific community, which stolidly adhered to an earlier formulated concept that was followed for years by leading scientists. The current climate debate resembles the examples mentioned above, as will be discussed in Section 8.

Here one should note a study by Barber, who as early as 1961 wrote on the general question of why scientists, not only during the mediaeval period, sometimes demonstrate a resistance to scientific discovery [17]. This discourse details the warning signals for conservatism e.g., even by Academies as will be mentioned in Section 5 that deals with the current social structure of the scientific community.

This is Barber’s short list of what he called resistance to substantive concepts, even by famous scientists:

> Brahe a great astronomer-observer remained a lifelong opponent of Copernicus.
>
> Pasteur’s discovery of the biological character of fermentation was not accepted for a long time by the chemist Liebig.
>
> Planck’s dissertation (1879) on the second law of thermodynamics was not accepted by Helmholtz and Kirchhoff.
>
> Mendel’s conception was resisted from the time of his announcement in 1865 until the end of the century because it ran counter to the predominant conception of joint and total inheritance of biological characteristics. Moreover, the fellows of the Royal Society did not accept the introduction of mathematics as an explanation for the distribution of genes over offspring.
>
> Lord Kelvin regarded the announcement of Röntgen’s discovery of X-rays a hoax and he also resisted the discovery of Ramsay and Soddy that helium could be produced from radium and Rutherford’s theory of the electronic composition of the atom.

Alongside those examples of what Barber called resistance to substantive concepts, he considered resistance to methodological concepts in the light of established models:

> Ampère”s theory of magnetic currents was resisted by Henry and others because they did not see how it could fit into the Newtonian mechanical model.
>
> Kelvin (again) resisted Maxwell’s electromagnetic theory of light.

More generally, Barber notes that an important source of resistance to discovery is doubt about the usefulness of mathematics. The case of Mendel has already been mentioned. The mathematician Adams communicated his discovery of the planet Neptune based on calculation, but the paper was rejected by its referees. The cause may have been the lack of understanding of what philosophy, mechanisms or physics lie behind the presentation of a mathematical formula. This might still be the case with the math behind the unifying concepts mentioned in the previous section when neglected in disputes among scientists of different disciplines.

We need not here elaborate further on the third Barber category, of historical examples of religious ideas interfering with scientific progress, as occurred in the medieval period. "Belief" seems today replaced by the authority of scientists who, because of their professional standing, are allowed to tell the public that an original idea from a non-expert in a specific discipline should not be considered seriously. Mendel was such an outspoken example of a non-expert, also Wegener (see Section 5.3) and Pasteur, who, although not a physician, nonetheless introduced the first ideas about immunization.

What causes occasional unfruitful discussions among scientists otherwise considered well known and well respected for their work? Scientists are just human beings, not high priests, with all the virtues and vices of ordinary men and women. Further, scientists are considered by psychologists [18] as a little autistic, but that is more advantage than set-back for minds which are predestined to belong to the circle of the most creative people among us.

A quote from the book referred to in [18]:

> The impression that emerges of the successful research scientist is that of a person considerably less sociable than average, rather serious-minded, intelligent, aggressive, dominant, achievement oriented and independent. In addition he/she is cognitively complex, has a radical imagination and a well-articulated self concept. In short, the creative person is both introvert and bold.

The Lomborg case mentioned above (Section 4.6) comes most nearest to the current controversy in the climate debate (Section 8), because it also concerns, like the "cold CO_2 war", environmental issues. Another scientific conflict, with a similar character, not reported here, concerns the feared decline of biodiversity in the world. The analysis of assumed exaggerated dangers in this respect has been reported in a book by U. Segerstråle [19]. It reaches the same conclusion as in the analysis of the Lomborg case [20] and attributes the exaggerations to the association of environmental issues with the interweaving of science and politics.

Quote [20]:

> The environmental sciences have a strong impact on politics, and the reverse. Observed unfavourable developments in the environment require measures and investments from governmental authorities and some of these investments are made in further environmental research. And all scientists, and not at least Lomborg who is a political scientist, show outspoken opinion on the desired political consequences of the interpretation of their scientific research. As a result scientific and political conceptions are easily mixed up, which makes the debate on the scientific aspects of environmental issues confusing to the outsider.

The analysis mentioned above suggests that the interweaving of science and politics strains the drive for truth-finding and consequently the progress of science. It is concluded by Segerstråle [19] that social factors such as power, rather than the presentation of scholarly evidence, determines who "wins" in academic controversies, at least for the moment. However, since power constantly changes hands, there also seems to be a possibility that, in many cases, truth-finding eventually wins out after all, since the accumulation of evidence over time becomes too much for even the very powerful to try to rebut or suppress.

Part II. The Present Situation in the Scientific Community and Problems Arising from Political Interference

> *I think we live in an unscientific age in which all the buffeting of communications and television—words, books and so on—are unscientific. As a result, there is a considerable amount of intellectual tyranny in the name of science*. (R. P Feynman, 1968) [21].

5. The Social Structure of the Current Scientific Community

5.1. Organization and Communication

Since the Renaissance (see Section 2.4) science has increasingly been globalized, coalescing into a worldwide scientific community. Research is still largely performed in local institutions with distinctive characters, but their mutual exchange of information has increased tremendously, especially over the last decades, by daily e-mail communication. This has almost completely replaced the traditional exchange of information by letter.

However, the outcomes of research are still mainly presented in print via official scientific journals. Compilations of research appear in review articles, textbooks and official reports of research institutions. Scientific conferences are also important means of communication. For the transmission of scientific "news" to the public at large, internet websites have become important instruments, not least by way of press releases from "public relations" departments of institutions.

This is not the only indication that science has become more of an enterprise, requiring active marketing to sell its products, rather than being comparable to the arts as a creative activity. In the meantime, for many scientific institutions and organizations the social environment has changed, affecting several other features elaborated below.

5.2. The Local Research Institutes

Countries have organized their research and scientific education in various ways. As an example, both Cambridge and Oxford each comprise a group of colleges with a small central university administration, rather than universities in the generally recognized sense. These colleges form special social communities with their own atmosphere (Snow 1951) [22]. General managerial aspects of today's scientific institutions will be dealt with in Section 12.

In other parts of Europe universities have often been grouped in campuses, following the American model. These have also become attractive sites for so called (small) private risk capital enterprises, which want to benefit from the spin-off of academic fundamental research for practical applications, while at the same time raising the interest of academics in applied research.

Fifty years ago, many countries had their applied research almost completely concentrated in specific institutes. As regards organization, some of were largely independent from government, e.g., the Fraunhofer–Gesellschaft in Germany and TNO in The Netherlands, both oriented toward industrial developments. Others institutes were agencies of ministries, e.g., in nuclear physics, meteorology, public health and agriculture. Most of these institutes, however, felt the need to seek closer collaboration with academic institutions, not least by joint appointments of staff. This all indicates a change from the traditional separation of fundamental and applied research into more of a joint venture structure which seeks to align science more generally with the interests of society.

However, the recent promotion of post-normal science (see Section 6) raises the question whether mixing fundamental and applied science adversely affects the original mission of universities as educational institutions teaching methods and producing results solely aimed at scientific progress. On the other hand, universities have always combined teaching and research, based on the philosophy that one cannot learn about science without personal practical experience of research at the limits of our knowledge. Certainly, not all graduates will have the ambition to work on the advancement of science. Some of them may become involved in decision- or policy-making on scientific progress. It is to be hoped that these potential "administrators" take some insights from the philosophy of science into their decisions rather than being influenced only by the specific goals of post-normal science, an issue covered later in Section 13 on university education.

Apart from the universities, most countries have research institutes devoted to fundamental science, with no undergraduate teaching, e.g., Max Planck in Germany, CNRS in France, and the Research Councils in the United Kingdom. They have a reputation of scientific excellence and retain some degree of freedom of investigation. Some are directly funded by the government, others by scholarly academies.

Some believe that our society is moving towards a second "dark age", with its specific social aspects. If this is true, it might affect the future status of these institutions; compare the views of the Italians Roberto Vacca (1971) and Umberto Eco (1972) (See Section 9).

Eco was less pessimistic than Vacca. He suggests that some of today's institutions will remain sanctuaries of classical insights for the progress of intellectual achievement, similar to the role of the monasteries in the medieval period. This may well be a future role of those current institutes particularly devoted to fundamental science. The message that they will have to transmit to future generations is that the promotion of post-normal science cannot be the ultimate solution in reaching a better understanding of the complex problems facing our science and technology–based society.

5.3. The Functioning of International Scientific Organizations

Each discipline in each country has its own professional organization. On the global level they form international associations. These play a major role in regularly organizing international conferences and occasional seminars on specific subjects. They are still of importance for the worldwide communication among scientists. These meetings became a cult in themselves, not least because it is considered an honor to be invited as a key-note speaker at these gatherings [23]. Moreover, the reports from these conferences are important as records of the state of the art in a particular discipline in a certain period. Although it is not their primary goal, these meetings contribute to the enhancement of cooperation among scientists.

Over the last fifty years another important phenomenon has emerged: the establishment of international laboratories and observatories. Examples are the European Centre for Nuclear Physics (CERN in Geneva), the European Space Research and Technology Centre (ESTEC in Noordwijk, The Netherlands) and the European Southern Observatory for Astronomy (ESO in Chile). This cooperation is primarily motivated by the need for access by scientists from different countries to costly facilities, such as particle accelerators, satellites and large telescopes. Affiliation with such research centers often enhances the prestige of the scientists concerned, especially in cases where they have been selected as a result of their outstanding work.

The UN has taken the remarkable initiative to create consultative bodies for the assessment of those scientific results considered to be of importance to the world community at large. Included in these are the World Health Organization (WHO), the World Food and Agriculture Organization (FAO), the Global Biodiversity Assessment (GBA) under the aegis of the UN Environmental Program (UNEP), and the Intergovernmental Panel on Climate Change (IPCC). (Section 8 will deal with the IPCC.)

Some of these consultative bodies have certainly gained in prestige, if only because they constitute worldwide collaborations of scientists and governmental representatives, appointed by their member states. Their leading scientists derive their standing from scientific quality, usually based on assessment of their contributions to the scientific literature in peer-reviewed journals (see further Section 5.6). Post-normal science goals arise predominantly from these UN-sponsored bodies. The characteristics op post-normal science will be dealt with in Section 6. Suffice to present here its definition in short as an attempt *to characterize a methodology of inquiry that is appropriate for cases where facts are uncertain, values in dispute, stakes high and decisions urgent* [24].

Quality as a perceived criterion is critically dependent upon the confidence one can place, with respect to scientific discipline, in a particular branch of science, including proper peer review. If these basic disciplines are flawed, the quality of the assessment studies becomes questionable.

Confidence in assessment studies may increase if they have stood the test of time. This is the usual approach in evaluating scientific results published in the past. However, within the current social structure of the scientific community such an evaluation of assessment studies rarely occurs. The current advisory culture in which assessment studies are made is often characterized by the presumption that experts who have spoken once but authoritatively are infallible, especially if their opinion is supported by the opinion of many of their colleagues. This is called the *consensus culture* in science, which has become fashionable on a global scale.

5.4. The Position of Academies

Among the scientific institutions, the national academies distinguish themselves by the selective co–option of new members from the scientific communities on the basis of creativity. Excellent scholarship is the most important prerequisite to become a fellow. Therefore, the academies are the most prestigious scientific organizations. They develop high-level scientific activities in and outside their own circles, such as seminars and conferences, publish their own journals, award prizes and other honors to outstanding scientists and supervise research institutes. In addition they give advice on scientific issues on request or on their own initiative, including advice on general issues, such as the maintenance of good scientific practice, central to all scientific disciplines.

There is, however, a growing tendency for academies not to limit their advice to purely scientific issues and to extend their recommendations to problems of social relevance. In chapter 8 an example will be given regarding the Netherlands Royal Academy of Sciences (KNAW), in which doubts are raised about the intrinsic value of the quality of the advice and its legitimacy, arising from its in-house scholarship. The selection of academy fellows is based on their proven creativity in a particular and often specialized field of science, not necessarily on their broader insight into that branch of science or the impact of the progress in that branch on society. In the experience of the author, as a member or chairman of international assessment committees, the best scientists, even Nobel laureates, are not necessarily also the best judges of the work of others, or the best experts to evaluate trends in even their own discipline.

Three aspects of the advisory role of academies deserve further attention from the point of view that any advice given necessarily originates from top scientists.

First of all, academies are multidisciplinary organizations. This implies that they are interested in the development of an overall view, which transcends the boundaries of particular disciplines. However, more often than not, this overarching perspective is restricted to merely taking stock of the views prevailing in various disciplines, without developing a real *common* position. There seems to be some tacit agreement among members about non–intervention in each other's territories. Against this background, it is hard to see how an academy can ever produce an authoritative message for society, if that advice has been produced by a select group of experts.

Secondly, the question has already been raised whether top scientists are always the best people to evaluate scientific developments since they are experts only in a narrow field. Moreover, it should be recognized that leading scientists show a general tendency to adhere to their "pet" doctrines. They do not always pay due respect to alternative views. Section 4 on previous erring ways in science, offers some striking examples of how leading scientists have hampered the progress of science.

Thirdly, the staff of academies does not only consist of senior scientists. Reports of the deliberations of fellows are often written up by junior staff members. In principle there is nothing wrong with that, but it may happen that fellows are paying insufficient attention to the correct translation of scientific views into language which is accessible for a broader lay audience, including politicians. The climate report of the Netherlands Royal Academy of Sciences (KNAW) (see Section 6), which was submitted to parliament, offers an example. The final report was even written by an external journalist from a daily newspaper, who had very explicit alarmist views on global warming. It was certainly not an unbiased report and could not possibly be regarded as a basis for further discussion, as the chairman of the evaluation committee suggested at a follow-up meeting organized by climate skeptics.

Academies, with all respect for the scholarship of their individual members, seem no longer to be the most adequate bodies to advance the progress of science, when they take outspoken positions in the public and political debate on social issues for which they lack sufficient expertise. It is beyond doubt that the current position and functioning of science in society deserves significant attention and Academies are of course included in this. The question arises, however, whether the current "marketing" methods they use to establish their authority in the eyes of the public matches the quality standards to be expected from a scholarly community. Any report made to the public should demonstrate evidence that the questions specified in Section 11 have been answered fully, and in an understandable way for the layman. To justify a judgment merely by its reliance on expert "authority" should not suffice in a society with a drive to improve scientific literacy.

5.5. Developments in Public Relations

After WW II there was a growing feeling that scientific efforts were generally not sufficiently oriented to the needs of society. Among the people who became worried were also many scientists. Some of them were very passionate and behaved as "warriors" in the front line against particular scientific and industrial developments. A more moderate current in this movement advocated the encouragement of public involvement in certain research fields, including the setting of priorities and even allowing a public viewpoint on the preclusion of specific lines of investigations and their applications. The underlying idea was that it should no longer be left to scientists alone to decide what is good or bad, even if their only motivation was curiosity.

The success of enabling society to participate in scientific priority-setting is critically dependent on the provision of objective information. In other words, the scientific community should be obliged to present the "two sides of the coin"; otherwise one cannot expect people to make their own choices in a rational and informed way.

After the "cultural revolutions" at the universities (1967–1968) the publicity climate seems to have changed. Publicity mainly became a marketing instrument for institutes and organizations to attract attention to their own activities and frequently one-sided views on social developments and values.

Dissemination of information about what goes on in these institutions, to which internet has strongly contributed, is certainly valuable. However, recipients should be able to judge the quality of the information presented. Only then is it possible to achieve an understanding and engage in a fruitful discussion of controversial issues.

The current intense communication among individuals on internet may in principle contribute to the development of a sense of critical discernment. However, experience shows that like-minded people tend to visit the same blogs, with the risk of reinforcing existing opinions and merely echoing them rather than taking note of opposing views. Nevertheless, comparing discussions on a variety of blogs may be of valuable assistance in helping the open-minded inquirer to learn about alternative views.

5.6. The Role of the Scientific Journals

E-mail exchange among scientists has undoubtedly speeded up and intensified exchange of ideas and information. Time zones constitute the only limitation to receive an immediate response. Seen from Europe, Australia is 9 h later and California is 9 h earlier. However, in practice it is less of an obstacle than it seems at first sight, because most scientists in Australia are nocturnal animals and in the US "early birds". Anyway, they all makes for very long days.

The most important and most reliable sources of scientific information and the progress of science are still the international scientific journals. Some journals are published by private publishing houses, others by scientific organizations. The scientific quality of their publications rests on peer review by fellow scientists, who check whether the submissions are up to the highest scientific standards. It is important that authors of a submission clearly show that they have adhered to the rules of good scientific practice and that the data presented are trustworthy and free from manipulation to produce a slanted view. Unfortunately, in some disciplines it happens that peer-reviewers reject papers if conclusions are not in agreement with personal opinions or with the mainstream in a particular branch of science. The author met this problem several times and especially when being guest-editor of a special issue which collected papers of a critical nature with respect to climate change phenomena [25]. This is a kind of censorship which should be foreign to science and which in the past has been shown to be very detrimental to its progress (see Section 4.7). There are also signs that chief-editors of well-known scientific journals prefer for commercial reasons to publish fashionable results rather than profound scientific treatises. On the occasion of his Nobel Prize Laureate (2013) the cell biologist Schekman proposed *a boycott of the "luxury" journals Nature, Cell and Science which favor publications of studies that are likely to make a splash and are subsequently overvalued by the frequency of their citation (which plays a major role in the career of ambitious scientists today)* [26].

