

WHAT WAS 'THE SCIENTIFIC REVOLUTION'?

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In this paper, the 'Scientific Revolution' is considered as an intellectual revolution, with its properties of localization in time, place and field of enquiry, special ideology, and its own cycle of achievement and decay. The ideology of the revolution may be expressed as follows: *The most valuable and powerful new truths are to be achieved by a certain new method of studying a natural world considered as dehumanized and disenchanting.* In the formula, the agreement and differences between the three founders of the scientific revolution may be identified. The varying fortunes of the 'new philosophy' in different places are sketched in; and its later evolution and contemporary relevance are indicated.

It may be appropriate, in this tribute to my Indian colleagues, to consider the event which is commonly accepted as establishing the modern science characteristic of European civilization.

The 'Scientific Revolution' of the seventeenth century has been the subject of many recent books and papers; yet I think that few will claim that we have achieved a satisfactory understanding of what it was, and how it came to be. There is a great variety of descriptions and explanations, some so well established that they are in danger of being overlooked in sophisticated studies, and some which have little but the authority of a once-great name behind them. It is certainly true that in that great century there occurred a rejection of the method of appealing to authority for evidence concerning the natural world, that the use of experiment was extended and developed, and that anthropomorphic and magical explanations of natural phenomena fell into disfavour. It is inaccurate to ascribe these changes to 'all men'; rather they are shifts in the patterns of thinking of groups of educated people, groups which have yet to be defined closely. Moreover, while these changes can be seen to have occurred, by themselves they do not lead us on to understanding the causes of the changes.

Among the candidates for the causes of the revolution which remain in the intellectual sphere, those which focus on the mathematical and cosmological fields are the most plausible. But their plausibility is reduced as soon as one tries to do serious history with them; as an example, the 'Copernican revolution' dissolves into a series of quite distinct phases, and those of the pre-Galilean period have little in common with the distinctive character of the revolution in natural philosophy which was soon to occur.

For some schools of historians (among whom I include myself) it is in principle more satisfying to relate an innovation in this very specialized intellectual activity, to changing currents of thought in the milieu. Any illuminating relations which can be perceived will necessarily be complex, and their study will take any single scholar further than he can safely go, in the histories of philosophy, theology, social thought and other spheres of human thought and activity. The earlier attempts in this direction have suffered from over-simplicity; for instance, it is an error to find in the craftsmen (even the mathematical practitioners) of the sixteenth century a 'scientific', experimental, 'rational' approach to the description and control of the natural world.

As a beginning towards an analysis, I propose to consider this event as a particular instance of the genus 'revolution', and to see whether some of the characteristic features of revolutions may be identified here, to good purpose. There are a few things that one can say about deep revolutionary movements, which we can apply to the present problem. First, they occur, or rather come to the point of crisis, in determinate places and times; and in each setting the general revolution takes special forms influenced by the local circumstances and history. Also, the revolution needs an 'ideology', a set of slogans defining its tasks and prospects; this is necessary both for maintaining enthusiasm and for giving general guidance. Further, the problems facing successful revolutionaries are entirely different from those associated with the earlier struggle; and since a revolution involved the rapid overthrow of the traditional structures for solving traditional problems, we have seen how these problems reassert themselves, even in the new context of the post-revolutionary era. This is perhaps the main cause of the loss of revolutionary *élan* in the period of consolidation and construction. Finally, once the revolution has been fully achieved, evolutionary change proceeds again, but on the basis of the irreversibly altered structures created by the revolution.

We may begin by localizing the 'scientific revolution' in space, time, and field of investigation. Although Francis Bacon must be included among the earliest revolutionaries, he did not enjoy a following in his own nation; whereas both Galileo and Descartes had circles of admirers, enthusiasts, and (in the case of Descartes) rivals in the same enterprise. We can say, then, that the most clear and sharp expression of the revolution found an audience in Italy (mainly of the North) and France in the 1620's and 1630's. In the 1630's it was brought to Holland by Descartes, and in the 1640's it spread to England. Although isolated individuals in other nations participated in sorts of investigations characteristic of the 'new philosophy', as a movement attracting groups of enthusiasts it then spread very slowly indeed. In the inward-looking and stagnant intellectual culture of post-Reformation

Catholic Europe, it never gained a strong foothold. We find it in Scotland in the eighteenth century, and its appearance in Germany in the nineteenth was the occasion for philosophical battles similar to those which had been fought in Italy some three centuries earlier.

Turning now to the fields of enquiry, we find real revolutionary changes in a small group of sciences: cosmology, mechanics and some other fields which could then be fruitfully studied by 'mechanical' methods, notably pneumatics and optics. Mathematics also progressed enormously in the seventeenth century, but it is not easy to find a qualitative break with the preparatory work of the later sixteenth. Chemistry received some new theoretical structures, but the pace of development of the science was not significantly altered. Progress in the life sciences and medicine was really a continuation of the great achievements of the schools of the previous century (and Harvey's discovery of the circulation of the blood is a signal example of this continuity). Finally, technology was not noticeably affected by the 'new science', in spite of the hopes and claims of its propagandists. The above list records only successes, and it might lead to the impression that the 'new philosophers' had achieved the secret of settling down to doing physics (in the nineteenth century sense), and doing it extremely well. This is incorrect; the example of Descartes, trying to create a mechanistic human physiology, is well known, and Newton's unsuccessful attempts to achieve a complete philosophy of the world, extending all the way over to Biblical interpretation, are at last being recognized as significant productions of a great genius.

