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An Historian's Perspective on the Origins, and the Limitations, of Modern Science

Abstract

A survey is given of principal contrasts between modern science as it originated in 17th century Europe and previous, Aristotelian natural philosophy. Some fundamental gains and losses attending the new science are discussed and illustrated, principally in terms of the extent to which the 'universe of precision' impinges on human autonomy. The argument culminates in a plea to conceptualize present-day debates over a needed reorientation of medical science in terms of the drawing of boundary lines demarcating the domain proper to the scientific approach, rather than in terms of sterile 'either/or' dichotomies.

Introduction

The remarks that follow are informed throughout by two principal guiding lines. One is that the reductionist mode of operating characteristic of modern science since the 17th century, however fruitful and admirable by itself, is also liable to severe limitations in a variety of domains, among which the domain of human beings as mentally active, conscious, and socially interacting entities is paramount. Hence, in my view scientists should consistently be on guard against overapplying their trusted methods, just as 'humanists' should seek to overcome their virtually inbuilt prejudice against science as a dehumanizing activity *per se*. To identify and to mark off proper boundary lines is therefore highly important for the social sciences and the humanities, but the task is nowhere so urgent, and nowhere so hard to carry out properly, as in medicine, where the human being itself stands at the cross-roads. I take this task – the mutual demarcation of potentially overlapping domains in a manner that does justice both to what science can legitimately accomplish and to the relative autonomy of what is irreducibly human – to be one of the principal concerns of our meeting.

My other guiding line is the idea that the overall theme of the symposium has deep roots in the past, so that a brief historical survey may add a useful dimension to the discussions.

From this particular stance I intend to address three main topics. I shall seek to characterize modern science by looking briefly into its origins in 17th century Europe. I shall explore some limitations set to the scientific enterprise. And I shall argue that the issue central to our symposium – possible directions for a reorientation of medical science – may benefit more from being conceptualized in terms of the limits set to the scientific approach than of the replacement of one 'model', or 'paradigm', by another.

My first topic is known among historians of science as the Scientific Revolution[1]. This is commonly understood as the period, starting either with Copernicus or with Galileo and Kepler and finding a provisional end in the work of Newton, when modern science was born. Rather than enumerating more or less at random a selection of scientific discoveries made at the time, I shall seek to identify some of the deeper issues which underlay these discoveries and which, together, constitute nothing less than a radical overhaul in man's conception of the world. In order to do so, I shall throw a quick glance at Aristotelian natural philosophy – the reigning conception of nature up to roughly 1600 – and contrast it with some major features of the deeply different type of science that emerged during the century that followed.

A view of nature prior to the birth of modern science

In Europe, Aristotle's conception of nature had, from the 13th century onwards, provided the dominant framework inside which it became customary to interpret a selected number of natural phenomena. We may certainly speak here of science in the sense of the systematic collection of facts of nature and the equally systematic attempt to make these intelligible by imposing some sort of order upon them. For Aristotle, as for virtually everybody else, the Earth was at rest at the center of the universe. Unlike everybody else, Aristotle could explain why this is necessarily the case: because the center of the universe is the *natural place* of all motions that occur in the world. Bodies consisting of the two heavy elements, earth and water, tend to move by a right line towards the center (thus a branch falling off a tree provides one example of the natural motion of a heavy object). Bodies made up of the two light elements, air and fire, move naturally in rectilinear motion away from the center. There are also motions contrary to nature. If one throws a stone or pushes a wheel-barrow, this exemplifies violent as opposed to natural motion. However, in the last analysis all motion in the world is directed towards an ultimate purpose – the realization of a completed state of nature. If the natural order to which all motion ultimately aspires were fully realized, we would find a perfectly spherical body of earth situated around the center of the universe (this we know as our Earth), followed by – successively – a sphere-shaped layer of water (the oceans), a similar layer of air (the atmosphere) and a similar layer of fire. At that point the portion of the universe ends that is subject to change in the sense of generation and decay, of qualitative and quantitative alteration, and of violent besides natural motion. Beyond the terrestrial sphere we find the immutable heavenly spheres. In ascending order, these are given by the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn, and finally, closing off the universe, the sphere of the fixed stars. Here natural motion is circular rather than rectilinear, all heavenly bodies (made of the immaterial fifth element) performing their revolutions in circles around the center of the universe where our Earth is by necessity situated.