Consequently, peer review in particular journals and by certain branches of science can no longer be trusted as an adequate ultimate check on the quality of published papers. The public at large is not sufficiently aware of this unfortunate development within the scientific community and still has confidence in what is now flawed quality control. This has led to misinformation about the status of controversial issues. Through internet media, many scientists have warned against this trend and have occasionally produced proof of wrong or biased interpretations of data. Unfortunately most of these interventions on internet have no or insufficient peer validation and so only a few have had wider impact. Moreover, in internet discussions, passions often run high on both sides of any debate, and have stained the image of science as a whole. There is also a detrimental spill–over effect on those branches of sciences, which, against all the odds, still seem to be able to preserve the highest possible degree of quality control.

5.7. Ranking Scientists for Excellence, Prestige and Authority

There are still many very good scientists in the world, who make great contributions to the progress of our understanding of nature. They are honored and recognized by the awards they receive, in terms of prizes and medals, election as fellows of scholarly institutions and invitations to be keynote speakers at important conferences. To add to these is a new method of ranking scientists which consists of reporting how frequently their work has been quoted by other authors of scientific papers in prestigious journals. This frequency might, however, merely indicate the volume of their work in a particular branch of science, rather than give a measure of the quality of the scientist in question, or the scientific standard prevailing in their particular branch of science. If mediocre scientists develop a culture to quote each other, the citation index becomes a misleading signal.

The prestige which goes with awards also deserves some reservation. They might have been received for one, or may be two important discoveries in a narrow field, but they are not necessarily proof of superior general scientific insight. This is a side effect of a high degree of specialization, which is currently one of the requirements to be in the forefront of scientific investigation. Of course, this does not mean that a scientist with only one important discovery should be excluded from the halls of fame such as the Pantheon in Paris.

But we need other criteria to have confidence in the advice of well-known excellent scientists, especially on controversial issues. One of the more important ones is the open-mindedness they show towards alternative opinions and approaches that vary from their own. Most weight should however be given to the logical arguments they follow in giving their advice, even, and probably in particular, to laymen. Logic is the basis of all sciences and the public should see this demonstrated in any result of scientific enquiry. If scientists take refuge in mere authority or argue that they are correct because mainstream opinion is of like mind—the consensus culture that has slipped into some disciplines—they disqualify themselves as scientists. They may still be considered as "science activists" for a certain cause, and therefore might deserve due attention, but no more than that.

5.8. Finance, Marketing and Political Ties

Over the last half century, these interconnecting elements, more than ever before, exercised a strong influence on the direction of the progress of science. This trend worries many a scientist who still claims that progress is best served by initiatives taken by individuals. Schema formulated a wish for the preservation of this approach recently when he received the Nobel Prize (2013) with an appeal to an important category of scientific funders, as follows:

> Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown. Freedom of inquiry must be preserved under any plan for government support of science [27].

This is in fact a quotation from an adviser to the president of the U.S. at the end of WWII during which of course much attention was paid to defense research. Under the pressure of the cold war this focus continued. Against the background of some suspicion, what was called the Military-Industrial-Scientific consortium developed, which was supposed to have a strong influence on the distribution of public funds for research. It became beyond doubt an important financial power, as was the experience of many scientists trying to build a scientific career. The pacifistic idealists who despised this tripartite influence, set up in principle for sound reasons—the threats of the cold war were very real—might however not have recognized that, this "consortium", to which NATO belonged, retained considerable and unexpected respect for freedom of investigation. This was evident even from the broad spectrum of sciences which were supported. For example the author enjoyed a NATO grant (1959) for a post-doc in Cambridge (UK) in fundamental molecular biology research, a project of his own choice and not even based on a previously presented research program.

Now how did it come to pass that scientists progressively experienced restrictions on their freedom in the fourth quarter of the 20th century? In Europe it probably begun with a coup by the Ministry of Public Health in the UK through a white paper presented by Lord Rothschild (1971). This comprised a proposal for portfolio management of healthcare under a concordat between the Medical Research Council (MRC) and the Ministry of Health [28]. It appeared that the UK government was not satisfied that the setting of priorities by the upper management of the MRC matched public interest. Did this signal suspicions of strategic incompetence among the MRC hierarchy? This was certainly the view of many opponents of the scheme who saw in it a threat to the freedom of research.

With the growing influence of ministries on the choice, and funding, of research projects based on perceived national interest priorities (e.g., in the environmental sciences), the responsibility for strategy development has been moving from institutes to governmental departments and their outside scientific advisors.

A common sentiment of scientists can be illustrated by quotations from Richard Lindzen, a well-known meteorologist, not least on account of his skeptical views on current progress in climatology [29]. He too comments on the interconnected elements of finance, marketing of research and the political ties. His paper was published in a medical journal, an indication that his worries about the behavior of scientists inside the scientific community are also recognized in fields other than climate research.

> Though valuable as a process, science is always problematic as an institution. Charles Darwin often expressed gratitude for being able to be a gentleman scientist with no need for an institutional affiliation. Unfortunately, as a practical matter, the gentleman scientist no longer exists. Even in the 19th Century, most scientists needed institutional homes, and today science almost inevitably requires outside funding. In some fields, including climate, the government has essentially a monopoly on such funding.
>
> Expanded funding is eagerly sought, but the expansion of funding inevitably invites rent-seeking by scientists, university administration, and government bureaucracies.
>
> The public square brings its own dynamic into the process of science: most notably, it involves the coupling of science to specific policy issues. This is a crucial element in the climate issue, but comparable examples have existed in other fields, including eugenics and immigration, and Lysenkoism and agronomy.
>
> Although there are many reasons why some scientists might want to bring their field into the public square, the cases described here appear, instead, to be cases in which those with political agendas found it useful to employ science. This immediately involves a distortion of science at a very basic level: namely, science becomes a source of authority rather than a mode of inquiry. The real utility of science stems from the latter; the political utility stems from the former.

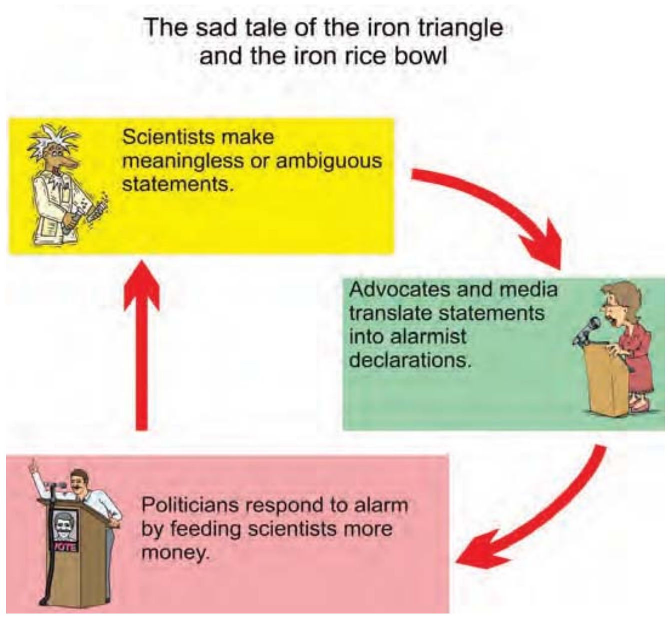
For science to be politically useful, several features are involved:

- Powerful advocacy groups claiming to represent both science and the public in the name of morality and superior wisdom;
- Simplistic depictions of the underlying science so as to facilitate widespread "understanding";
- "Events," real or contrived, interpreted in such a manner as to promote a sense of urgency in the public at large;
- Scientists flattered by public attention (including financial support) and deferent to "political will" and popular assessment of virtue; and
- Significant numbers of scientists eager to produce the science demanded by the "public".

These factors are hardly independent. Moreover, they interact in important ways (see Figure 1). The tale illustrated in the figure is not meant to explain any particular abuse of science but rather to demonstrate why the system is vulnerable to abuse.

The consequences of the Iron Triangle include ascendancy of politically correct mediocrities or incompetents such as T.D. Lysenko, which is inevitable given public inability to judge science. Unfortunately, this also often induces better scientists to join the pack in order to preserve their status. Advocates grossly exaggerate results in order to promote their cause. An obsessive focus on unimportant or irrelevant aspects of the issue develops. A profound dubbing down of the discussion (including the abdication of logic) interacts with the ascendancy of incompetents.

Figure 1. The sad tale of the iron trangle and the iron ice bowl.



Lindzen continues:

> Global climate alarmism has been costly to society, and it has the potential to be vastly more costly. It has also been damaging to science, as scientists adjust both data and even theory to accommodate politically correct positions. How can one escape from the Iron Triangle when it produces flawed science that is immensely influential and is forcing catastrophic public policy?

Here speaks a scientist who is not only specifically worried about post-normal science and its obstacles to the progress of science as such, but also about its impact on the distribution of governmental funds at the expense of promising "pure" research projects. Not all of Lindzen's comments are within the scope of this essay, but they should not remain unnoticed, because they represent a general feeling of uneasiness among some skeptical scientists in other disciplines.

It could be argued that there may be an element of envy in this kind of reasoning. That might be true, but several elements in Lindzen's philippic deserve further attention in the following chapters. We may note the press release of IPCC on the occasion of the presentation of its Summary for Policymakers (SPM), 30 September 2013, in Stockholm. This beyond doubt is a strong example of public advocacy and the marketing of particular scientific convictions. Lindzen takes an interest, like Huxley, in the question of the authority of expressed authority. One could also say the SPM points to a lack of modesty in the IPCC school that its convictions might be challengeable. Unfortunately for us, Lindzen does not offer any easy answers to the problems he lays out in his triangle.

What we have attempted to express is that in the current structure of the scientific community scientists themselves contribute to the erosion of standards in their profession which in the past were highly valued. However, structural reorganization as the only solution in improving conditions for scientific progress is questionable and even a waste of time and money. As recent successes in a variety of disciplines have earlier demonstrated, many scientists seem able to perform very effectively and with scientific integrity within the current imperfect structure. What may in fact be the most defining factor in improving scientific progress is a change of spirit among scientific practitioners themselves. That points our way towards the corridor leading to scientific discovery: academic education (Section 13).

6. Post-Normal Science. A New Philosophy?

6.1. The Authors of the Concept and Its Definition

Silvio Funtowicz taught mathematics, logic, and research methodology in Buenos Aires, Argentina. He is now head of the Knowledge Assessment Methodologies Sector, Institute for the Protection and Security of the Citizen (IPSC), European Commission-Joint Research Centre (EC-JRC). He has numerous papers in the field of environmental and technological risks and policy-related research.

Jerome Raymond Ravetz received his Ph.D. in mathematics from Trinity College in Cambridge, UK, but soon changed his field to the History and Philosophy of Science, which he taught at Leeds University. He is now an independent scholar and self-employed consultant, working mainly on problems of the management of uncertainty in risks and environmental issues.

Post-normal science is defined as an attempt to characterize a methodology of inquiry that is appropriate for cases where facts are uncertain, values in dispute, stakes high and decisions urgent [24]. It is primarily applied in the context of long-term issues where there is less information available than ideally desired by stakeholders.

According to its creators, post-normal science is simply an extension of situations routinely faced by experts such as surgeons or senior engineers on unusual projects, where the decisions being made are of great importance but where not all the factors are necessarily knowable. The authors state: although their work is based on science, such individuals must always cope with uncertainties, and their mistakes can be costly or lethal.

As yet post-normal science as a methodology appears not to be accepted as a valid approach in science philosophy, since it is not mentioned in professional handbooks such as that by Curd *et al.* [6] or even in a more recent book [7] in its chapters on philosophy, sociology and psychology of science.

Perhaps post-normal science should for the moment be classified as a method of assessment of possible threats rather than as a branch of scientific inquiry itself. However, it certainly puts forward a "concept" of how science can be seen to function within society.

The authors and their followers are beyond doubt driven by a vocational motivation to have scientific investigation regarded as the servant of public interest with an especial focus on environmental developments and, more widely, on the drive for so-called sustainable development since the 1980's [30].

6.2. The Use of Scientific Knowledge for Political Decision Making

We do not need to summarize the movement for political decision making based on post-normal science; the founding fathers can speak for themselves with quotes from their recent publication (2008) in The Encyclopedia of Earth [31] Some key points are italicized to mark their relevance to this essay and their need for further attention.

> "The shift to a post-normal mode is a critical change. The approach used by normal science to manage complex social and biophysical systems as if they were simple scientific exercises has brought us to our present mixture of intellectual triumph and socio-ecological peril. The ideas and concepts belonging to the umbrella of post-normal science witness the emergence of new problem-solving strategies in which the role of science is appreciated in its full context of the complexity and *uncertainty* of natural systems and the relevance of human commitments and values."
>
> "In the sorts of issue-driven science relating to the protection of health and the environment, typically facts are uncertain, values in dispute, stakes high, and decisions urgent. The traditional distinction between 'hard', objective scientific facts and 'soft', subjective value-judgements is now inverted. All too often, we must make hard policy decisions where our only scientific inputs are irremediably soft. The requirement for the 'sound science' that is frequently invoked as necessary for rational policy decisions might affectively conceal value-loadings that determine research conclusions and policy recommendations. In these new circumstances, *invoking "truth" as the goal of science is a distraction,* or even a diversion from real tasks. *A more relevant and robust guiding principle is quality,* understood as a contextual property of scientific information.
>
> A picture of reality that reduces complex phenomena to their simple, atomic elements can make effective use of a scientific methodology designed for controlled experimentation, abstract theory building and full quantification. However, that is not best suited for the tasks of science-related policy today. *The traditional "normal" scientific mind-set fosters expectations of regularity, simplicity and certainty* in the phenomena and in our interventions. However, these can inhibit the growth of our understanding of the new problems and of appropriate methods for their solution."
>
> "As a theory, post-normal science links epistemology and governance, for its origins lie in the relations between those two domains. Its authors were concerned that the sciences devoted to solving health and environmental problems (such as ecological economics and toxicology) are radically different from those that are instrumental in creating them (such as the applications of physics and molecular biology). In comparison to those traditional sciences, *the policy-relevant sciences have enjoyed less prestige and funding,* are less

matured scientifically, and are more subject to external influences and constraints. By the criteria of the traditional philosophy of science, their results frequently fail to attain the status of 'sound science'. It has been argued that they should therefore be rejected as evidence in policy debates; but a more appropriate conclusion would be that the *philosophy of science needs recasting. Post-normal science provides a response to these crises of science and philosophy, by bringing 'facts' and 'values' into a unified conception of problem-solving in these areas, and by replacing 'truth' by 'quality'* as its core evaluative concept. Its principle of the plurality of legitimate perspectives on any problem leads to a *focus on dialogue, and on mutual respect and learning, wherever possible.*"

"There are now many initiatives, increasing in number and significance all the time, for involving wider circles of people in decision-making and implementation on health and environmental issues. The contribution of all the stakeholders in cases of post-normal science is not merely a matter of broader democratic participation. For these new problems are in many ways different from those of research science, professional practice, or industrial development. Each of those has established its own means for quality-assurance (peer review, professional associations, or the market) for the products of the work. But for these new problems, *the maintenance of quality depends on open dialogue between all those affected.* This we call an "extended peer community", consisting not merely of persons with some form or other of institutional accreditation, but rather of all those with a desire to participate in the resolution of the issue."

"What we call 'science' has undergone many changes over the centuries in its objects, methods and social functions. In the nineteenth century, mathematical science matured and became the unquestioned model for all other sciences, regardless of how appropriate it might be to their special circumstances. With post-normal science we are characterizing the changes in science which will be necessary in this new century for our civilization to become sustainable, and thereby worthy of survival."

6.3. The Critique

The critique of the post-normal science is elaborated on in later sections The next highlights the view that science is declining in its attempts to embrace aspirations for sustainable development. It summarizes the objections collected when a first manuscript of this essay was subjected to peer-review by those who are skeptical about the prophecies propagated by the "school" of the Intergovernmental Panel on Climate Change, (PICK). This school's major views are that rise of CO_2 in the atmosphere may be the cause of (dangerous) anthropogenic global warming (AGE) and that political decision-making is *urgent* because *the stakes are high*.

Scientists who are skeptical about post-normal science are in particular concerned about its doctrinal statements that "*invoking truth as the goal of science is a distraction*" and that "*truth can be replaced by quality*" without also proposing a better definition of quality in scientific research. It is the belittling of the drive for truth-finding which is considered by these critics as a *distraction of the goal of science.*

Some statements central to the concept are particularly considered to be unfounded, e.g., that science as such is in a crisis.

The counter view is that many disciplines—physics, chemistry, molecular biology, geology, nanotechnology, cancer research—have in fact flourished progressively over the last half century, perhaps even more in recent years than ever before. This is certainly the case with the rapid rise of useful practical applications based on new insights which were previously *uncertain* or unknown.

On the contrary it is post-normal science that requires *recasting*. The outcome of the Anthropogenic Global Warming (AGW) philosophy which is based on that concept, can serve as a recent example. The development of new strategies for problem formulation encompassing the incorporation of *uncertainties* at hand with the modeling of future prospects has not had a valid outcome. It has to be noted here that the correlation of CO_2 rise in the atmosphere with global temperature change is not proven.