What were the slogans raised by the earliest revolutionaries? In Bacon, Galileo and Descartes we find pronouncements on the true path for philosophy; in spite of their marked differences, they have distinct family resemblance. I think it is possible to isolate the kernel of their common thought in such a way that their differences are seen as different interpretations of certain key ideas. As a tentative statement of the slogan which expresses the ideology of the Scientific Revolution, I offer the following: *The most valuable and powerful new Truths are to be achieved by a certain new method of studying a natural world considered as dehumanized and disenchanting.* This formula is tightly packed, and some discussion of its terms may be useful.

The *value* of the work must come first; for it needed something of great value for men as brilliant as these three to decide to devote their lives, and risk their careers, in its pursuit. The idea of *power* over Nature has a long ancestry; what was new here was philosophers adopting it, rather than the craftsmen and magicians of various sorts who had previously been its only seriously committed supporters. The theme of the achievement of genuine *novelty*, of surpassing the ancients, was only a few generations old in the early seventeenth century, and was then and later a topic of fierce debate.

Indeed, the idea that novelty was itself a good rather than a bad thing was then by no means universally agreed. The object of the enquiry was *Truth*. Of this there can be no doubt, in spite of 'positivistic' or 'probabilistic' statements by Galileo or Descartes, in moments of caution or discouragement, and by their less heroic followers. This was the root of Galileo's collision with the Church; had he been able to argue that the Copernican system is the best of all possible hypotheses, he would have had no difficulties at all.

When we come to *method*, the divergences appear. We should recall that the problem of method has a continuous history, from Aristotle and Galen, through medieval thinkers to such as Ramus. With Bacon, the 'method' was formed by analogy with his own experience as a master of jurisprudence: careful and controlled induction from a mass of tested particulars. Descartes hoped for a deductive system from indisputable axioms, but early came to recognize that such systems need to be tested by carefully contrived and skilfully executed experiments. For Galileo, the motto 'sense experience and necessary demonstration' covered an eclectic approach; while his 'demonstration' was modelled on Euclid and Archimedes, his 'experience' covered the range from craft experience, through controlled experiments, over to pure thought-experiments.

The concentration of attention on the *natural world* marks a break with the humanistic traditions of the previous century. For Descartes, the break, as recorded in the *Discours de la Methode*, was sharp, savage and painful. Bacon never did make a consistent break; and, it seems to me, never resolved the contradiction of the place of his beloved legal and humanistic studies in the world of true 'interpretations of Nature' defined in his *Novum Organum*. Having less depth and concern in such philosophical matters, Galileo seems not to have noticed any difficulty in principle. When we realize that both Bacon and Descartes were consciously in search of the highest human wisdom, their choice of the natural world for the foundations seems odd; and for this reason alone it is significant. All three excluded politics from the domain of their revolution, and sought for patronage and support consistent with this. The natural philosophy of the political radicals of the seventeenth century was a continuation of a much older tradition, in which illumination, empiricism and radicalism were united against the dry, bureaucratic, literary culture of the intellectual professions adhering to the ruling classes. Only in the eighteenth century were the radical implications of the thoughts of Bacon and Descartes developed, and then by a movement appropriately called *philosophes*.

Finally, this world of nature was to be considered as *dehumanized* and *disenchanted*. In the first is the reaction against the system of the neo-Scholastic Aristotle; its 'final causes' were the prime target of ridicule. The reaction against the 'magicians' was equally strong, although few besides

R. Lenoble have identified it. Thus, as in so many revolutionary situations an adequate picture starts with at least three opposed sides. Depending on local problems, alliances between them could shift in a seemingly illogical fashion. In the 1630's, Mersenne forgave Campanella his philosophical sins because of his courage in defending Galileo; but in the 1650's in England, the threat from 'illuminated' sectarian politics (with its Paracelsian natural philosophy) was so pressing that all other tendencies found themselves working on common lines against it. We should notice finally that the natural world was *to be considered* as having these negative properties. Whether in fact the philosophers of the seventeenth century were able to live in the dead world that Bertrand Russell popularized in the 1920's, is a question whose answer is probably negative.

Accepting this as a tentative formation of a rather complex revolutionary ideology, we may hope to use it to investigate two sorts of questions. The more difficult one is the conditions which gave rise to a few men of genius organizing their personal philosophies along these lines; somewhat less difficult is the question of the conditions under which the diffusion of such a philosophy could take place, where it would seem 'common sense' to a new generation. This is not the occasion for such an investigation; it is clear that there is in general some correlation of the diffusion of the 'new philosophy' with Protestant religion and a mercantile, capitalist economy. Of course, there are so many exceptions that any general statement of the affinity between the 'Geist' of Calvinism or capitalism, and that of 'science', abstracted from an historical and political context, sheds more obscurity than illumination.