One important feature of the natural philosophy here most summarily sketched is that it is, indeed, a *philosophy*. Its leading concepts are derived from a much more general system that equally comprises doctrines on the nature of Being, on how to conduct our lives well, etc. Science was rarely if ever cultivated as a matter of interest in its own right. Scientific knowledge was a part of philosophical knowledge, and the leading scientific concepts were derived from an overarching philosophy rather than developed for their own sake. To the extent that empirical facts entered into science – and with Aristotle the extent was considerable – these were the kind of raw facts daily life provides for us. Aristotelian science is about a world that immediately presents itself to our senses. What Aristotle does, in his system of natural philosophy, is to rationalize, in the sense of imposing a rational order upon, the world of daily experience, straightforwardly perceived.

In so doing, he as well as every other investigator examined nature in order to satisfy his intellectual curiosity. The idea that nature can be put to usage is ruled out *a priori* because nature, as an organism, cannot possibly be imitated, let alone surpassed, by mechanical means. Finally, Aristotle's natural philosophy was scarcely quantitative. Aristotle wants to know why bodies fall; the nature and shape of the path they follow in the act of falling do not evoke his interest.

All this and much more changed profoundly in the course of the Scientific Revolution.

The Scientific revolution

In contrasting, as I am about to do, Aristotle's natural philosophy with the science that was born in the Scientific Revolution, I do not wish to suggest that the break was a completely abrupt one. Rather, the Scientific Revolution may be seen as a kind of laboratory in which mankind, or at least some of its brightest representatives, worked out the consequences of a radically different mode of coming to grips with the secrets of nature. I am committed to the view that the break between old and new was quite drastic; not that it took place overnight.

In the first place, mathematics acquired a fundamentally new place in science. This happened principally in the work of Galileo and of Kepler.

Before Kepler, planetary astronomy had been handled in mathematical fashion, to be sure; however, the resulting systems were meant to deal with a fictional world of circles and vectors, hardly with any physical reality taken to be actually there in the heavens. Kepler almost single-handedly constructed a 'heavenly physics' that was both realistic and mathematical. Before Galileo, such phenomena as free fall and projectile motion had been considered in a purely qualitative manner. Galileo almost single-handedly showed how to subject these and other phenomena of motion to mathematical treatment. The world with which Galileo's axioms and theorems dealt, though, was no longer the world of daily experience explored by Aristotle. Rather, Galileo's experiments were set up so as to imitate as closely as possible a non-existent, 'ideal' world, in which perfectly spherical objects fall alongside ideally smooth, inclined planes amidst an equable flow of time. This ideal world of geometrized space and time, although liable to mathematical treatment, is far removed from our own world; it is not immediately accessible to our senses. To some extent, the gap can be bridged by experiment, and this is one of the other, principally novel things of the new science. Setting up experiments was made possible by, and at the same time reinforced tremendously, the building of something new – scientific instruments such as the barometer, the telescope, and the precision clock.

Another respect in which the world of the new science diverges from the world of daily experience is that it runs counter to many of our most natural intuitions. Nothing more self-evident than to suppose that the Earth is at rest at the center of the universe. The new science, as pioneered by Copernicus and Kepler, adduces very powerful evidence that this is not the case at all, but that in reality the Earth is one of six planets which together revolve around the Sun. Nothing more natural than to suppose that white light is the original, primary kind of light, of which the colors are modifications. The new science, as pioneered by Isaac Newton, adduces very powerful evidence that the colors are primary, and that white light is a blending of all colors together. In short, the new science is characterized by a systematic distrust of the teachings of common sense and of our immediate sensations.