The statement *The traditional "normal" scientific mind-set fosters expectations of regularity, simplicity and certainty* is also a serious misconception. Certainly examples can be given from the history of science that man-made hypotheses produced by normal science turned out to be wrong, but to assume that these scientists were simplistically minded is disingenuous. Again on the contrary, a major achievement over the last half century has been the recognition of the irregular behavior of complex processes in Nature which are ruled by unsolvable non-linear partial differential equations [32].

Lastly the statement that the policy-relevant sciences have enjoyed less prestige and funding, is an observation which flies in the face of the perception of those who are involved with the traditional search for the unknown. That policy-relevant sciences *are more subject to external influences* is of course inherent to a philosophy that propagates a manifesto which requires *involving wider circles of people in decision-making.*

With this, however, the question arises whether this would result in an increase of the *quality* of the research to be pursued. There is of course nothing against a *focus on dialogue, and on mutual respect and learning* when those people who are involved have sufficient acquired scientific literacy. In this respect the post-normal science concept seems to put the cart before the horse in the sense that dialogue is proposed as a good in itself without firstly considering the competence of the people who are invited to join in. (See further Section 11.2 for requirement for a certain level of scientific literacy to be able to take part in a scientific dialogue).

The dialogue among scientists has of course always been an important element in the progress of science and was useful as long as the questions in Section 11.2 formed the accepted structure.

In the opinion of the author the urgency of solving environmental problems has been subject to exaggeration since the 1990's [33]. This point of view is borne out in Appendix I that lists some 80 so far unfulfilled prophecies made by pessimists on the state of the world. It should also be noted that many prosperous countries have been able to cope reasonably well with the major environmental menaces.

With all respect for the view that in e.g., the social sciences there is no ultimate proof on what can be interpreted as being true or untrue, it is very hard to assume this could be the case in the natural sciences. Man-made hypotheses may also turn out to have been wrong, but to assume that Nature has such degrees of freedom seems absurd. See Section 3 on the philosophies of science. Fundamentally, if the approaches of post-normal scientists are subject to recasting, a first priority should be to find the way back to establish a willingness for truth-finding to prevail in the search to discover the real seriousness of assumed environmental threats. See Section 7 n sustainable development.

One of the reviewers of this manuscript [34] suggested that post-normal science in its current state of development should be renamed as post-moral science, "where one is permitted to stretch the truth to prove one's interpretation of the data".

This is however a bit unfair because we must assume that the followers of the Funtowicz and Ravetz philosophy are honestly driven by the conviction that environmental threats deserve the greatest possible attention. However, before addressing justification of these we have to move on to the more general alarming message presented in the next section.

7. Research on Sustainable Development

7.1. The Bearing

From the previous sections it has to be kept in mind that today the societal drive for sustainable development is a most important issue to reckon with. This is true also from the point of view of science, not least because research efforts are expected, if not requested, even forced, to contribute to the drive. In the previous sections it has been taken almost for granted that enhancement of the progress of science and the removal of impediments are a prerequisite to serving also the goal of sustainable development. At this stage the Socratic question may however be posed: Is that so?

The answer requires some shading because of the wide scope of the subject. It is useful as a starting point to first return to the original definition of sustainability in the "Brundtland report" from which we can also establish its goal [30]:

> It (sustainable development) is not a fixed state of harmony, but a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are made consistent with future as well as present needs. We do not pretend that the process is easy or straightforward. Painful choices have to be made. Thus in the final analysis, sustainable development must rest on political will.

The two last words define the challenge in a nutshell: it is politics rather than science per se. How science comes in was suggested in Section 6 on post-normal science approaches which can be rather seen as a set of *assessment methods* of scientific observations, than as a branch of scientific inquiry itself.

To reach in the future a maintained "state of harmony"—thus not necessarily a former state—scientific research enters with the no doubt challenging question as to how a future harmonic state should be defined and, next, with contributions on how it could be reached. This certainly concerns the "exploration" of "the unknown" which, in order to be successful, based on arguments presented in the previous chapters, is expected to require "freedom of inquiry" and a corresponding restraint of political convictions. Or should we say in a more positive sense that we expect a *political will* not to force such convictions on scientists.

In 1993 the author co-published a book (in Dutch) on sustainable development entitled "Turning point 2000 Border conditions and scenarios for sustainable development in the Netherlands and

Europe" [33] It was based on five international seminars organized by the Dutch Organization for Applied Research TNO, which at the time had a rather large research group (700 co-workers) working on various aspects of environmental problems. The issues that were raised at the time seem to be still relevant at least in the consciousness of many countries, although several of these have so far quite been able to cope with the most eminent environmental threats. The essence of the book was the presentation of various optimistic and pessimistic views on environmental developments. It was awarded the nickname "color book" because its chapters were named: the "black paper" which comprised the pessimists' view, the "white paper" for the optimists' view, the "green paper" in which ecological issues were raised and the "red paper" in which critical comments were collected. The last chapter was entitled "blue print", which dealt with scenarios, especially with regard to the physical limitations and the idealistic views which influence the drive for sustainable development.

Here we of all need to present what was expected to become a major guideline after the year 2000 to consider maintenance of states of harmony.

7.2. Transition Management

Alarm about threatening environmental developments began as early as 1968 especially by the establishment of the "Club of Rome" which brought a report, "The Limits of Growth", to the attention to the public in 1972. There were at the time sufficient reasons for such an alarming message.

The major threat was the technological development and increased industrialization after WWII, promoted to increase economic growth but leading to a consumer society, already noted in 1960 to be paying insufficient attention to concurrent environmental pollution [35]. The "limits of growth" highlighted also that natural resources are in principle limited.

With all respect to scientists who raise their voice against autonomous developments with possible detrimental effects for the environment if "business proceeds at usual", several objections can be presented from a fundamental scientific view against their approach to meeting challenges. "Transition management" was the name given for the drive to establish sustainable development with an outspoken political will behind it.

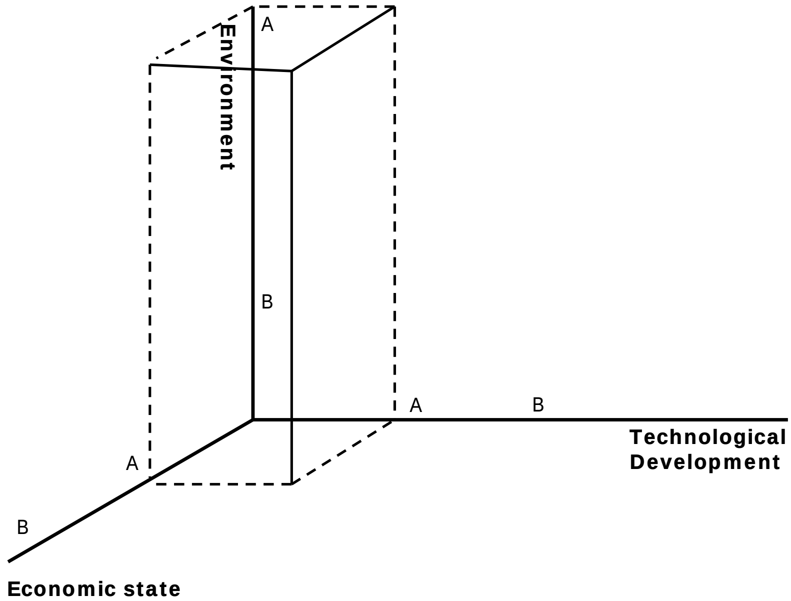
> Abstract: In this paper we examine and elaborate on the central elements of sustainable development and governance, considering their interrelations as they have emerged from the core themes in sustainable development discourses over the past decade and a half. We argue that sustainability is best viewed as a socially instituted process of adaptive change in which innovation is a necessary element. We discuss four key elements of governance for sustainability, which are integrated into the concept of transition management.
>
> The result is a conceptual framework for policy-making and action-taking aimed at progress towards sustainability [36].

For a critital consideration see however Pieterman *et al* (2002) [37].

In principle, societal transitions require consideration in at least three dimensions. First of all, technological developments, if they proceed autonomously, may be detrimental to the environment but beneficial to economic state and human welfare. The second dimension is the environmental state itself, and the third the economic state to be considered as representative also of human welfare.

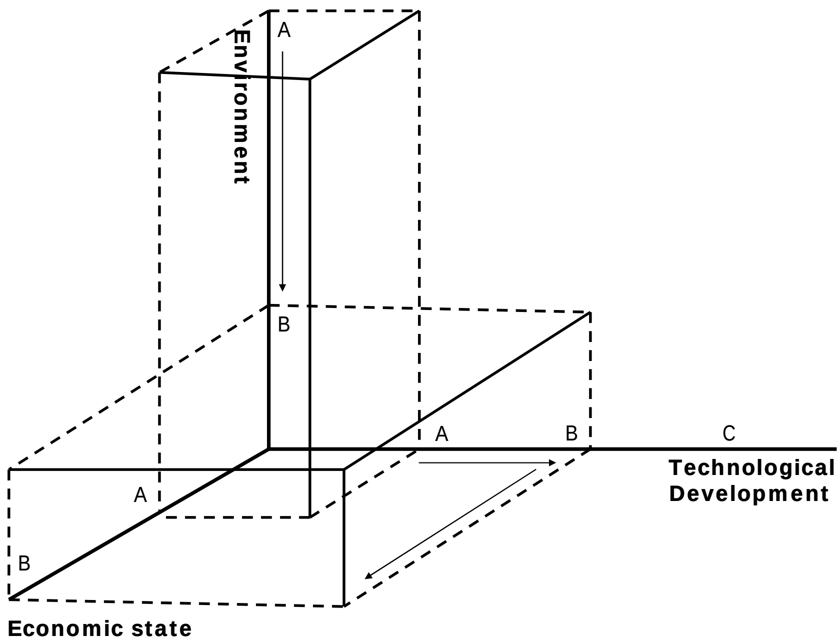
Figure 2 presents a particular situation at a certain state of technological applications (point A) with a particular value for the economic and the environmental state in the three dimensions.

Figure 2. A theoretical three-dimensional state of society.



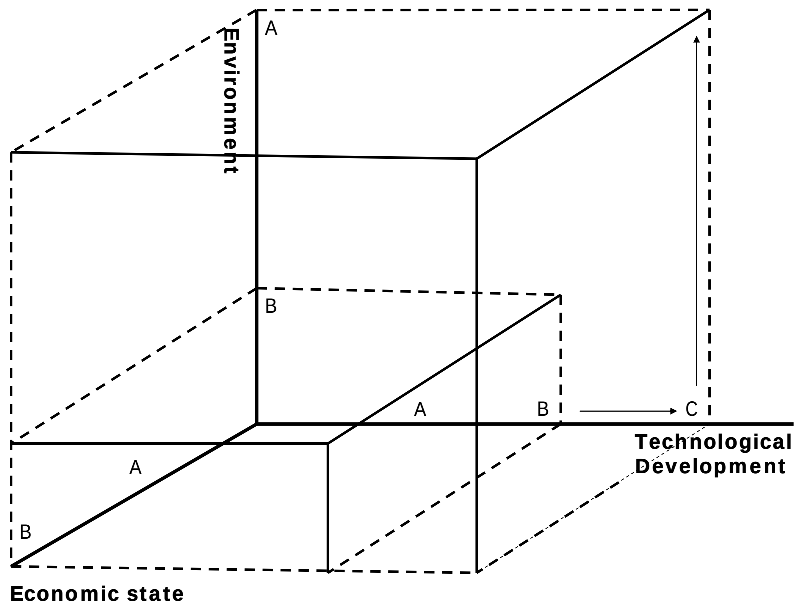
Then an autonomous technological development A→B may be favorable for the economic state but not for the environmental state. See Figure 3.

Figure 3. Change of the three-dimensional state with damage to the environment.



Subsequently an additional technological development (C) on the X axis can be induced to undo the detrimental effect on the environment (return to condition A) on the Y axis without necessarily a negative effect on the economic state (B) on the z axis. See Figure 4.

Figure 4. Recovery from a poor environmental state with the application of improved technology.



The development over the last half century can be observed to have taken a course which is not in agreement with the alarming prospects presented in Section 7.3. That is to say, in countries which have a sufficiently high economic state to allow for investments in specific technologies that can solve environmental problems arising from human activities. Air and water pollution is still an important problem in many developing countries. The Netherlands is a remarkable example of a country with one of the greatest population densities in the world in which environmental problems have been handled rather well. It exports environmental technology, based on innovation, to other countries that can afford to pay for it. Search the web for "transition management" and one will see that several action groups that promote "sustainable development" are still not satisfied with the results that have been achieved and are continuing to push for more. They are not beyond criticism because their political motivation seems to be stronger than their scientific insight into what is feasible and really needed.

7.3. The View of Pessimists on the World [16]

Appendix I presents a compilation of 80 quotations from the book "The Skeptical Environmentalist" by Bjørn Lomborg (2002) [16]. The quotations refer to the pessimistic view on the state of the world of the earth expressed by World Watch Institute (WWI), World Research Institute (WRI), World Wildlife Fund for Nature (WWF), Greenpeace, and several well-known authors such as Asimov, Ehrlich, Brown, Pimentel, Myers, Gore and Wilson. Very few of these alarming views from well known scientists have however materialized.

7.4. The Opposing Optimistic View

The positive view was in short formulated in the "white paper" of turning point 2000 [33] in that human inventiveness has shown in the past to be able to cope with threats that mainly arose from the autonomous population growth. The proposal is that there is no need to despair, that by innovation and new scientific discoveries the world will be able to solve its foreseen problems. Pessimists are considered to suffer from a doomsday syndrome (Section 9) by exaggerating problems that have not emerged and as yet to be proven real. The response from pessimists is, however, that expected problems may indeed be still of a theoretical character, but so is the view that, without sustaining arguments, the problems will be solved by human ingenuity. The pessimists state that the optimists are taking out a mortgage based on this theoretically expected ingenuity without sufficient forward proof that it can be redeemed. This is in fact the argument which leads to the wish to adhere to the precautionary principle, to be dealt with in the next section.

7.5. The Precautionary Principle

As stated in Section 7.2 at the time of the club of Rome there were sufficient reasons to formulate the precautionary (or prudence) principle [36]. It states [38]:

> "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

However we have to consider the fact that this approach can paralyze change for the reason that it takes considerable time to evaluate consequences. Our knowledge in complex fields such as ecology and climate is still limited, and we know from complexity theory that even if we knew all the forces, and the immediate effect of each, predicted limited predictability would still apply in such complex systems.

Another expression of the precautionary principle is that if we foresee a detrimental development we should take measures now to prevent it from developing, as stated in the post-normal science approach, even if there is insufficient evidence that these developments will actually materialize.

It is here assumed that everyone will agree that vigilance is required, but it should be noted that we have to deal with a number of autonomous developments that are outside our influence. These include world population growth and the understandable wish of two thirds of the world's population to increase its standard of living towards that of the developed world. There is no choice but to meet the increasing burdens from these demands. It is simply not practical to apply the precautionary principle unilaterally unrestricted to prevent a particular change which at first sight looks detrimental. The professional approach among forecasters on technological and concurrent economic developments is to consider next to a scenario "business as usual" two or more above and below an initial expected extrapolation.

Among the prospects presented by well-known scientists on detrimental environmental developments, during the previous decades, very few seem to have materialized. (Appendix I)

7.6. Limits for Scenario Development

We here have to consider the border conditions on each of the axes of the three-dimensional state of sustainable development which hamper the achievement of an optimal state. From the point of view of furthering the progress of science, this is an important approach to adopt in making its efforts most effective in time to reach particular goals.

Two types of conditions can be distinguished on the axis "technological development" and "environment" respectively.

(1) absolute physical limitations
(2) marked by idealistic views

With respect to the "economy" axis, worldwide there is no indication that there is a "natural" limitation of economic growth, except owing to the exhaustion of natural resources. This, however, becomes less relevant if complete recycling with a non-exhaustible energy source comes into the picture.

The natural limitations governing technological development are formulated in the two laws of thermodynamics. The yield of work from energy is limited and can never be 100 percent. The second law states that every conversion in a closed system increases disorder up to thermodynamic equilibrium which is characterized by absolute chaos.

Outside the field of physics and mathematics, however, it is still poorly understood that this law concerns only closed systems. In an open system, in which there is a continuous energy influx, order can be maintained or will even increase. This is the reason why living organisms stay organized and is the basis for biological evolution to complex organized higher organisms. The earth is an open system with respect to energy with solar radiation as the single source.

However, since the industrial revolution, technological development has required more energy than can be easily captured from the solar source. Fossil fuels have been exploited and this source is in principle exhaustible. But a practically unlimited energy source is available if the energy producing process in the sun (that is hydrogen fusion) can be mimicked on earth, or if the abundant solar energy reaching the earth can be captured more economically. With respect to the latter, it can be noted that Nature (by the biological evolution) has provided us with a not very efficient process: photosynthesis. Manmade photocells do already ten times better. They require, however, much further improvement to become competitive with other available energy sources. This is yet another example of placing the cart before the horse; if the drive for sustainable development is stimulated by state subsidized use of photocells with current capacity, instead of firstly encouraging photo-electric research.

For other natural resources such as minerals, the earth can be regarded as a closed system. Technological development results in minerals being transformed (into metals, ceramics, chemicals, *etc.*) and spread over the earth as manufactured goods and ultimately waste. Containment and recycling provide possibilities for recovery, but at an energy cost according to the laws of thermodynamics as applied to open, organized systems.