We may also reconsider the relations of this revolutionary ideology with the practical work of the investigations of the natural world. At the present stage of the development of the history of science, hardly anyone tries to interpret the 'mechanical philosophy' as analogous to the philosophies of science of the recent past, developed *post hoc* to explain and rationalize the results of the positive sciences. On the other hand, it would be inaccurate to imagine the philosophy appearing full-blown, and transforming magical, ineffectual renaissance science into the successful mechanical science of the seventeenth century. The relation is more complex than that. For the style of science which we may call 'pre-mechanical' had, on a few fronts, reached a pitch of excellence by its own internal development. The three leading examples here are Gilbert, Kepler and Harvey, whose work grew out of the most highly developed applied sciences of the sixteenth century: hydrography, astronomy and anatomy. Outside the few fields where the 'mechanical' approach yielded incomparably superior results, this older style persisted, and soon interacted with the newer philosophy. We do better to see the revolution as one concerning human knowledge, which focused attention and enthusiasm on one sector of the studies of the natural

world which were already under way. It did intend to transform all such studies and, where it could be effective in the technical context of the age, it did succeed magnificently. Moreover, as time passed, and educated common sense in various countries caught up with at least part of the 'new philosophy', its effect diffused even more widely through the world of natural science. The phenomenon here is analogous to that of the penetration of the nineteenth-century movements of radical social protest, by Marxism.

Of the many who have said, 'je ne suis pas Marxiste', the most famous is Karl Marx. For when the later Socialist movements assimilated what they could of the revolutionary ideology of the *Communist Manifesto*, the 'Marxism' that resulted was not what its creator had intended in the great struggles of the 1840's. The great revolutionaries have a vision which sees clearly into the distant future, and which also makes the most patent blunders concerning the present. For they have risen above the inherited common patterns of thought, and at a stroke resolved the contradictions that had hobbled men of lesser intellect and daring. The loyal men who follow them, who must articulate, consolidate and apply their insights, encounter a host of less exalting but extremely difficult problems. For them, life is not so clear, simple and heroic.

In the case of the 'mechanical philosophy' one might say that the period of disillusion and heartbreak began at the very moment of its first great pronouncement. The trial and condemnation of Galileo caused his humiliation and suffering; but it shattered Descartes. His programme of revealing 'The Universal Science' to the world was distorted before it ever reached the printers; the Sixth Section of the *Discours de la Méthode* shows a man who has lost his way. Galileo's disciples were few but illustrious; but they were choked by a hostile environment. Of the 'Cartesians' of the latter part of the century, those with depth either returned to theology or took the letter and killed the spirit of the Master. The leading centre of the 'new philosophy' from mid-century on was England. But it is a commonplace that any philosophically consistent system, which is adopted in that most empirical of nations, is turned into something far less tidy and rational. Of all the early enthusiasts for the philosophies of Galileo, Descartes and Gassendi, only John Wallis can be said to have worked in their spirit. The early Cartesians (as Henry More) used him as a theological rescue operation. Men like Petty and Hooke were really more interested in gadgets than in atoms. Robert Boyle had his intellectual formation with Helmontian chemists, and never got over it. The greatest men in the life sciences, as Francis Glisson and John Ray, were largely untouched by the new currents. This may seem a paradoxical and uncomplimentary picture; but the evidence from the end of the century is incontrovertible. In 1688 Boyle argued for 'final causes' in biology and cosmology; somewhat later Newton and Locke had their most

intensive discussions on problems of the interpretation of Scripture; and at the turn of the century Newton patronized the brilliant but eccentric Whiston, co-operating on the work of Biblical chronology and cosmological proofs of the existence of God.

Of course, as the educated common sense of northwestern Europe became secular and reasonable, the basic world view of the 'new philosophy' became trivially obvious. But it lacked its revolutionary cutting edge, and did not inspire to enthusiasm. Knowledge of the natural world, at the conversational level, became fashionable; inspired research was not there. The revolution was over, and evolution proceeded, at a gentler pace.

But the revolution had indeed occurred, and things would never be the same again. There could not even be another revolution of the same sort. For the revolution was, as we have seen, in the philosophy of nature. Out of the revolution came, in one field after another, positive sciences. As these grew in size and power, the philosophy of nature was pushed to one side, where it remains to this day. Even if the philosophy of nature should at some time revive, it would first have to re-create a tradition of study which started with the pre-Socratics and began to decay rapidly after 1700. Also, it would have to reckon with the specialized knowledge and real expertise of those hosts of positive scientists whose work it would criticize.

The historical consequences of the 'scientific revolution' are well known. By the late nineteenth century, the positive physical sciences were sufficiently developed to begin to bring reality to the dream of power which had animated the early revolutionaries. Steel, steam, and the Maxim gun brought Europe to a peak of dominance, which had been a half-millennium in the building. Rather quickly afterwards the civilization entered crisis, with two internal wars and the break-up of empires. It is now clear that the dehumanized world of the seventeenth-century scientific revolution is not adequate for solving the practical problems faced by contemporary societies, either in this civilization or outside it. Whether a new philosophical revolution will occur in time, is as yet an open question.