Another mark of such distrust comes forward in what was known at the time as the 'mechanical philosophy'. That is to say, it was rather generally supposed that objects which present themselves as wholes to us are in reality aggregates of imperceptibly small material particles. A large part of the task 17th century scientists set themselves was the explanation of natural phenomena in terms of the motions carried out by tiny corpuscles of various shapes and sizes. We appear to live in a very rich and variegated world, in which phenomena present us with a host of subtly distinct sensations – sounds, colors, fragrances, etc. In the corpuscular conception of nature, these sensations are called the 'secondary qualities', all of which can be reduced to the truly 'primary' qualities that reside in the various shapes, sizes, and locations of those tiny material particles. For example, a musical note is nothing but the affection of our auditory nerve by the rapid vibrations of small particles of air. The corpuscular conception involved a radical dichotomy between living and dead nature, with a daring thinker like Descartes confining the truly living element of the universe to man's capacity to think and feel. The psyche, and the creative mind, were relegated to a remarkably small region in the universe indeed.

As opposed to the attempt made by virtually all natural philosophers to encompass, in their systems, the totality of things, the new science consciously confined itself to partial insights taken to deal with well-defined segments from the world of phenomena. But the way it went about its admittedly partial business, lacking a foundation in philosophical first principles, was strikingly fruitful. If we seek to subsume the nature of the overhaul that had taken place under one specific heading, I choose to borrow it from one of the great historians of science of our century, Alexandre Koyré. What took place around 1600 as something wholly unprecedented in world history, so he said, was the transition from the 'world of the more-or-less' to the 'universe of precision'[2].

Gains and losses

If we look back now at the process thus summarily sketched, we find that beside enormous gains in precision and certainty as were yielded by the mathematical handling of phenomena and by the feedback provided by experiment, a great deal had been lost, too. The gains manifested themselves in the plain fact of history that ever more domains of experience successively gave way to mathematical treatment – were absorbed, so to say, in the 'universe of precision' that Galileo and Kepler had pioneered. What, early on, started with so resounding successes in isolated problems in terrestrial dynamics and planetary theory, finding a first point of culmination in Newton's laws governing the solar system, proved capable of expansion over ever more domains. I need not enumerate the domains successively absorbed – they are broadly familiar to all of you. Nor is it necessary to spend much time on explaining what the gains made consist of – predictability, mathematical rigor, systematic procedures for the elimination of error are some of the key-words (none of which work with absolutely warranted certainty, as philosophers of science never tire of pointing out; but that does not invalidate the principle). To be sure, the mode of expansion was hardly an automatic affair – creative scientific thought almost always proceeds by leaps and bounds, not by orderly, straightforward, logically impeccable reasoning from A to B. The point is rather that an inherent motor drive can be seen at work here, which carried the scientific enterprise relentlessly forward. And the question comes up of whether the historical trend of successive absorption into the universe of precision that started in the early

17th century may not be extrapolated indefinitely. In other words, may the inherent motor drive at work here perhaps be regarded as all-powerful?

I wish to seek a response to this question at two distinct levels – at the level of principles, and at the experiential level. For principles, we turn to a number of losses incurred by mankind when it made the fateful step of entering the universe of precision. These have been brilliantly sketched by one of the first historians of the Scientific Revolution, the American philosopher E.A. Burtt, who died four years ago at the age of 97. Here are two characteristic quotations, both taken from a book he wrote in 1924. In the first the 'old' and the 'new' conception of nature are penetratingly contrasted:

> 'Just as it was thoroughly natural for medieval thinkers to view nature as subservient to man's knowledge, purpose, and destiny; so now it has become natural to view her as existing and operating in her own self-contained independence, and so far as man's ultimate relation to her is clear at all, to consider his knowledge and purpose somehow produced by her, and his destiny wholly dependent on her.'[3]

In the second passage Burtt observes that the successes of the Newtonian enterprise were so overwhelming as to close the eyes of generations to come for its less fortunate implications:

> 'None of these keen and critical minds, however – and this is the major instructive lesson for students of philosophy in the twentieth century – directed their critical guns on the work of the man who stood in the center of the whole significant transformation. No one in the learned world could be found to save the brilliant mathematical victories over the realm of physical motion, and at the same time lay bare the big problems involved in the new doctrine of causality, and the inherent ambiguities in the tentative, compromising, and rationally inconstruable form of the Cartesian dualism that had been dragged along like a tribal deity in the course of the campaign. For the claim of absolute and irrefutable demonstration in Newton's name had swept over Europe, and almost everybody had succumbed to its authoritative sway. Wherever was taught as truth the universal formula of gravitation, there was also insinuated as a nimbus of surrounding belief that man is but the puny and local spectator, nay irrelevant product of an infinite self-moving engine, which existed eternally before him and will be eternally after him, enshrining the rigor of mathematical relationships while banishing into impotence all ideal imaginations; an engine which consists of raw masses wandering to no purpose in an undiscoverable time and space, and is in general wholly devoid of any qualities that might spell satisfaction for the major interests of human nature, save solely the central aim of the mathematical physi-

cist. Indeed, that this aim itself should be rewarded appeared inconsistent and impossible when subjected to the light of clear epistemological analysis.

But if they had directed intelligent criticism in his direction, what radical conclusions would they have been likely to reach?'[4]

A whole list of losses attending the advent of modern science is encapsulated in this brief passage. There is the loss in immediate experience implied by the new science. Aristotle's branch falling to the ground is a branch taken from daily life; in Newtonian, rational mechanics it has been abstracted into a mass point. We know much better how it falls, to be sure, but it is hardly our irregularly curved, brown/green, freshly smelling branch any more. In experimental Newtonian mechanics, the branch is supposed to reach the ground at the same time as a feather falling from the same height – but this is plainly untrue, unless we envelop both in the wholly artificial environment of a vacuum pump and remove the ambient air. There is something intensely impoverished and artificial about the level at which nature is being investigated by the modern scientist, and although these features do not detract from the validity of the results reached – to the contrary – they make themselves felt in the very daily lives of us from which they had been abstracted in the first place. There is a very odd paradox here. I shall illustrate how it works by means of a seemingly trivial example, where we see the abstract character of modern science return to the flesh, as it were. Look at your digital watch, if you have one, and ponder the way the numbers 1 through 9 stand written there. Here is a case of typically scientific abstraction: on the display we find our familiar Arabic numbers reduced to their bare essentials, with their characteristic curls and ornamentations being abstracted away. In their unornamented abstraction they are quite ugly, but no matter: you can read them, and what more should you really want from the display of a watch? But then look around in the world at large, and note how these selfsame digitalized numbers have emancipated themselves from the Liquid Crystal Displays which enforced their reductionist uglification, starting a life of their own as house numbers, letterings, and in many other functions previously filled by our nice, curly numbers (and letters too, by the way). Why we put up with this – why we uglify our living surroundings far beyond the inevitable requirements of scientific abstraction is much of a mystery to me. Here I confine myself to noting the phenomenon, and to observing that the reductionism inherent in modern science is not solely an occasion for lofty debate, but is rather of urgent concern to our entire mode of living.

Reducing the world of experience to the world of modern science had more consequences, equally pointed at by Burtt. The passage I quoted ends with an expression of vivid surprise that the very human spirit ruled out by the mathematical conception of the world (or at least reduced to a 'pitifully meagre' place[5], as Burtt wrote elsewhere) has nonetheless proved itself able to set out for that marvellous adventure of the human spirit that modern science undoubtedly is. How could such a dependent entity as the human mind is in the scientific view of the world, ever accomplish such a glorious enterprise? What Burtt is saying here is that the view of human beings which lies implied in modern science is, once again, an intensely impoverished one.