Next, technological developments require investment in research and machinery. Technological development is largely a cyclic process in the sense that value added by the production process provides the funds for subsequent investments.

From the above mentioned divergent views between pessimists and optimists, it can be deduced that changes on the "environmental" axis are largely determined by differences of an idealistic character. This mainly reflects the extent to which Nature preservation requires primary attention, e.g., the maintained biodiversity and, secondly, the rejection or necessary acceptance of new technologies, e.g., energy production by nuclear processes, of which the risks are differently assessed. Another example is the application of "genetic engineering". Its progress also may be considered as a demonstration how in a particular field a "crisis" in science (as suggested to be the case by post-normal scientists) was overcome despite hampering political interference [39]. The alarm was raised inside the scientific community in 1973 by molecular biologists who later became Nobel Laureates for their important contributions to the development of a technique which today is common practice in biological research institutes. Safety rules were established in the early days to handle so-called recombinant organisms with care, which, with the benefit of hindsight, appeared to have been overdone. Remarkably, the original alarm continued to perturb society due to publicity-seeking environmental activists whose scientific literacy can be seriously contested. Among molecular biologists it led to disappointment in the public's reaction, more than anything else, after all had they not, at a conference in Asilomar (California) in 1975, themselves voluntarily accepted the suggested rules on how to advance the research under strong containment conditions? Why were the revealing follow-up results not recognized by the public? Since then, thanks to successful gene transfer, we have learned a lot about the properties of genes that are involved in carcinogenesis and are able to unravel complex biochemical pathways. As a successful application, several useful but costly natural products such as insulin can be produced with much higher efficiency than in the past.

Looking back at these events, Watson and Tooze and most of their colleagues see the initial brake put on these advancements of science as an unjustified political interference and it is no wonder that they were left with great reservations about the lack of quality demonstrated in the public scientific dialogue. At the time of the publication of the DNA story 1981, those authors summarized their view in the final sentence of the book: "Politics preoccupied the first years but that phase fortunately is fast becoming history". But, as we can observe, activists still fight the use of genetically modified foods and have their voices amplified with arguments other than scientific ones. Nevertheless there are many demonstrations of how brave scientists with effective measures have overcome the precautionary principle.

7.7. The Progress of Environmental Sciences

Students of complex systems in a dynamic state, ruled by non-linear (and unsolvable) differential equations, use special mathematical techniques to investigate the ultimate borders in which such a system will be contained (called "the box"). Using space/time diagrams, they investigate how a system moves from one stable dynamic state to another, passing through an intermediate deterministic chaotic state during the transition (these conversions are ruled by natural constants, such as the Feigenbaum numbers [32]). Finally they search for conditions under which the system would collapse into a state from which no recovery into a cyclic dynamic or deterministic chaotic state is possible.

A full mathematic description of the dynamics of changes on the planet cannot of course be presented, and this will probably never be possible. However, this should not prevent us from considering the principles developed through complexity theory. We should:

(1) not over-emphasize changes over short periods of time (that is the principle of predictable limited predictability),
(2) search for "boxes of containment" and,
(3) search for real examples of collapsing conditions.

So far this has not become general practice in environmental studies or in the broader scope of sustainable development.

To progress, we need to come to a clear understanding of the technological, economic and ecological choices we face. In order to do this, we need to recognize and discriminate more clearly than in the past the degree to which constraints in this multidimensional world of thought are due to natural limitations or to social limitations.

Concern was certainly justified in the 1960s (although perhaps exaggerated), when it was predicted that without global action the "north" would die in its waste and the "south" might starve [40]. Lomborg's book [16] is in fact a testimony to how these early warnings have been taken to heart resulting in effective action to deal with the most serious problems. *Things have got better, not worse*.

In the author's opinion, several UN subsidiary bodies (such as FAO, WHO, UNDP) have done effective jobs in identifying and monitoring unsatisfactory situations and calling for and monitoring action by politicians and by scientists.

Unfortunately this cannot be said of the "hot" topics [41] of climate change and global warming we are dealing with today and which have polarized opinion in an extremely controversial way. On one side, we have scientists who consider the threat of global warming, as presented by the IPCC, to be equivalent to the threat from weapons of mass destruction. On the other side, there are scientists who consider that the way the IPCC analyses have been translated into the Kyoto protocol is a scientific swindle. But, in the next chapter, we will deal with the CO_2 case not as a swindle but as a remarkable demonstration of imposed authority by a particular scientific school with no or little regard for skeptical voices.

8. The CO_2 Case

8.1. Need to Reconsider CO_2 as a Greenhouse Gas

The legal decision of CO_2 being a "greenhouse gas" originated at a congress in Rio de Janeiro in 1992. It was largely based on evidence submitted by climate experts at a conference in Villach, 1985 [42] and sustained by circumstantial evidence with origins in the 19th century [43].

This judgment makes use of a principle known as Occam's Razor [44]. This principle states that, among competing hypotheses, the hypothesis with the fewest assumptions should be preferred. In other words, the simplest explanation is usually the correct one.

The evidence is based on the fact that CO_2 absorbs infrared (IR) radiation and is expected to transfer heat to the molecules in the atmosphere. In addition, the fact that its concentration increased in the atmosphere during the last century coincided with a small global average temperature rise over the same period. This association has been further sustained by sophisticated global circulation models (GCMs) of mass and heat flows through the atmosphere and the oceans. Although these models are very sophisticated, they still do not include a number of presumptions that are expected to be of major importance in predicting a particular global climate.

For more than a decade the CO_2 concentration in the atmosphere has however continued to increase but no further rise in global average temperature has been observed, contrary to the prediction of the climate models. Consequently, the models are due for revision.

The evidence for the influence of CO_2 on climate needs to be reconsidered from the point of view that complex systems show a tendency for stability by self-organization [45]. In the case of the Earth's climate, this is established by the circulation of water, which regulates the troposphere and surface temperature to a great extent by evaporation of liquid water from the oceans. The evaporation of water from the oceans and its condensation at various levels within the troposphere acts as a transport of, and control on, heat emission back into space. The processes related to water vapor in the troposphere would better be described as a "water house", rather than as a "greenhouse"; in the latter an elevated temperature is maintained by the suppression of circulation. Accordingly, the effect of CO_2 absorption and emission of heat in their respective influences on that water house need further examination. In the light of current observations the theory that CO_2 *must* have a significant effect on the global temperature seems to be short of sufficient insight how a variety of forces are able to stabilize a complex system.

It is generally acknowledged that radiation energy from the Sun is the driving force warming the atmosphere and the Earth's surface. The applicability of Occam's razor to the CO_2 hypotheses is challenged primarily by the fact that CO_2 is in itself not an energy source. How can it *warm*? According to the greenhouse-gas theory it would contribute as a kind of insulator to *keep* the surface warmer than in its absence (see further Section 9.2).

Because of the physical structure of CO_2 molecules, only photons of energy in certain wavelengths can be absorbed and emit energy by radiative transfer (*cf.* collisions). The absorption and emission signals of CO_2 are well recorded by spectroscopic observations. Present climate conditions in addition to temperature indicate that the reconstruction of the atmospheric processes in "models" with CO_2 as the driver might have been weighted incorrectly against other in cause and effect relationships. Even prior to the period of over ten years of near constant average temperatures accompanied by steady CO_2 increase in the atmosphere, doubt was thrown on the perfection of the models at that time [46]. "*With regard to the coupled nature of entropy, entropy transport with heat sources and sinks, scaling arguments fail in attempting to isolate scales of differential heating corresponding with certain scales of atmospheric circulation*".

In the discussion on the origin of climate variability and the possible effect of increased atmospheric CO_2 concentration on climate, with assumed Anthropogenic Global Warming (AGW), many different disciplines are involved, e.g., physics, meteorology, oceanography, geology, palaeobiology, atmospheric physics and astronomy. The complexity of the subject and the perspectives and knowledge from these different disciplines give rise to a large spectrum of contradictory arguments by adherents to the AGW concept (the protagonists) and by skeptics (the antagonists). Many people, among them "policy makers" and also scientific specialists in the fields mentioned above, may not now be able to see the wood for the trees. This is no wonder because of the great complexity of many different physical forces interfering with each other in the troposphere, at the air-surface interaction and in the deep sea. Also many positive and negative feedback loops do exist in "natural cycles".

Prior to 1965 the generally accepted thinking on climate variability was:

> "The broad pattern of climate change since the end of the Ice Age is consistent with the hypothesis of an alternate weakening and strengthening of the planetary atmospheric circulation, associated with alternate pole-ward and equator-ward shifts of the wind zones.
>
> At times of minimum circulation the circumpolar belt of west winds contracts and anticyclones are frequent in middle latitudes. Winds are variable, rainfall is small and the climate 'continental', with cold winters and warm summers. When the circulation is stronger, westerly winds predominate, storms are more frequent and penetrate into lower latitudes; the rainfall is heaver and climate more 'oceanic'. This with a few short interludes, was the general condition after A.D. 1200." [47].

Before 1965 no specific role in climate variability was attributed to CO_2, although such a suggestion was made in the 19th century [43].

The radiative property of CO_2 and water vapor to absorb, and subsequently emit, infrared radiation are well known. The theoretical base of this radiation transfer process through a column of "greenhouse" gases is well described in theoretical handbooks [48,49] for an established (static) equilibrium state throughout the column. AGW antagonists question the applicability of that theoretical model to the more complex model of the unconstrained atmosphere, which is always attempting to reach equilibrium but is at the mercy of constantly changing dynamic forces.

8.2. The Scientific Controversies

In considering the CO_2 case further, it is taken as read that AGW protagonists have not yet presented convincing proof that CO_2 in the atmosphere must affect the climate by temperature change. However, neither have AGW antagonists proved beyond doubt that CO_2 will not have a significant effect. The reasoning of each has shortcomings. The protagonists translate fundamental properties of CO_2 too easily as also being effectively unconditioned in the complex Earth's atmosphere as might be expected. The antagonists base most of their arguments on the classical and conceptual global meteorological model as mentioned above in which in principle no important role is attributed to what are today called "greenhouse gasses".

It should also be noticed that several investigators [50,51], theoretical physicists who have an admired record for interpretation of observations but who are not respected by the IPCC school, have serious doubts about the application of the radiation laws of Kirchhoff, Planck and Stefan-Boltzmann to the conditions in the gaseous atmosphere.

In a perhaps slightly hidden but significant development, Robitaille contributed to a book *Questions of Modern Cosmology; Galileo's Legacy* [52] the preface of which reads:

> ...it is our aim here to discuss another important parallelism between Galileo's epoch and the present, that is enclosed in the following questions.

> Galileo was condemned for his ideas and several people fought against the progress of the new scientific vision of the Universe. Are we living with the same things today? How much space is there for alternative ideas that may prompt a new scientific revolution? Are we close to a deeper understanding of the current paradigm or to a new scientific revolution, or rather, are physics and astrophysics going through a profound crisis?

This strongly highlights the need for reinvestigation of the established authoritative position on the climate debate, which is almost exclusively focused on the possible effect of CO_2 on the climate. It is worthwhile recalling here that a mathematical model, whatever his level of sophistication, is not a proof by itself, as the outcomes only reflect the hypotheses made, leading to the now famous statement: "garbage in = garbage out". If the algorithms used to write the model state, for example, that an increase in CO2 will create an increase in global temperature, as done in the IPCC models but which is nothing more than a hidden working hypothesis, then automatically, when the CO2 concentration increases (which is the case) the model will predict that the temperature increases.

We will not here rehearse in greater detail all the technical aspects of the different opinions between AGW protagonists and antagonists, the latter having a range of opinions rather than speaking with a single voice like the former. Suffice to say that the heart of the matter lies in the differing assessments of the value of model building for truth-finding. The reader who is interested in the protagonist's view is referred to the official and laborious IPCC reports with their contributions from many well-known scientists. But he should not just restrict himself to the summarizing Assessment Reports—the so-called Summary for Policymakers—because it simplifies much of the main report and shows a degree of certainty that is not borne out in the main text.

From the beginning, however, the procedures adopted for the collection of scientific information and the way it is communicated to the public and governments through IPCC channels has been the subject of serious criticism by many individual independent scientists, who have expressed strong doubts regarding the existence of AGW. They began to convene in unofficial bodies of which the ESEF [53] was one of the first. Today there are many networks and organizations in several countries, e.g., U.S., Canada, Australia and New Zealand, which regularly raise their voices against IPPC proclamations. The NIPCC [54] and the ICSC [55] are active in promoting alternative views at international level.

The relative positions of the AGW protagonists and the AGW antagonists have much the same character as other fundamental debates: relativism and idealism versus positivism (see Section 3.2) or post-normal versus 'normal" scientists (see Section 6).

8.3. The Dialogue

From the history of science it is clear that dialogue on controversial scientific issues often had a great impact, for better or for worse (see Section 4), on the progress of science [11] in many cases this dialogue has been emotionally loaded or, indeed, overloaded.

In the concept of post–normal science (Section 6), the word "dialogue" is mentioned several times: "the maintenance of quality depends on open dialogue between all those affected"; the need to "focus on dialogue, and on mutual respect and learning, wherever possible". If AGW protagonists favor a post-normal science approach, then one would expect them to encourage a profound and fundamental scientific dialogue.

Over the last few decades, however, the dialogue among protagonists and antagonists of AGW has instead often been characterized by passions running high, reciprocal presumption of malevolence, mutual accusations and insults, and frequent "ad hominem" attacks. Some protagonists have described antagonists as "deniers", which has a clear connotation with denial of the evidence of Jewish Holocaust in World War II. On the other hand, many antagonists have called protagonists "liars" and believe that they deceive the public. This kind of mutual disrespect is, of course, not conducive to a productive dialogue.

Depressingly, there have been very few fruitful discussions among scientists of the two schools. Well-known AGW antagonists have not been invited to participate in official IPCC gatherings. Some AGW antagonists have been "expert reviewers" of draft IPCC reports but often their comments were ignored or curtly dismissed. This is hardly surprising, given the fact that the antagonists challenge the "consensus" already determined by "experts" inside the IPCC community.

Antagonists in several countries have organized their own "skeptic" meetings as a response but when protagonists have been invited to participate, only a few, if any, have attended.

The chasm between the two groups is also seen in scientific publishing where most journals have sided with AGW protagonists and have accepted very few papers from AGW antagonists. The rejection of papers written by AGW antagonists may have been done on good grounds but the reviewers seldom take the trouble to advance substantive arguments for their rejection. Worse, the "Climategate" emails [56] showed AGW protagonists colluding to try to remove journal editors and shut down journals which did not support the protagonists' position and, if all that failed, to try to prevent antagonist papers from being cited in IPCC assessment reports.

The author has twice been invited to act as guest editor for special issues based on selected papers by the publisher of one of the few journals which are skeptical about AGW: *Energy and Environment* [25,57]. With two exceptions, AGW protagonists refused to contribute, either as author or as referee. The papers in these special issues are very seldom referred to in the mainstream journals, allegedly because they have not been properly reviewed. As a matter of fact, they were not reviewed by AGW protagonists but all papers were in both cases peer-reviewed by, respectively, 20 and 50 well–known antagonists and, after several rounds of discussion among authors and referees, accepted for publication.

Over the last decade antagonists in the Netherlands organized four meetings on the main scientific issues of the climate debate. It should be noticed that, compared with the situation in many other countries, in the Netherlands the relationships between antagonists and protagonists of AGW are not of an unfriendly nature, even if exchanges of view are largely restricted to correspondence by private e-mails. But again, at the four mentioned seminars very few protagonists took the trouble to participate.

After "Climategate", the Netherlands Royal Academy of Sciences (KNAW) took a surprising initiative to organize a seminar to which both protagonists and antagonists were invited—three of the latter even as main speakers—with non-partisan chairpersons moderating the various sessions. At the time, participants seemed to consider this seminar as being informative. The antagonists eagerly awaited the report of the meeting. However, they were in for an unpleasant surprise. Not less than a year later and without consultation with the antagonists participating in the meeting, the KNAW published under its own authority a report prepared by a small number of its fellows. This report, which exclusively presented the usual litany of climate fears, was expeditiously brought to the attention of members of parliament. Antagonists identified many flaws in the report, but this was rejected by the chairman, who explained that it was only meant to be a discussion note. Subsequently, no initiative for further discussion occurred and the report's authors kept silent. Some months thereafter the antagonists decided to organize such a meeting themselves. They invited the report's authors but none of them attended. Only one member of the Netherlands IPCC delegation accepted an invitation to present a paper. But he arrived rather late at the meeting and left too early to play a substantial role in the discussion.

This is only one example of many similar events occurring in many other countries. For more than two decades numerous attempts have failed to bring about a serious scientific discussion on the controversial issues concerning the planet's greenhouse effect. AGW protagonists have consistently refused to enter into discussion, often claiming that discussion was pointless because there was a consensus among a large number of scientists on AGW. It goes without saying that consensus does not belong to the realm of science. Science requires irrefutable proof, not consensus. As Michael Crichton once quipped: "There is no such thing as consensus science. If it's consensus, it isn't science. If it's science, it isn't consensus. Period."

8.4. The Consensus Culture

The IPCC and many of its spokespersons claim that there is consensus among participants taking part in their assessments and contributing their views about AGW. From an epistemological perspective two issues require further attention: (1) whether the consensus is as large as claimed (2) whether this claim of consensus can legitimize the momentous policy implications presented in IPCC's Summary for Policymakers (SPM).