Contrary to what Burtt suggests, however, this has been acknowledged virtually from the start. Throughout the centuries there have been thinkers who recognized the capacity of the universe of precision to flood every conceivable domain, and, to the extent that they abhorred the consequences they dimly foresaw, they have cried out in protest. Almost without exception their protestations have taken the form of a more or less blunt, but invariably sweeping anti-scientism. The case against science comes in many different shapes and packages, but the more intelligent ones tend to focus on one single issue – the autonomy of the human mind, of human creativity, of human uniqueness and spirituality, or, phrased negatively, the impoverished, unhuman emptiness of a world governed by the world-view they see rightly or wrongly implied in modern science. Such protestations are rarely quite consistent with their own conduct, since almost no one nowadays can abstain from reaping such fruits of modern science as are yielded by modern industry and modern medicine, to mention only the two most obvious examples of science-begotten spenders of desirable commodities. Still, the protestations deserve to be taken seriously, for they do have a point, however one-sidedly it is usually being put forward. The point is, simply, that there are indeed limitations to modern science, and that it is of urgent concern to determine where the boundaries are to be situated.

Determination of boundaries

That such boundaries exist can be illustrated, no longer from principles but from experience. The history of science shows time and again the sterility of attempts to overstep those boundaries and to seek to absorb into the universe of precision domains that properly lie outside, although almost never entirely so. My own scholarly discipline provides a case in point. Although efforts to put the discipline of history on an allegedly 'scientific' footing come and go in waves (we are now in a trough) the results, while not negligible in such quantifiable domains as historical demography, appear invariably to abstract away the very things that form the marrow of human history. Or take an example that may mean more to you, since, just like medicine, it is situated at the cross-roads between the domains of mechanical causation and of human uniqueness. This is the art of music[6]. Although to the ordinary music lover there is nothing scientific whatever about his or her experience of musical sounds, it was shown in very early times, in the

Pythagorean school of thought, that such a connection does exist. The very building blocks of music – the consonant intervals – appear to be produced by vibrating chords of which the respective lengths are to one another in ratios of the first few integer numbers. For example, the octave is given by strings of lengths 1 and 2; the fifth corresponds to the ratio of 2:3, etcetera. One question that has run through the history of musical theorizing is how this regularity can be explained; another, what such an explanation would mean for our understanding and enjoyment of music. There has been a perennial antithesis between those who regarded the problem of consonance as the clue to the appeal music exerts over us, and those who upheld the pure and untainted autonomy of the musical experience. The latter had strong points, arguing among other things that consonant harmonies are static buildings, so that no possible mathematical or physical analysis of consonance impinges on the melodic flow equally characteristic of music. Composers have naturally upheld this view, and up to this point it is unexceptionable. But most went on to jump to the conclusion that the mathematical/physical analysis of consonant intervals is altogether worthless, and here they have proved mistaken. The whole domain of acoustics emerged in the 17th century out of a transformed understanding and investigation of the problem of consonance, and in 1863 Hermann von Helmholtz offered an explanation of the Pythagorean riddle which does have very important things to say about regularities underlying musical harmony in actual composition.

I find this an exemplary story of how to proceed in a scientific inquiry situated close to the boundary line between mechanical causation and human autonomy. Those who optimistically sought wholly to reduce the musical experience to a mathematical/physical/physiological account of how we hear consonant intervals have proved far too optimistic, and there is no reason to expect that the vast region not thus mathematized is soon, or ever, to be overflown by the universe of precision after all – human pleasure in musical sound obeys laws of an altogether different order, too. But, and this is the other side to the same coin, there was no harm in trying to see how far you could get. Those who joined Aristoxenos (3rd century BC) in denying that there was anything to be learned here at all[7], can be shown to have sought to foreclose a fruitful domain of scientific inquiry – if in obedience to their strictures the topic had not been pursued at the time, our knowledge of the functioning of human hearing would have been much poorer.