Several people have investigated the process as to how the 2007 IPCC AR4 working group (WG1) report on the "Scientific Base" came into being. Here it might suffice to refer to a note by J. McLean [58]:

> The only consensus within the IPCC came from a plenary meeting of government representatives and they only reach a consensus on whether the report is an accurate summary of knowledge at the present time, not whether the report contains irrefutable evidence of a human influence. We know little about the scientific expertise and possible personal biases of these representatives but we do know that most governments have signed and ratified the Kyoto Agreement and incorporated it into government policy, so a consensus that supports the views of governments is hardly any surprise.

So far for the perceptive study by McLean on the review procedure. The conclusions of McLean do not relate so much to the quality of the procedure itself rather to evidence disproving IPCC's claim that thousands of scientists agree on AGW.

The procedure as such has however also been subject to criticism. Flaws in the procedures have been brought to light by an assessment group of the international Inter Academy Council (IAC) [59] the membership of which includes national scientific academies. This is not surprising, since the IPCC process is a massive international undertaking. It resembles a mass production factory—an ambiance that does not necessarily attract the best scientists in the world. The consensus on what is brought to the attention of governments as a result of a comprehensive survey of the literature is skewed by "voting" in an assembly, including governmental representatives, which ultimately produces the Summary for Policymakers. The influence of government representatives on the final outcome of the process jeopardizes the independence of science. As the editor of *Energy and Environment*, Sonja Boehmer–Christiansen, once observed: "Science on tap, not on top." The NIPCC, ICSC and national climate "coalitions" of scientists, whose alternative views have consistently been ignored, have repeatedly condemned this fundamental flaw in the process; so far to no avail.

Apart from that, it should be emphasized that consensus is alien to science. Science requires proof. In 1931 Einstein's opponents tried to denounce his theories. They published a book: "One Hundred Authors Against Einstein". When asked to comment on this denunciation of relativity by so many scientists, Einstein replied that, to defeat relativity, one did not need the word of 100 scientists, just one fact.

Scientific truths—which are best described as provisional truths in case they are later revised—are not determined by the popularity of a hypothesis but by how well a hypothesis can account for scientific observations.

The IAC assessment has overlooked this aspect. It could and should have recommended that the IPCC had to pay explicit attention to alternative views on various issues. But it did not.

This is a conceptual aspect of the management of science as one should be able to expect from its "leaders" and Section 12 will elaborate on this.

8.5. Criticism on Particular Scientific Approaches

Despite criticism, the voluminous WG1 reports, underlying the SPM, are a valuable source of information for specialists of peer–reviewed literature, with the proviso that they are of a somewhat one-sided nature, since they are almost exclusively focused on AGW.

The scientific approach followed in the treatment of the "scientific basis" of AGW deserves critical attention, e.g., the way "uncertainties" are being dealt with.

Various chapters of the report of WG1 refer to uncertainties. In the executive summaries they are quantified as percentages of estimated certainties. How were these figures obtained? Most probably by a show of hands among participating scientists. This is alien to the scientific method.

More important is that all these uncertainties are focused on only one single hypothesis: the presumed increased greenhouse effect of CO_2 as a climate effect. Numerous alternative hypotheses that originate from fundamental climatology are ignored, leaving the impression that the leading and most vociferous theories on AGW are accepted as unshakable truth, which is, of course, an important distinguishing feature of pseudo-science.

Section 4.5 dealt with the importance of cross-fertilization between various disciplines, especially physics, biology, chemistry and mathematics. A multi-disciplinary approach to particular phenomena is not only valuable as such, but it might also lead to the recognition that natural laws that have been discovered in one discipline may have a bearing in others. Climatology is certainly a typical multidisciplinary science, in which birds of very different feathers are expected to cooperate. For that reason one could expect that results in climate research would also contribute to the understanding of natural phenomena studied in other disciplines, especially physics and mathematics. In physics one can think of the behavior of processes that occur far from the (static) equilibrium state and seek a dynamic equilibrium in which a lower entropy is maintained than expected at first sight. In mathematics one can think of a better understanding of the behavior of interacting non-linear partial differential equations, leading to theories on how order will be produced and must arise from fluctuations at first sight seeming "chaotic".

It is rather remarkable that the meteorologist Lorenz made, as early as 1963, an important contribution to the understanding of the behavior of an atmospheric system in a dynamic equilibrium state [60]. The importance of this observation was well recognized in other disciplines but hardly any other significant contribution from climatology has emerged since then. One might have expected, for example, that the study reported by Johnson in the handbook of General Circulation Models [46] would have become an important indicator leading to a better understanding of the forces which contribute to stabilization in the climate system, bearing in mind the absence of global average temperature rise despite continuous CO_2 rise.

8.6. The AR5 (2013) Summary for Policymakers

Among the natural sciences the IPCC seems to operate in "splendid" isolation, almost exclusively focusing on the threat of AGW from a post-normal science perspective.

In early 2013 there were some indications that within the IPCC community confidence in the imminence of the threat of (man-made) global warming was waning. It was recognized that over the last decade no significant temperature increase on a global scale could be detected, despite a continuous increase of CO_2 in the atmosphere. It was also acknowledged that over the previous 10 to 15 years, predictions derived from climate models were significantly higher than the recorded global average temperature anomalies derived from observational data.

But these signals and several other doubts were played down during a plenary meeting of scientists and government representatives at Stockholm in September 2013. There they reached consensus on the latest SPM covering the underlying fifth IPCC Assessment Reports.

At a press conference, on September 27, vice chairman Thomas Stocker bluntly stated that more than 50% of the warming (0.7°C) since 1950 should be attributed to anthropogenic influences and that the IPCC was 95% certain of its case, a 5% increase in confidence compared with the previous report [61]. This statement was surprising in the light of the IPCC's explicit recognition of a number of uncertainties that had not been identified before and, of course, it defied all logic.

Some 100 scientists were mobilized to disseminate the message in the individual UN member states. The same procedure was followed in 2007 after the presentation of the SPM at the time in Paris on 2 February, almost half a year before the final version of IPCC AR4 WG1 was published. Soon after this publication it became clear that the final version contained some significant changes (not peer-reviewed) on the previous draft.

Within 24h after the press conference in Stockholm, seven AGW antagonists, active in the blogosphere, hastened to reject this alarming message. They variously described the IPCC's message as “hilarious incoherent”, “incredible”, “misleading to the public” and went so far as to describe it as “being based on science fiction” [62–68].

8.7. The Academies; the Followers

This same alarming message was nevertheless echoed with no nuances in a subsequent joint report by the U.S. National Academy of Science (NAS) and the British Royal Society [69] in a so called “question answer” format.

It states in its “projection background”:

> “The Royal Society and the U.S. National Academy of Sciences, with their similar missions to promote the use of science to benefit society and to inform critical policy debates, offer this new publication as a key reference document for decision makers, policy makers, educators, and other individuals seeking authoritative answers about the current state of climate change science. The publication makes clear what is well established, where consensus is growing, and where there is still uncertainty. It is written and reviewed by a UK-US team of leading climate scientists. It echoes and builds upon the long history of climate-related work from both national science academies, as well as the newest climate change assessment from the United Nations’ Intergovernmental Panel on Climate Change.”

The academies continue to hammer on about the consensus and about their mission to inform the public, relying on their status and without any new experimental evidence that CO_2 increase is the cause of climate changes.

Judith Curry (a skeptical meteorologist) concluded [70]:

> This report is an unfortunate step backwards relative to the IPCC AR5 itself, and the previous RS report Climate change: a summary of the science [71] which I thought was pretty good.

One should note in the context of all this that within the Royal Society also critical voices have been heard but were overruled by a leading group of fellows who considered it necessary to bring their conviction on AGW to the attention of the public.

At the time of writing (August 2014) of this essay there can be little doubt that the AGW debate will continue for considerable time, certainly in the blogosphere. But will it be possible to find common ground in the academic dialogue between protagonists and antagonists of AGW? It seems still too much to expect from the protagonists to have them consider the possibility that the concept of CO_2 “climate forcing” on a water planet based on calculations in model atmospheres in a static thermodynamic equilibrium, will not work out at all in a non-equilibrium system. This is for the reason that the non-model atmosphere must be considered to have its own continuous energy flow. Objectivism and modesty about individually-held convictions seems to have faded away completely. And that can be considered as an impediment on the progress of science and recognized as a source of anger for the “pure” investigators of the unknown.

In the context of this essay CO_2 is merely highlighted as an example of one of the most recent “feuds in science”—an illustration of the difficult social climate in which science has to operate in society today. It is marked by strength in the drive of authoritative bodies, and especially of their senior executives, to inform the public with overconfident answers to simplified questions.

It is notable that the British Royal Society took as its motto when it was instituted (1660) *nullius in verba* "do not swear by the words of any master". We do not any longer see it mentioned on its opening web site ("About Us") [72].

With the question/answer protocol becoming the norm for their presentations to the public authoritative bodies became used to having the license to impose simplistic specific views. This is in marked contrast to their obligation to make a contribution to improving scientific literacy by providing pluralistic observations that advance the capability of people to judge for themselves. The overconfident answers, constantly expressed on critically important issues can hardly be considered in compliance with the expected scientific literacy among scientists on which will be elaborated in Section 11.

It suffice to summarize here that antagonism on AGW is largely based on doubts that a trace-gas such as CO_2 can significantly interfere with the temperature regulating function of the global water circulation.

9. The Doomsday Syndrome

9.1. The Belief in Authority

Some pessimistic writers in our time forecast a second "dark age" analogous to the medieval period; they also predict an apocalypse in which unregulated and largely autonomous developments in our societies cause a collapse of our Western civilization. This theme was referred to by both Roberto Vacca [73] and Umberto Eco [74].

Vacca published on the coming "dark age" as early as 1970. He issued in 2000 a revised electronic book, with footnotes to his first publication. In this he admits he had some forecasts wrong thirty years ago but he keeps to his view there is a great risk that our current apparently prosperous western society will collapse. Here are some quotes from Vacca, largely sustained by Eco.

> The passage describing the Apocalypse (St. John 20:1–15) succeeded in convincing multitudes of people that the world would come to an end in the year A.D. 1000. Feeling doomed and powerless, they sought refuge and pardon in prayer and penitence. The able-bodied lost innumerable working hours, spending on their knees time that they had formerly given to productive work. Then the year 1000 passed, and the world did not come to an end—a notable fact that nevertheless did not modify the apocalyptic beliefs and superstitions in any way. Indeed, in the centuries that followed there were many other occasions when astrologers and numerologists predicted cataclysms and ruins. While cataclysms and ruins have not been absent during recent centuries, they have on occasion turned out to be in actual fact rather different from the improvised anticipations of the prophets.

> My thesis is that our great technological systems of human organization and association are continuously outgrowing ordered control. They are now reaching critical dimensions of instability. As yet, a crisis in a single system would not be enough to bring a great

> metropolitan concentration to a halt. But a chance concomitance of stoppages in the same area could catalyse a catastrophic process that would paralyze the most developed societies and lead to the deaths of many millions of people."

We are generally aware of the extent that we are dependent on sophisticated technology to maintain our daily lives. And we can readily imagine what might happen if we suffer from a severe snowstorm which coincides with an electric power, internet and railway breakdown. But rather than taking technology to task, we should realize that it is the quality of the local management of available technology that counts. Take for instance railway transport in winter in the Netherlands, Belgium, England and Germany, which is frequently in a mess, but not at all in Switzerland, where the train is seldom more than a few minutes late.

To what extent are current developments in science and its guiding philosophies relevant for a comparison with the Middle Ages?

It is "belief" in the form of religion imposed by the Church, which plays a major role in the "dark ages" and not the search for truth or respect for the interpretation of observations of natural phenomena. It can now be observed that certain scientists and such longstanding "schools" as academies and royal societies who claim overwhelming scientific authority, have taken over the dominant role of earlier doomsday clerical forecasters on environmental issues and resource depletion, all, however, largely yet to emerge.

The promotion of post-modern science looks like an attempt to give this forecasting a philosophical legitimization on the borderline of science and sociology. Or is it for that reason just a conviction, a belief, a new form of religion, because of the statement that "truth as a goal of science is a distraction".

With the acceptance in society of the claim of authority of schools of scientists goes another phenomenon inside the scientific community, which is the trust in the value of views which are produced inside a school with a high degree of anonymity and little personal accountability. This is called "consensus". Ignoring, or even condemning, divergent views is certainly foreign to scientific traditions regarding the disputes which spurred the progress of science. Thomas H. Huxley expressed it very strongly:

> The improver of natural knowledge absolutely refuses to acknowledge authority, as such. For him, skepticism is the highest of duties; blind faith the one unpardonable sin.

The reliance on consensus in the IPCC school is based on its reports from Working Group 1 "The Scientific Base", which is an evaluation study of scientific papers in publications restricted to so-called peer-reviewed journals.

This approach resembles a typical characteristic of learned people during the Mediaeval Period. From a Dutch edition of Eco's essay [75] the following quote.

> The medieval scholar pretends he has nothing new invented. He always refers to older authorities who can be the Eastern church fathers, Aristotle or the Bible. If we come to think of that, it is the opposite of what happened after Descartes until now, in which the great scientist or the philosopher is a person who brought really something new. The medieval culture looks from the outside as a borderless gray monologue in which all the

> time the same style, the same arguments, the same terminology is maintained with the result the impression that nothing new is being said."

Another typical aspect of the "dark ages" is "fortune telling" which adopted a modern face in today's scientific practice by the use of statistics and highly sophisticated computer models. These do not necessarily contribute to our better understanding of phenomena. For the old computer adage applies completely: garbage in (as wrong assumptions) means garbage out. The computer is still not a robot capable of better thinking than Man; rather it is just more rapid in data retrieval and processing then the neuron connections in the brain.

When the author in his early days as an experimental scientist was taught statistics, and needed to calculate error bars for actual observations, he was strongly warned against the misuse of statistics for forecasting. A quote [76]:

> There was a time when popes and kings had astrologers at court to help them plan for the future. Nowadays government departments have statisticians for the same purpose. […] The reader will guess that my views on time series are biased and unsympathetic. When I think of curses on modern civilisation I feel in me the spirit of St George and I long to dash into battle with this dragon of superstition in the pit of idle computation. All you can hope for is a bald account of the obvious mechanisms."

It is the last sentence that counts most. Statistics applied to illustrate a phenomenon can be a very helpful tool as an indication for future research. In the natural sciences data analysis is not itself a proof for an underlying mechanism. Judges of forecasts based on models should in particular pay attention to point 5 and 6 in Arons' marks of scientific literacy (Section 11.2).

9.2. Planning the Future

In the post-normal science manifesto is stated (Section 2.6.2): "What we call 'science' has undergone many changes over the centuries in its objects, methods and social functions."

Here "many" might be a bit of an exaggeration if we consider the view of the successful scientist Schekman (2013) who quoted V. Bush (1944) "*Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown.*" [77].

This is an observation that holds true over all centuries and from it the deduction that progress had a strong element of autonomous development because it is expected to arise from "free play of free intellects, working on subjects *of their own choice*". The precise level of significance of this deduction is illustrated by many historical examples. "Objects" and "methods" may have varied a bit—progress in different disciplines changed with time, but not to a remarkable or significant level. The post-normal manifesto however is right in putting emphasis on the changes with respect to "social functions", notably with regard to the care of the environment. The compelling need for this care can hardly be disputed in the light of other autonomous developments which arose from increased industrial production in response to free market explorations for sales to potential consumers.

A major difference between the past and the present is, in brief, the development of the wish of society at large—and its scientific administrators of all kinds—not to let social and scientific progress proceed autonomously, but to impose planning and restriction on what formerly was carried out autonomously. The major instrument that has been employed to ensure planning and central control at whatever level is power of distribution of public funds over predetermine activities. The use of this instrument does not guarantee however that the goals are actually reached. That will stay dependent firstly on the "intellect" and imagination of the available researchers, their scientific competence and literacy then on the insight, competence and literacy of those administrators who are publicly responsible for the spending of public funds. The final contribution to goal achievement is, as has been demonstrated above, crucially dependent on the expertise, scientific and otherwise, of those employed by specialized governmental agencies in advising and planning. For example, in The Netherlands the Netherlands Environmental Assessment Agency (PBL) and the Rathenau Institute, in the U.S., a White House department.

All those who are involved in giving direction to science management should bear the stamp of Arons 8 *Comprehend the limitations inherent in scientific inquiry.* (Section 11.2)

Another warning, probably more important, can however be added: be aware of the basic natural laws which cannot be violated, e.g., those of thermodynamics, and which limit the current possibilities to change the world order with respect to energy consumption, despite particular ideological views. In in Section 7.7 possibilities for planned sustainable development was elaborated on.

To return to the issues on research for sustainability this personal view. We should not doubt the principle that natural resources are limited, although as yet no signal of definitive depletion has emerged despite the weight of pessimistic views. It is however insufficiently noticed that the planet is a closed system for natural resources, except the energy (radiation) transfer processes. No natural products are being lost. They are dispersed after consumption. In principle they can be recovered. But according to the laws of thermodynamics, to do this requires an energy input. Consequently the drive for sustainable development should not be focused on the limitation of energy production (energy waste should of course be prevented), but on the contrary, on intensified research as to how new energy resources can be exploited. We need more energy, not less, that is to say, more efficient ones then those available today. And there are prospects, e.g., with nuclear energy sources. The current drive to replace fossil fuels, which provide for an efficient and still lasting energy source, by less efficient ones e.g., wind, is again putting the cart before the horse. To neglect this renders planning for sustainable development based on the reasoning of a doomsday syndrome not very realistic.

Drive by idealism to better the world is far from a vice, but it should be largely left to politicians, clerics and other philosophic ethicists. The contribution by objective scientists should be focused on insisting on logical reasoning and truth-finding in order to stay away from what Huxley names the unpardonable sin.

Part III. Pathways to a New Renaissance and Age of Reason

> *Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown Freedom of inquiry must be preserved under any plan for government support of science.* (V. Bush 1945 and R.W. Schekman 2013) [77].

10. The Utopia

The wish to establish an ideal state is as old as western civilization itself and dates back most notably to Plato's "The Republic" (380 BC). His treatise concentrates especially on the justice and ethics to be maintained in a social community and grants authority for these to highly qualified scholars especially philosophers. It is still considered to be one of the most intellectually and historically influential works of philosophy and political theory [78]. However, Popper [79], a "darling" of many of today's scientists, strongly contested Plato's ideas. He thought Plato envisioned state totalitarianism because he advocated a government composed only of a distinct hereditary ruling class, with the working class—who, Popper argues, Plato regards as "human cattle"—given no role in decision-making. He argues that Plato has no interest in what are commonly regarded as the problems of justice—the resolving of disputes between individuals—because Plato redefined justice as "keeping one's place" [80].

Let's face it, in the two thousand years since Plato, not a single philosopher or any other scholar, and certainly no scientist, has been able to design a perfect state or has come up with a better proposal on how to select our administrators other than by democratic election. And it is no use to go back to Plato when we consider the problems we are facing in today's complex society as described by Vacca or by Eco in Section 9, problems which are of another dimension than those which arose among the ancient Greeks.

This forces us to show some modesty by not assuming that our civilization has advanced to such a level that it can construct a fool-proof plan for an ideal state in which the science community forms an important "province". As an aside it should be noted that this has been the approach throughout this treatise, namely bringing to the reader's attention that the most 'learned" members of the scientific community are not infallible. They do not have a monopoly on wisdom. Further, the question has been addressed as to whether the arrogance that goes with enforced authority by individuals over the course of the history of science is justified (Section 4). The current rumbling about the internal affairs of science can be taken as a sign that scientists are no better than politicians—as Popper would have it—at resolving the disputes among individuals or their schools.

According to Vacca's pessimistic view [73] the new 'dark age' is already upon us and he sees its continuation for some time as inevitable. He does not however specifically address the scientific community and it is legitimate to contest the thesis of the post-normal scientists that science as a whole is already in a crisis. As mentioned several times, in astronomy, molecular biology, medicine and chemistry, there is little reason to grumble about the progress that is still being made. The discontent seems to be limited to disciplines that are active at the interface of science and society. It is about the position of science *in* society. The reality of the dispute is that it is centered on whether science is sufficiently fulfilling its supposed obligations to society; those scientists who doubt that it does attempt to make all scientists feel the same obligation. (Section 6) That attitude is felt by other scientists to be an obtrusive reproach: they still value the principles of academic freedom and truth-*finding* to be their essential driver.

11. The Need to Develop Scientific Literacy for Decision Making

11.1. The Definition

The use of "scientific literacy" as a precursor of scientific progress needs some further explanation. "Scientific illiteracy", its opposite, of course does not mean illiteracy in the sense of not being able to read all scientific papers whatever their disciplines. It rather signifies ignorance or lack of understanding of the potential wider scope and implications of the practice of science. According to the contributors to the special issue of *Daedalus* [81] on scientific literacy, illiteracy is alarmingly widespread among the public at large.

Some sort of illiteracy may also be recognized in the scientific community itself. This essay put forward the observation that today's scientists are often so highly specialized in a particular branch that they may be insufficiently aware of advancements in other fields which might impact on their own subject of study. But this does in itself not equate to scientific incompetence. These specialized scientists may have received numerous honors for outstanding research in their own field. The ignorance of so-called unifying concepts in the natural sciences comes however near to a degree of incompetence when the defining study of particular natural phenomena demands a multidisciplinary approach and this approach is not applied. Attention has been given three such unifying concepts: which lack attention

(i) the laws of thermodynamics
(ii) the principles underlying the evolution of complex systems by the interaction of natural variability and selective forces, and
(iii) the mathematics which describe the potential power of non-equilibrium systems to come to self-organization. The formulation of these concepts comprise some of the major achievements in science during the last two centuries. Their relevance for all natural sciences is however still undervalued by many.

There is also good reason to assess public comprehension of the progress of science.

In broad terms, the general public shows admiration for "learned" men and women and treat them as celebrities. The accolades are often well deserved and well appreciated. However, many very learned people so feted might have scientific beliefs that are in fact quite erroneous. The personal fallibility of scientists leads to the consideration that judgments of the value of scientific issues, even when raised by celebrated scientists, need "depersonalization". In practice this comes down to testing the logical reasoning behind a particular conclusion. That is of course what scientists among themselves always should do when there is disagreement or dispute. Several cases has been presented in which practicing scientists failed to do so and whole "schools" were formed which sent science on an erroneous route.

In the face of obvious increased political influence on the direction in which science should and could progress, the public, confronted with the inference of observations and theories, should be aware of such inborn errors of the scientific community. However, that recognition requires a minimum level of scientific literacy.

Arons [82,83] approached this problem from the positive side and produced a list of twelve points defining the abilities a person needs to possess to be considered as having acquired a minimum level of scientific literacy. Several of Arons' points have been put to the test in this essay and used to consider other obstacles to scientific progress such as scientific orthodoxy with respect to established authority and the influence of directive funding power and its resultant political interference. Therefore, given their centrality to the argument, Arons' suggestions are quoted here in full from his teaching book.

11.2. Marks of Scientific Literacy

Quote from Arons:

I suggest that an individual who has acquired some degree of scientific literacy will possess the ability to:

(1) Recognize that scientific concepts (e.g., velocity, acceleration, force, energy, electric charge, gravitational and inertial mass) are invented (or created) by acts of human imagination and intelligence and are not tangible objects or substances accidentally discovered, like a fossil, or a new plant or mineral.

(2) Recognize that to be understood and correctly used, such terms require careful operational definition, rooted in shared experience and in simpler words previously defined; to comprehend, in other words, that a scientific concept involves an idea first and a name afterwards, and that understanding does not reside in the technical terms themselves.

(3) Comprehend the distinction between observation and inference and discriminate between the two processes in any context under consideration.

(4) Distinguish between the occasional role of accidental discovery in scientific investigation and the deliberate strategy of forming and testing hypotheses.

(5) Understand the meaning of the word "theory" in the scientific domain, and have some sense, through specific examples, of how theories are formed, tested, validated, and accorded provisional acceptance; recognize, in consequence, that the term does not refer to any and every personal opinion, unsubstantiated notion, or received article of faith and thus, for example, to see through the creationist locution that describes evolution as "merely a theory".

(6) Discriminate, on the one hand, between acceptance of asserted and unverified end results, models, or conclusions, and, on the other hand, understand their basis and origin; that is, to recognize when questions such as "How do we know...? Why do we believe...? What is the evidence for...?" have been addressed, answered, and understood, and when something is being taken on faith. (See Box 1)

(7) Understand, again through specific examples, the sense in which scientific concepts and theories are mutable and provisional rather than final and unalterable, and to perceive the way in which such structures are continually refined and sharpened by processes of successive approximations.

(8) Comprehend the limitations inherent in scientific inquiry and be aware of the kinds of questions that are neither asked nor answered; be aware of the endless regression of unanswered questions that resides behind the answered ones.

(9) Develop enough basic knowledge in some area (or areas) of interest to allow intelligent reading and subsequent learning without formal instruction.

(10) Be aware of at least a few specific instances in which scientific knowledge has had direct impact on intellectual history and on one's view of the nature of the universe and the human condition within it.

(11) Be aware of at least a few specific instances of interaction between science and society on moral, ethical, and sociological planes.

(12) Be aware of very close analogies between certain modes of thought in natural science and in other disciplines such as history, economics, sociology, and political science; for example, forming concepts, testing hypotheses, discriminating between observations and inference (*i.e.*, between information from a primary source and the interpretations placed on this information), constructing models, and doing hypothetico-deductive reasoning.

I hasten to indicate that this list is neither exhaustive nor prescriptive. [Unquote]

Arons's criteria for scientific understanding are of course especially relevant in the case of those who have to decide over the public funding of research.

It is arguably too much to ask of politicians for them to acquire all these competences. But surely we are justified in demanding that they should have as a minimum requirement the ability to distinguish between situations when questions such as have been adequately addressed and answered by expert scientific advisers and situations or when something is being taken on trust.

Box 1 The major Arons' questions.

"How do we know...? Why do we believe...? What is the evidence for...?"

These questions are in fact a reformulation of the questions Socrates used to ask in his dialogues to expose the positions of the sophists of the time who used rhetoric to hide the true nature of their assertions of wisdom.

It contains a plea to especially learned societies to return to philosophical attitudes that founded our western civilization (Section 2.1).

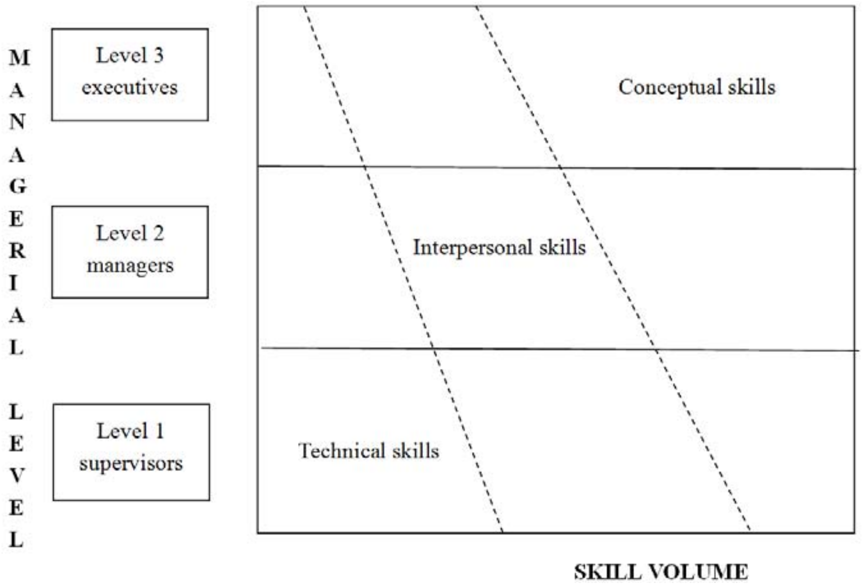
We are justified also in demanding basic scientific literacy as described above from administrators in the ranks of the scientific hierarchy above that of the groups of working investigators. They are the people who dictate policy—the section leaders, directors of institutes, professors in university faculties and academic boards. Therefore special attention is given in the next section to the quality of management in scientific establishments.

12. The Need to Improve Scientific Leadership

12.1. General Aspects of Science Management and Its Supervision

The following diagram (Figure 5) analyzing levels and competences in the management of scientific enquiry as adopted from the textbook by Badawy [84] (as taught by the author in management courses).

Figure 5. The general scheme for managerial competence.



It focuses especially attention on three types of skills which are expected to be required at three management levels. In level 0, below the diagram, one has to imagine the practitioners, the investigators, who are supervised by a working group leader performing in management level 1.

In small institutes, level 2 will be the position of an institute's director and, in a university, the senior professor in a chair.

In a large institute, level 2 may be a head of department, with a director at level 3.

In a university, the dean of a faculty can be placed on the border of levels 2 and 3 and the Rector Magnificus (the Vice Chancellor) on level 3.

This third level, the executive cadre, comprises also the governors and administrators who are ultimately responsible in large organizations for the performance of a number of institutes. For example, the science administrators and board members of the Max Planck Gesellschaft in Germany, the CNRS in France, NIH in the U.S. In governmental services, cabinet ministers might fall within the scope of level 3 if they directly supervise particular institutes.

With respect to skills, the Badawy diagram indicates only three among the many needed for effective performance and indeed there can also be many managerial levels and subdivisions. Other competences are dealt with in his textbook in sections such as "guidelines for management" and "why managers fail". In limiting our example of a management structure to just three levels we intend to highlight above all how applied skills are expected to differ to meet the demands of the three managerial levels in the diagram.

The definition "technical skills" applies to all applications of Good Scientific (Working) Practice or, in a somewhat broader sense, of the so-called "Scientific Method" comprising testing, formulation and re-testing of hypotheses [85]. Conceptual skills, however, have to exist side-by-side with other important facets of management; resetting of "theorems" is not really a daily practice. The key words are "strategy and tactics" and "portfolio management". Suffice to say that a rise in hierarchical level brings an increased requirement for conceptual skills. And that, with this rise, the required competence in the application of technical skills lessens and becomes limited to supervision of the correct use of the "scientific method". The rising demand for conceptual skills means of course a commensurate increase in the need for scientific literacy as previously defined.

12.2. A Minimum of Conceptual Skills

There is however another more cogent point to be considered with respect to the conceptual and interpersonal skills which are today required from leading scientists to run their home institutes. On promotion from just supervising a working group, have they been selected for the specific conceptual skill to judge strategic advice brought to them by "advisory bodies" which have themselves no result responsibility? Are they sufficiently science literate to ask, and judge the quality of the answers to, the Arons questions? (See Box 1) Rather then addressing these questions to their subordinates, and relying on their answers, they should in today's advisory and consensus culture be able themselves to scrutinize the leaders of the advisory bodies who act without result accountability.

Recently two papers were published in *Nature* with proposals for protocols how to judge the quality of scientific claims by Boyd (2013) [86] and Sutherland *et al.* (2013) [87]. In the opinion of the author these proposals have the feature of a new bureaucratic measure to meet observed scientific illiteracy by addressing symptoms rather then providing a cure. To adhere to these protocols could however be a first step to improve scientific literacy in advisory bodies and among decision makers.

Through hacked e-mails (2007) [56] it came to light that several lead authors in IPCC were guilty of "unfair" play. The International Council of Academies (IAC) reviewed the performance of the intergovernmental panel but restricted its judgment to the administrative rules of the IPCC and its bureaucracy and did not extend its inquiry to the crux of the matter—the key issues which would have been exposed by the above three basic questions of the Socratic type. The more grass roots scientific leaders and authorities could, and should, have raised these questions much earlier in the process when it was already likely that climate models did not fulfill the expectations of them.

Scientific illiteracy seems to have spread more widely, even in the higher ranks of the scientific community, than the authors of the Daedalus issue perceived in 1983 [81].

13. Science Education

13.1. Retrospective View

Let's assume the reader is in the company of a number of emeriti professors, who retired some 20 years ago, and the subject of discussion is the current state of academic education. Scientists who enjoyed their lecturing duties did not see them as a burden which distracted their attention from the contribution they wanted to make, or had to make, to the progress of science in the fields of biology, medicine, physics, chemistry and geology in the years 1960–1990. Indeed they still try to do so on a more modest scale in their private study rooms. What would the reader notice as he or she listens in? The first noticeable thing is probably that the emeriti do not seem to regret leaving their chairs for various reasons not unconnected to the current structure of the scientific community as mentioned in the preceding chapter. However, the "old boys" do not complain about the scientific progress being made in the above disciplines, even after their retirement. They admit they were lucky to work in this period of the history of science because of the facilities that became available after WWII to explore the unknown. Equally they do not complain about the simultaneous growth of the number of students filling the classrooms and the laboratories. This was the result of population growths but also stemmed from the societal development that gave the opportunity of higher education. The underlying objective was to have more knowledge spread among people in the society and not necessarily to promote the education of more scientific researchers. The consequence should have been to improve scientific literacy in the community. But did it? In the *Daedalus* issue in 1983 [81] it was ascertained that people's comprehension of science was still poor. So did the old boys themselves during their active educational period fail in their mission to teach the basic principles of science, the meaning of theories and models and the disciplines of the questions formulated by Arons?

If this is so, then a mea culpa is appropriate. Or did the increased student population bring about reduced attention to the educational needs of both the large group who gained bachelors or masters degrees and the select group who, post-PhD, became active researchers? The old boys experienced in their time the diminution in personal contact between teacher and student owing to growth in student numbers, as oral examinations were progressively replaced first by written ones and then by multiple choice tests as examiners had no longer the time to read students' essays. The author's experience when he was a student was that the oral examination was an essential part of his education in learning to answer the Arons' questions. (See Box 1).

13.2. Teaching Today

In Section 11, one particular point 11 made in the essay by Arons is that a part of scientific literacy consists of "the awareness of interaction between sciences and society on moral, ethical and sociological planes". After the discussion of post-normal science philosophy in Section 6 we need to pay additional attention to this awareness because the core concepts of that philosophy relate strongly to this societal aspect and, in any case, few people would contest in principle the importance of relevant societal issues, such as the mastering of environmental pollution. What was criticized was the particular approach propagated by post-normal science philosophy on truth-finding and its bearing on the ultimate purpose of scientific research. The vocation of the principle of societal awareness may have slipped too strongly into many university curricula, making old-fashioned scientists worry about the value of today's education as it affects scientific performance as such. How teaching on social awareness could be improved for university students but also for laymen will be described in the next section. The author sent his very first manuscript to referees all over the world, and received many suggestions to give emphasis to their specific objections against developments in their universities. Among these was the fact that the top administrators of universities have favored the appointment of professors in natural sciences who have outspoken social positions; they are champions in attracting public attention and consequently public funding, rather than being known for their scholarship. There is nothing wrong with curricula which teach social sciences as such, but this should not be one-sided towards "relativism" and "idealism" (see Section 3.2). In addition, when natural science faculties become permeated with such teachers indoctrinated by the spirit of post-normal science philosophy, the basic principle of a natural science philosophy education is undermined. Where this has happened the referees perceived that indoctrination by particular political views overwhelms the teaching of (natural) science objectivity.