A moral to the story

So altogether I want to say this about the viability of the program of scientific reduction imposed by the universe of precision: Let its practitioners go ahead and (within ethical bounds which I leave out of account here) see how far they can get in any given case, yet let them keep their eyes widely open for how far their conclusions actually extend. I am just an historian with very little knowledge of the practice and theory of medicine, yet I would fancy that the same applies here. There is a valid area in medicine that pertains to the universe of precision – there is an equally valid area of uniquely human, medical experience. We should not conceptualize this state of affairs in terms of 'scientific revolutions' or 'models' or 'paradigms', for that way you are almost inevitably led into needless dichotomies and fruitless 'either/or' antagonisms. Talk of 'revolutions', or 'paradigms', with their closely associated notion of mutual incompatibility, masks the basic fact that there has been one overriding revolution in the history of science only – the one I began my talk with. I have wanted to argue with all circumspection that befits the foreign intruder into your proceedings that in the domain of medicine the two levels of experience – the abstract one of the universe of precision and the concretely tangible one of human uniqueness – meet one another in a fascinating way. One may make the two clash, arguing forever over what should count – the human body's receptiveness to scientific treatment, which suggests it is just a machine – or rather the human being's responsiveness to such non-scientific things as interior psychic states, empathizing treatment, placebos, and so on, all of which suggests that the human being transcends the universe of precision. It seems to me much more fruitful to recognize, as Immanuel Kant insisted long ago, that the human being is indeed machine-like up to a point, while equally transcending his machine-like state. The challenge as I see it is to find out, with patience and a willingness to recognize this dual state, where the boundaries are situated in every given case[8]. The investigation of underlying mechanisms at the molecular level is neither less nor more valid than the treasures of experiential insight gathered every day by the intuitive knowledge of human nature at the command of the attentive general practitioner. The huge problem facing you here, which I do hope this symposium to bring somewhat closer to a resolution, would, in my layman's opinion, require as a decisive first step an acknowledgment that it is about the thoughtful drawing of specific and proper boundary lines, not about wholesale revolutions that would do more harm than good in the aftermath of the one truly Scientific Revolution that formed my principal topic.

Notes

1. Not wishing to clutter the main text with tokens of my awareness of how drastically simplified a picture I am presenting here, let me state once and for all that I am condensing here into a few pages a topic which has given rise to a huge, specialized literature. In a book due to appear in spring 1994 with the University of Chicago Press, The Banquet of Truth. An Historiographical Inquiry into the Nature and Causes of the 17th Century Scientific Revolution, I have critically surveyed a large portion of

that literature. The outline of the emergence of modern science that follows in the present text is taken, more or less verbatim, from pages 11-14 in my paper 'The Emergence of Early Modern Science in Europe; with Remarks on Needham's 'Grand Question', Including the Issue of the Cross-Cultural Transfer of Scientific Ideas'. Journal of the Japan-Netherlands Institute 3, 1991, p. 9-31.

2. A. Koyré, 'Du Monde de l'"à-peu-près" à l'univers de la précision'. In: idem, *Études d'histoire de la pensée philosophique*. Paris: Colin, 1961 (2nd ed. Paris: Gallimard, 1971); p. 341-362 (originally 1948).
3. E.A. Burtt, *The Metaphysical Foundations of Modern Physical Science. A Historical and Critical Essay*. London (Routledge & Kegan Paul), 1972 (reprint of 2nd edition of 1932; first edition: 1924); p. 4-5; 10-11.
4. Ibidem, p. 298-299.
5. Ibidem, p. 114.
6. In what follows on musical theory I have collected points I made at various places in my book, *Quantifying Music. The Science of Music at the First Stage of the Scientific Revolution, 1580-1650*. Dordrecht: Reidel, 1984.
7. A captivating exposition of the antithesis is offered by A. Barker, 'Plato and Aristoxenos on the Nature of Melos', in: C. Burnett, M. Fend & P. Gouk (eds.), *The Second Sense. Studies in Hearing and Musical Judgement from Antiquity to the Seventeenth Century*. London: The Warburg Institute, University of London, 1991; p. 137-160.
8. An illuminating exposition of how Kant drew the boundary lines may be found in a 'Kant breviary' put together by Raimund Schmidt in *Die drei Kritiken in ihrem Zusammenhang mit dem Gesamtwerk*. Stuttgart: Kröner, 1975. Although two centuries of intervening scientific discovery have made Kant's specific solutions obsolete beyond repair, his underlying distinctions still seem to me quite fertile.