Another observable consequence of increased mass education at university level is its increasing cost for the taxpayer. This has led to the adoption of measures to encourage students to gain their degrees in the shortest possible time. This development is in stark opposition to the notion of incremental increase in, and application of, knowledge which indicates the need for a longer education in order to reach insights about the frontiers of understanding of natural phenomena. Instead, academic education became a "crash course" in acquiring in a minimum of time a maximum of factual knowledge, with little or no time for either self-reflection or the exploration of boundaries essential for becoming a creative scientist.

Methods of teaching science and its philosophy vary from country to country, even between Northern Belgium (Flanders) and the Netherlands, despite a common language. During a stay in the People's Republic of China (1995) when the country was recovering from its Cultural Revolution, the author found that teaching of history and philosophy gets far more attention than in the West, beginning from the first class in secondary education to the last year in university. The secondary school he witnessed was however a special one, attached to a University in Sheng Du (Si Shuan) particularly devoted to the education of lecturers. The curriculum of the course was a remarkable mixture of sociology and philosophy, in fact an education in civic virtue from Tao to Mao. In this respect it should not be recommended as a guideline for liberal western education. The author experienced, however, in teaching a university course in the fourth year of biology on the principles of Darwinian evolution [88] regarding molecular scale and complexity theory, that the students were very competent in questioning the lecturer on facts from figures in a way more or less comparable to the Socratic method, though their course (from Tao to Mao') looks at first sight more like Sophistry. A more general experience was that students with a profound education in the Chinese classics, were not very uncomfortable with "uncertainties"—as we are meant to be in the West. Today they are also taught the history of Western science; the author attended a lesson on the fate of Galileio in the third grade of the secondary school.

13.3. Suggestions for Improved Teaching at University?

One should wish teaching members of the scientific community to have acquired a good level of scientific literacy themselves. This is not the equivalent of optimal expertise in a specific sub-discipline but includes in the first few years of an academic education teaching in the history, philosophy and sociology of science. However, teachers should guard against exaggeration and emphasize the mechanisms which animate the progress of science in the past and today. This should include emphasis on the dangers of imposed hierarchical authority; teaching Socratic questioning (Section 2.1) should ensure that students learn how science really progresses.

Let’s become practical. We must accept that the current education at universities is no longer a mere preparation for a career in scientific research and that teaching is no longer solely based on face to face contact between master (tutor) and student (pupil), the traditional approach to learning which, by the way, originates from the mediaeval period.

The EU universities have meanwhile developed a more or less uniform system for the definition of grades named bachelor and master. By the latter is meant preparation in particular for a PhD regime in which the thesis should function as proof of acquired self-reflection and independent thought. The fulfillment of that proof would give passage through the next corridor, leading to the first ranks of scientific investigator.

An education terminating with a bachelors and, in particular cases, with a masters is considered preparation for a variety of other functions in society among which several deserve special attention from the point of view of the desirable spread of scientific literacy. This is especially so for those graduates who will go on to teach in secondary schools and other vocational training establishments. We must also consider science journalists and PR functionaries of scientific institutions to be “lecturers” who wish to communicate advances in science to the public and politicians.

Regarding the latter, it should be seen also as an obligation by university communities themselves to ensure that potential politicians are educated properly with respect to scientific literacy. The reader is kindly invited to reread Section 11.2 for what is meant by that. As expressed previously, political influence on the progress of science seems hardly avoidable because of the importance of the budget for science in national public funding estimates.

We must however become suspicious if this teaching results in pure propaganda for enlargement of budgets for science in general or specific fields. We refer you to the critical remarks made in Section 5.5 on public relation efforts in current scientific institutions and Section 5.8 on finance, marketing and political ties. What should also be taught is the need for analysis and awareness in these areas.

Lastly let’s become even more practical and consider the dosage and timescale of teaching general scientific literacy during academic education.

The minimum dose is suggested in Section 11.2 One could wish it was already partly administered in secondary school, but as long as this is considered to be insufficiently the case, it should be provided at an early period in academic study, probably however not in the first half year, if we assume that students choosing sciences like physics, astronomy, chemistry, biology, geology, fields of engineering, have done so primarily out of enthusiasm for these disciplines. They can be expected to want to learn firstly the basics of what lies ahead of them in the next years. However, before they enter the sophomore it would be good if they have acquired at least the ability to put the three major questions to their teachers in the following years. It would also be to the benefit of teachers to learn from naïve even stupid questions from their students in improving their courses.

It must be noted however that universities today will experience drop-outs at the end of the first year, but these students may be able to fulfill other functions in society for which a bachelor in science is not a prerequisite. The question arises then whether a university can afford to circumvent the obligation to have all alumni initiated into the primary secrets of the progress of science. Should they not consider the possibility that all students, at the end of the first year, even those who drop out, should be obliged to pass a specific examination on scientific literacy with a certificate attached to it? The advice is in fact that drop-outs (in the first or next years) should not be seen as pure waste and therefore disposable. On the contrary, this prematurely leaving population deserves some attention and investment from the university or fellowship, and this would not be very costly to society (one could see it as an aspect of "sustainable development" in the sense that a "waste product" is being upgraded before entering the "environment").

At the bachelors or/and the masters level degree, in order to reach a more elaborate level of scientific literacy, a second examination should be made obligatory based on the content of special lectures which are related to the philosophies which underlie the progress of sciences and its impediments, as touched on in Sections 4.6 and 2.6 This should deal especially with the subjects mentioned: how to handle uncertainties and unknowns of very different kinds and the importance of unifying concepts in the sciences. Would it really be too much to ask in an entire academic education for some three months' study on the subjects related to reaching wider scientific illiteracy among all alumni of a university, having in mind the great impact of science on societal developments?

One could wish that every teacher in every discipline would in his own course pay attention to what is considered the necessary critical attitude towards what is accepted as knowledge or the "truth" and to the need to continue truth-*finding* as the main route to a new age of reason.

We are also left with the question of how to propagate the teaching of general scientific literacy to students who are not directly involved in the progress of science, who study history, sociology, literature, law or other humanistic subjects but who, nevertheless, on leaving university, might become involved in decision-making on science policy, in directing scientific progress as policy-makers. A short course as indicated above before the sophomore year, around the three major Arons' questions, seems the essential minimum. How can one get their interest and avoid that lessons going in one ear and out the other? One should anticipate that these students might feel that these subjects are special curiosities of the sciences itself, not directly relevant to their own interests during their academic education.

To teach these students will probably require inspiring lecturers who, with a sense of humor, know how to present the process of maturing science (Section 2) and how progress may be hampered (Section 4) as a first introduction to the philosophical and societal problems we are dealing with today.

When contemplating the suggestions made above, it becomes obvious that a change is needed in the spirit of how we cope with progress in science and its impediments. This will necessarily require a change in the motivation of how to teach. To learn about the mechanisms of progress in science is in fact a process of learning: "*how to learn*" from observations in Nature as well as bringing a critical mind to the dialogue about the interpretation of these observations by others who may or may not deserve the authority they seem to bring to the discussion.

14. Other Recommendations in the Light of the to be Continued Wish for Truth Finding

Having noticed the emotions that have risen in the CO_2 case, it seems to the author that many do consider the construction of a one-minded scientific community to indeed be a utopia. But should one strive for such a utopia? Is it not fundamentally foreign to scientific practice to see consensus as an ultimate goal? Is not it this a utopia with unanimity among scientists simply counter-productive to scientific progress? Whatever the answers to these questions, can we not replace a pessimistic attitude by a more optimistic one, that is to say that the dispute at least demonstrates that climate science is still very much alive? A drawback to this dialectic is that logic as a basis for argument is often not respected and is all too often replaced by a simple dispute over which side is better for the planet and human society.

Irrespective of what the contributions and obligations of various disciplines in science to society may be, science's foremost vocation ought to be the logical interpretation of objective observations. If the results of that approach are recognized as characteristic of the earlier Renaissance and pursued again today, then this reaffirmation will in itself prevent the drift to the mediaeval characteristic of unconditional belief in the authority of prophets.

Let us face it—to strive for a scientific community which every member would be satisfied with would be chasing an illusion. We can even argue why such a goal is impossible, even undesirable. It is built into scientific practice, as a result of its anarchistic nature, to make progress by revolutions. This requires thinkers who dare to contest existing doctrines, however widely they may be accepted in the community. Looking back into periods in the history of science when progress accelerated or decelerated, some rules can be deduced for the boundaries within which "anarchy" should be contained. We might even think of these "rules" as "laws" by drawing an analogy between the scientific community and society at large. In the latter, even given acceptance that an ideal state is an illusion, we nevertheless strive for the best by setting limits to human behavior, concentrated on the maintenance of justice and combating banditry. Of course, some rules that apply to society extend also to the scientific community. Cheating, to take one example, is a misdeed because it sets back the progress of science by misleading the process of truth finding.

In the same category sits "belief" enforced by authority when applied without regard to logical reasoning and when accompanied with sophistry. This implies we need some authority to control the quality of scientific performance and with it the unabated pursuit of truth finding. Scientific authority should be held accountable for that but nothing beyond that and certainly not for upholding any supposed wisdom which, as we have seen, may prove to be fallible even fallacious. That is the sole function to be attributed to learned societies like academies. Let them continue to put criticism forward on lack of logical reasoning on concepts presented by other institutions and cease providing society with their own advisory concepts.

Academies should be the *first* in the row of scientific institutions to test the quality of the answers made by other authorities and experts to the Arons questions.

The *second* echelon to advise on the progress of science are national advisory bodies to government. They are less "learned" but hopefully have acquired a higher degree of professionalism than learned societies, in particular in the understanding of interactions of science and society and consequent frictions some of which have been identified in previous chapters as unavoidable. This professionalism should be especially demonstrated in their proven ability to judge the answers to the Arons questions. As a function of their societal role, they should put similar questions to politicians and judge the answers on quality and content scrutinizing them for orientation towards specific political convictions.

If it comes to an assessment of the performance of current advisory bodies in the recent past, the conclusion must unfortunately be that they have taken the position of being authoritative themselves in the style of report brought to the attention of the public at large. If this fact would have been recognized by scientifically literate public and political opinion it certainly would have limited the credibility of many self-confident statements in these reports. See for example the recent report from NAS/RS mentioned in Section 8.7. How should we imagine the authors of this report—the usual question-answer game—to have responded to the Arons questions if they had been aware of the importance of the answers to these three questions in confirming their own scientific literacy? Let's make a guess.

Q: *How do we know* (CO_2 is a greenhouse *gas?*).

A: It absorbs infrared radiation and is expected to contribute to keeping the atmosphere warm.

Q: What do we believe?

A: That this property of CO_2 will operate unconditionally in the complex earth climate system as judged by experts in the IPCC school.

Q: What is the evidence for this?

A: That authoritative scientists say so... Those who accept models as "proof".

Would these answers satisfy a lay audience with some degree of scientific literacy about theorem and model handling?

For a balanced view also the possible answers of AGW antagonists to the questions derived from Section 8 should be considered.

Q: *How do we know* (CO_2 is NOT an important greenhouse gas?)

A: Despite the fact that CO_2 is absorbing IR the latter cannot warm the water surface because it enters the surface, (unlike sun light) only a few microns and this will lead to removal of the absorbed energy by latent heat removal with evaporation.

Q: What do we believe?

A: That the radiation energy captured by CO_2 in the atmosphere is transformed into heat which in the complex earth climate system will not deregulate the planet's water thermostat because the latter provides for a non-static equilibrium state with an entropy sink.

Q: What is the evidence for this?

A: The observations: (1) No coincidence of temperature rise with CO_2 rise on all time-scales; (2) No significant or extraordinary climate changes since human emissions begun other than a small temperature rise. This can be explained by several different mechanisms accounting for climate variability; (3) The models failed to project temperature rise with CO_2 increase (thus the models need thorough revision before becoming credible).

To come back to the position of other national advisory bodies (less learned than academies) we can expect their co-workers to comprise both university graduates from science and sociology. If the latter in particular are strongly politically motivated, e.g., by the post-normal science concepts—in the absence of sufficient scientific literacy—their objectivity about scientific issues with respect to truth finding deserves critical attention.

Today a *third* echelon has gained significant influence in informing the public about scientific developments; this is the public relations department of scientific institutions. These have developed into advertising agencies under the pressure of getting public attention in order to attract public funds. The messages from these public relation departments are usually uncritically reported in the media by science journalists and become widespread as being authoritative. It can be regretted that any scientific institution in today's societal context (see Section 5.8) would need this kind of publicity in advancing the merits of their contributions to the progress of science in order to keep up their image as being highly qualified in scientific performance. But we cannot disapprove of an institution's pride in its own achievements. One should not expect that everybody in modesty will hide one's light always under the bushel if self-convinced of the value of a contribution to the progress of science. Moreover, the public will be interested if CERN in Geneva announces it has found evidence for the existence of the last fundamental (Higgs) particle to be identified. Or when a famous scientist like Stephen Hawking attracts attention by throwing doubt on the possible existence of a "black hole" in space. It is a matter of satisfying curiosity among an interested public, which journalism provides to the public at the end of the information chain to the public. Unfortunately most of today's press releases from scientific institutions have a strong tendency to impose on the public doctrines to be accepted solely on their authority and with the ulterior motive of securing financing.

Consequently we should hope that the *fourth* echelon—the journalists of the scientific press—would critically examine any attempts to indoctrinate. Has not that been the major function of journalism in Western democracies? Is not it this fourth echelon which we must continue to expect to demand answers from specialists employing at least the spirit of the Arons questions?

If the fourth echelon failed in this respect, it might have been expected that the very *first* echelon, the learned societies, would bring it to the attention of the public at large. The Dutch Royal Academy indeed took a lead in the 1960s with a committee tasked with informing the public on controversial subjects. The original drive was to teach the public to make responsible *choices* between various scientific developments through a balanced explanation of possibilities and consequences. The initiative, however, drifted away into other institutions (planning and assessment bureaus) which no longer *left* choices open as such but *suggested* specific ones based on their own insights.

15. Conclusions

In previous chapters several noteworthy comments have been made on how certain self-confident statements from individual scientists, authoritative bodies or "advertising agencies" have attempted to convince the public and colleague scientists that science should progress in particular directions based on fixed insights. Several recommendations have been made "between the lines" of what has been written on how perspectives may be widened. Succinct reference will be made here to some of these proposals:

* The view of Schekman should be supported:

Freedom of inquiry must be preserved under any plan for government support of science.

* Unifying concepts need greater attention in all branches of science.
* Among the unifying concepts derived from complexity theory, the importance of the drive of non-equilibrium systems to a state or order should be recognized.
* The impulse for a state of harmony of Mankind with its environment should be adhered to, but a future state might not necessarily be equivalent to a former idealized one.

* The seriousness of potential environmental scares needs to be investigated first before publicized doomsday prospects can grow out of hand.
* Estimations of uncertainties as such should not only be treated as not supporting fully a particular theory but rather as unknowns that might lead to new theories.
* The post-normal science approach needs recasting with respect to the positioning of what *is* the truth and the drive for truth-*finding* in the light of other philosophical considerations.
* Overcome the paralyzing belief in the collective authority of the consensus culture.
* Bringing advice to the public any body involved in it, should abstain from a simplified Q&A approach in which self invented Questions are presented, followed by “authoritative” answers. Instead the three Arons’ questions should we used to contribute to the development of scientific literacy.
* And last but not least, searches for excellence in the leadership of science need to emphasize the values of personal and unqualified accountability and robust personal investigation in all statements and findings for scientists in the upper reaches of research institutes, and advisory and assessment bodies of all types.

A final quotation from Karl Popper [89] to think about:

> “We all have an unscientific weakness for being always in the right, and this weakness seems to be particularly common among professional and amateur politicians. But the only way to apply something like scientific method in politics is to proceed on the assumption that there can be no political move which has no drawbacks, no undesirable consequences. To look out for these mistakes, to find them, to bring them into the open, to analyze them, to learn from them, that is what a scientific politician as well as a political scientist must do.
>
> Scientific method in politics means that the great art of convincing ourselves that we have not made any mistakes, of ignoring them, of hiding them, of blaming others for them, is replaced by the greater art of accepting responsibility for them, of trying to learn from them, and of applying this knowledge so that we might avoid them in the future.”

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Appendix I. The View of Pessimists on the World

The figures marked with p refer to the page and with r to the reference number in The Skeptical Environmentalist by Bjorn Lomborg. Cambridge University Press 2002 [17].

General Statements

1. Our resources are running out. The population is ever growing, leaving less and less to eat. Air and water are becoming even more polluted. The planet's species are becoming extinct in vast numbers—we kill off more then 40,000 each year. The forests are disappearing, fish stocks are collapsing and the coral reefs are dying. We are defiling our Earth, the fertile topsoil is disappearing, we are paving over nature, destroying the wilderness, decimating the biosphere, and will end up killing ourselves in the process. The world's ecosystem is breaking down. We are fast approaching the absolute limit of viability, and the limits of growth are becoming apparent (Asimov and Pohl 1991, p. 10, r 12).
2. Throughout the past century humanity did everything in its power to dominate nature. We dammed earth's rivers, chopped down the forests and depleted the soils. Burning up fossil fuels that had been created over eons, we pumped billions of tons of greenhouse gases into the air, altering atmospheric chemistry and appreciably warming the planet in just a few decades. And as our population entered the year 2000 above the 6 billion mark, still spreading across the continents, dozens of animal and plant species were going extinct every day, including the first primate to disappear in more than 100 years.

   At the start of the 21st century there were signs that exploitation of the planet was reaching its limit—that nature was beginning to take its revenge. Melting ice in the Polar Regions suggested that the climate was changing rapidly. Weather was even more erratic than usual, giving some places too little rain and others too much. Fires race across the parched American West in summer, and recent storms spread devastation from Britain to Taiwan. No specific event could be directly blamed on global warming, but scientists say that in the greenhouse world, deluges and droughts will be more frequent and severe. Already the hotter climate has increased the range of tropical diseases such as malaria and yellow fever. Other ominous signals from an overburdened planet include failing grain and fish harvests and fiercer competition for scarce water supplies (Anon. in Time Magazine special edition 2001, p. 4, r 11).
3. The balance of nature is delicate but essential for life. Humans have upset that balance, stripping the land of its green cover, choking the air, and poisoning the seas (Scott 1994, p. 3, r 7).
4. For more than 40 years, earth has been sending out distress signals. The decline of Earth's ecosystems has continued unabated (Linden, 2000, p. 3, r 8).
5. Our oils are vanishing, fisheries being killed off, wells are drying up and the burning of fossil fuels is endangering the lives of millions. We are heading for cataclysm (New Scientist 2001, p. 4, r 9).
6. The key environmental indicators are increasingly negative. Forests are shrinking, water tables are falling, soils are eroding, wetlands are disappearing, fisheries are collapsing, range-lands are deteriorating, rivers are running dry, temperatures are rising, coral reefs are dying, and plant and animal species are disappearing (WWI, 1998, p. 13, r 71).

7. The problems arising since 1984 are population growth, soaring oil prices, debilitating levels of international debt, and extensive damage to forests from the new phenomenon of acid rain.
   As we complete this 17th State of the World report, we are about to enter a new century having solved few of these problems. The bright promise of a new millennium is now clouded by unprecedented threats to humanity's future (WWI 2000, p. 13, r 79, r 80).
8. As the global economy expands, local ecosystems are collapsing at an accelerating pace (WWI 2000, part II, p. 14, r 87).

Population Growth

9. Psychologically, the population explosion first sunk in on a stinking hot night in Delhi. The streets were alive with people. People eating, people washing themselves, people sleeping, people working, arguing and screaming. People reaching their hands in through taxi windows to beg. People shitting, people pissing, people hanging off buses. People driving animals through the streets. People, people, people (Ehrlich 1968. The population bomb, 1968. p. 48, r 336).
10. The risk in a world adding nearly 80 million people annually is that so many sustainable yield thresholds will be crossed in such a short period of time, that the consequences will become unmanageable (WWI 2000, p. 15, r 94).

Food and Starvation

11. The food problem emerging in the less-developing regions may be one of the most nearly insoluble problems facing man over the next few decades (Brown 1965, p. 60, r 415).
12. The battle to feed humanity is over. In the course of the 1970's the world will experience starvation of tragic proportions—hundreds of millions of people will starve to death (Ehrlich 1968, p. 60, r 412).
13. Grain yields are no longer improving as fast or have perhaps even stopped completely, because increasingly we are reaching the physiological limits of the plants (Brown and Kane 1994, p. 8, r 39, r 40).
14. Three billion people are malnourished, the largest number and the highest rate in history (Pimentel *et al.* 1998, p. 24, r 185).
15. Throughout the last 30 years of population increase the agricultural production could no longer keep up and prices would now start increasing (Brown 1997, p. 93, r 609).
16. Rising world grain prices may be the first global economic indicator to tell us that the world is on an economic and demographic path that is environmentally unsustainable. An early hint of the shift to an economy of scarcity came in late April 1996, when wheat price on the Chicago board of Trade scored above $7 a bushel, the highest level in history and more than double the price a year earlier (WWI 1998, p. 93, r 611).
17. The average amount of grain per inhabitant in the world grew until 1984—indicating that the Green Revolution did work—but then it dropped by 11 percent thereafter (WWI 1994, 1997, 1999, p. 94, r 614–15).

18. In 1983 America produced 2.65 tons per hectare, however, since then, there has been no further rise. Japan's rice yield in 1984 was 4.7 tons per hectare. Since then, it has levelled out. Farmers in the two countries appear to have hit the wall at about the same time.
    We must start facing biological reality. It does seem likely that more countries will hit the wall in the years immediately ahead and eventually the rise in grain yields will level off everywhere. The world moves into an age of scarcity with price increases on grain (WWI 1998, p. 96, r 637–40).
19. Today human activity appropriates 40 percent of all land-based photosynthesis. A doubling of the population implies an appropriation of 80 percent. A 100 percent appropriation is both ecologically as well as socially impossible (Agger *et al.* 1997, p. 99, r 652).
20. China may soon emerge as an importer of massive quantities of grain—quantities so large, that they could trigger unprecedented rises in food prices. China is teaching us that the western industrial model is not viable, simply because there are not enough resources (WWI 1998, p. 102, r 6–90).
21. In 1984 we lost worldwide 25.4 billion tons of topsoil annually (Brown and Wolf 1984, p. 104, r 712).
22. Pimentel estimated the global erosion at 75 billion tons of lost topsoil annually (Pimentel *et al.* 1995, p. 104, r 713, 716–17).
23. The world's farmers are struggling to feed more than 80 million more people each year, good weather or bad. And now for the first time in history, they can no longer count on fishing fleets to help them expand the food supply.
    Humanity depends heavily on the oceans for food (WWI 1997, 2000, p. 106, r 736–38).
24. In 1950 500 million people (20 percent of the world population) were considered malnourished. Today (1998) more than three billion people are malnourished, (one half of the world population), the largest number and the highest rate in history (Pimentel 1998, p. 24, r 185, 188–89).

Health

25. Forty percent of all deaths are caused by various environmental factors, especially organic and chemical pollutants. The consequence of more malnutrition and more pollution is more disease and more infectious disease (Pimentel 1998, p. 24, r 186–87).
26. Disease prevalence is projected to increase 77 percent during the period from 1990 to 2020. Infectious diseases, which cause 37 percent of all deaths throughout the world, are also expected to rise. Deaths in the US from infectious diseases increased 58 percent between 1980 and 1992 and this trend is projected to continue (Pimentel 1998, p. 26, r 216, 207–08, 210).
27. The public needs to be rescued from "the current cancer epidemic" (Kidd 2000, p. 216, r 1626).
28. The cancer epidemic continues to rage around the world. The rising rates of cancer, infections and immune system dysfunctions, are a function of our increasingly polluted environment (Anon. 1997, Midlife Woman, p. 216, r 1629, 1631).

29. The most dramatic and troubling sign that hormone disrupters may already have taken a major toll comes from reports that human male sperm counts have plummeted over the past half century (Colborn *et al.* 1996, p. 238, r 1853).
30. Chemical pollutants are a major cause of rapidly rising breast cancer rates worldwide (Greenpeace 1993, p. 242, r 1919).
31. By far the most alarming health trend for women is the rising rate of breast cancer. The link to pesticides is made very clear (Colborn *et al.* 1996, p. 243, r 1923–24).
32. Many forms of cancer are on the rise, not least in children, and mounting evidence suggests a strong correlation between pesticide exposure and the development of cancers in humans (Meyerhoff 1993, p. 245, r 1957).

Water

33. Thirty countries containing 40 percent of the world's population (2.3 billion) now experience chronic water shortage that threaten their agriculture and industry and the health of their people (Miller 1998. p. 20, r149–50).
34. Time magazine summarizes the global water outlook with the title "wells running dry". (Couzin 1998, p. 149, r 1059).

Forestry

35. The rate of forest loss in the Amazon rainforest had increased since 1992 by 34 percent a year. (WWF 1997, p. 9, r 45–46)
36. Each year another 16 million hectares of forest disappear (WWI, 1998, p. 13, r 75–76).
37. The soaring demand for paper is contributing to deforestation, particularly in the Northern hemisphere. Canada is losing some 200,000 hectares of forest a year (WWI, 1998. p. 13, r 77–78).
38. A Time magazine environmental survey carries the headline "Forests: the global chainsaw massacre" (Time 1997, p. 110, r 760).
39. The World Research Institute simply calls it: "Deforestation: the global assault continues" (WRI 1998, p. 110, r 761).
40. The WWF has disseminated a similar message on its website. The forest front page that greeted the visitor until April 1998 "We must ACT NOW to preserve the last remaining forests on Earth" (WWF 2000, p. 110).
41. WWF claims that "The world's forests are disappearing at an alarming rate" (WWF 1998. p. 110, r 762).
42. WWF's international president Claude Martin, in 1997 called a press conference named Eleventh Hour for World's Forests. Here he said: I implore the leaders of the world to pledge to save their country's remaining forests now—at the eleventh hour for the world's forests. Equally he claimed that the area and quality of the world's forests have continued to decline at a rapid rate (WWF 1997, p. 110, r 763–64).
43. Worldwatch Institute even claims that "deforestation has been accelerating in the last 30 years" (WWI 1998, p. 110, r 765).

44. President Carter's environmental report, Global 2000 estimated an annual tropical forest loss of between 2.3 and 4.8 percent (p. 113, r 796).
45. Norman Myers estimated as recently as the early nineties that 2 percent of all forest was being destroyed every year and believed that by the year 2000—in just nine years at the time of his prediction—we must have lost about a third of the tropical forest area. In just another few decades, we could witness the virtual elimination of tropical forests (Myers 1991, p. 113, r 797–98).
46. Estimates in the same range of 1.5–2 percent were common among biologists (Ravens and Prance 1991, p. 113, r 799).
47. Even in July 2000, WWF argued for saving the Brazilian Amazon since, "The Amazon region has been called the lungs of the world" (p. 115, r 819–20).
48. The WWF proclaimed 1997 as the year the world caught fire, and their president, Claude Martin, stated unequivocally that this is not just an emergency, it is a planetary disaster. WWF maintained that in 1997 fire burned more forests than in any other time in history (WWF 1997, p. 116, r 830).

Energy

49. Here is the scenario: Sticker shock at the gas pumps, with prices nearly doubling overnight. Long lines at the few stations that are open. Crude cardboard signs reading "out of gas", blocking incoming traffic, at the ones that are closed. Huge sales on "full sized" vehicles. Long waiting lists for econoboxes. 1973? 1979? How about 2007? (Motavalli 2000, p. 118, r 847).
50. "Limits to growth" showed us that we would run out of oil before 1992 (Meadows *et al.* 1972, p. 121, r 861).
51. Ehrlich told us in 1987 that the oil crises would return in the 1990s (Ehrlich and Ehrlich, 1987, p. 121, r 862).
52. "Beyond the limits" predicts once again that we will run out of oil in 2031 and gas 2050 (Meadows *et al.* 1992, p. 121, r 863–64).

Other Resources

53. "Limits of growth 1972", Gold would run out in 1981, silver and mercury in 1985, zinc in 1990 (Meadows *et al.* 1972, p. 137, r 1000).
54. The bet of Ehrlich, Harte, Holdren versus Simon. The latter challenged the established beliefs that the price of chromium, copper, nickel, tin and tungsten would increase in 10 years. (Simon 1996, p. 137, r 1002).

Pollution

55. Acid rain is the invisible plague, which is creating an ecological Hiroshima (Claudi 1988, p. 178, r 1286–87).
56. The UN Brundtland report stated that in Europe, acid precipitation kills forests. Several present-day ecology books repeat the charge (Christensen 2000, p. 178, r 1288–89).

57. An acid plague is sweeping the Earth. One third of the German forests have been attacked, so the trees are either dead or dying. 4000 Swedish lakes are dead and 14,000 are in the process of dying. In cities all over the Earth, people are being suffocating, or dying, because the smoke cannot escape (Albert 1989, p. 178, r 1290).
58. A group of German scientists predicted that Europe's forests were threatened by acid rain and as many as 10 percent of all trees were at risk (Abrahamsen *et al.* 1994, p. 179, r 1293).
59. American Journal of Public Health in 1999: acid rain destroys forest (Rosner and Markowitz 1999, p. 181, r 1319).
60. Sulpher in the atmosphere produces acid rain. And acid rain kills forest (Politiken 1993. p. 181, r 1220).
61. As landfills overflow, incinerators foul the air, and neighbouring communities and states attempt to dump their overflow problems on us, we are now finally realizing that we are running out of ways to dispose of our waste in a manner that keeps it out of either sight or mind (Gore 1992, p. 206, r1577–78).
62. Almost all the existing landfills are reaching their maximum capacity, and we are running out op space to put new ones (Asimov and Pohl 1991, p. 206, r 1580).
63. The devastating blow wreaked on the environment by the oil spill after the Gulf war will increase the impact on human life for a long time to come, and yet the events are only indicators of the coming long-term problems (Greenpeace 1992, p. 191, r 1424).

Biodiversity

64. Norman Myers told 22 years ago we lost 40,000 species a year, 109 a day (Myers 1979. p. 249, r 2005).
65. Al Gore repeats the figure (in 1992) in his Earth in the Balance (Gore 1992, p. 249, r 2007).
66. E.O. Wilson points out that we are losing between 27,000 and 100,000 species a year (Wilson 1992, p. 249, r 2009).
67. Paul Ehrlich estimated in 1981 that we lose some 250,000 species a year, with half the Earth's species gone by the year 2000 and all gone by 2010–2025 (cited in Stork 1997, p. 249, r 2010).
68. Pimentel has evaluated the total worth of biodiversity an estimated it between \$3–\$33 trillion, 11–127 percent of the world economy (Pimentel *et al.* 1997, p. 251, r 2020).
69. Biologists do not need to know how many species there are, or how many disappear annually to recognize that Earth's biota is entering a gigantic spasm of extinction (Ehrlich and Ehrlich 1996, p. 256, r 2084).

Global Warming

70. The 23 years from 1947 to 1969 averaged about 8.5 days of very violent Atlantic hurricanes, from 1970 to 1987 that dropped to 2.1 days, and in 1988–1989 rose again to 9.4 days a year (Asimov and Pohl 1991, p. 8, r 41).
71. The polar ice caps will melt more rapidly, sea levels will rise. In Africa malaria is being found at higher and higher altitudes where it used to be too cool for the mosquitoes. There will be a

lot of very bad, more dramatic weather events. There will be flooding that will be quite bad and there will be more public health crises (Clinton 1999, p. 259, r 2108).

72. Global warming will cut agricultural productivity drastically. This would imply large-scale famines (Asimov and Pohl 1991, p. 287, r 2363–64).
73. The HOT ZONE, blizzards, flood and dead butterflies, blame it all on global warming (Newsweek 1996, p. 289, r 2381).
74. Global warming could cause droughts, disease, and political upheaval, and other nasty effects, from pestilence and famine to wars and refugee movement. Malaria could be a public health threat in Vermont. Nebraska farmers could abandon their field for lack of water (Shute *et al.* 2001, p. 289, r 2382–83).
75. UNESCO courier shows us a picture of a large iceberg, asking us: will global warming melt the polar ice caps? (Agarwal and Narian, 1998, p. 289, r 2385).
76. Al Gore has claimed that we know that as a result of global warming, there is more heat in the climate system, and it is heat that drives El Nino…. Unless we act we can expect more extreme weather in the years ahead (Cook 1998, p. 292, r 2429).
77. The National Wildlife Federation issued a report, predicting that increasing numbers of extreme weather will threaten and endanger species (Anonymous 1999, p. 292, r 2430).
78. Congressional Quarterly told how since the signing of the Kyoto protocol, the weather has intensified. It was a time of killer storms, waging wildfires in Florida and stifling drought in Texas. Floods in China displaced 56 million people (Pope 1998, p. 293, r 2445).
79. Earth Island Journal linked to global warming fiercer winds, deadlier floods, longer droughts, dust storms, tornadoes (Smith 2000, p. 293, r 2446).
80. The global environmental outlook 2000 claims that global warming models indicate to affect precipitation, wind velocity, raise the incidence of extreme weather conditions, including storms, heavy rainfall, cyclones and drought (UNEP 2000, p. 293, r 2447).
81. Global warming causes higher temperature, where the result is that storm systems are more intense, more frequent and more destructive (WWI 1997, p. 294, r 2471).
82. Some of the expected effects of climate change are now becoming evident. Weather related damage in 1999 was $67 billion worldwide. The damage in 1990 was five times the figure in the 1980s, a testimony to a world at the peril of ever more extreme weather (WWI 2000, p. 295, r2472–73).

[End of abstracted alarmist views from the book of Lomborg, who indicated these as being a "litany".]

Conflicts of Interest

The author declares no conflict of interest.

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whether locally the concentration of CO_2 is rising requires no more than the expectation it will, caused by the burning of fossil fuels. It should be rather indicated as a "presumption". To present the expectation and the "proof" that CO_2 is actually an important greenhouse gas and will influence the global average temperature falls in the class of a the wider, conceptual scope of an hypothesis, which can be named a "theorem".

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