# CONCLUSION: THE FUTURE OF SCIENCE

For several centuries, the understanding of science has been conditioned by a belief in the separateness of knowledge and society. The faith in the attainment of human knowledge which is absolute and unconditioned inspired the pioneers of the new philosophy out of which natural science grew; and it has been the easiest line of defence of the autonomy of science against its many enemies. That simple faith is no longer adequate for its function of maintaining the integrity and vitality of science. Attempts to refine it through purely epistemological analyses do not provide a basis for defending science against the dangers and abuses arising from its new social conditions; but to consider science as merely a special branch of industrial production would lead to its speedy degeneration. The argument of this book has attempted to exhibit the ways in which genuine scientific knowledge can be a product of a social endeavour, and yet embody truth, at least within the fundamental metaphysical framework of the civilization in which it is achieved. From this analysis we have been able to study the conditions under which science can advance towards knowledge, to identify diseases and abuses to which science is subject, and to examine the special features of the application of science to the solution of technical and practical problems.

*Recapitulation*

Our analysis necessarily started with an abstraction from a complex reality: considering the investigation of a problem as the unit-task of scientific inquiry. We saw that this work comprises several distinct phases, each involving sophisticated craft skills. Contact with the external world is made in the production of data; but this must be converted into information, and then used as evidence in an argument. The argument concerns artificial objects, intellectually constructed classes of things and events; and it is about these that the conclusion is drawn. Since no argument in science can be formally valid, and hence no conclusion necessarily true, the acceptance of conclusions must be governed by criteria of adequacy. These impose a complex and subtle structure on the argument, and ensure the avoidance of the known pitfalls which can be encountered in manipulation or in inference. They belong to the body of craft knowledge of the methods of the field, along with particular techniques of using tools and with other controlling judgements such as those of value. The methods are informal and even tacit, and are transmitted interpersonally rather than publicly; they are incapable of being tested scientifically themselves, but arise out of the collective craft experience of the field.

The conclusion of an adequately solved problem is still far from being knowledge or even a fact. The research report on a solved problem must be assessed by a referee before it is certified through publication in a recognized journal. Even then, it must prove its significance (by being put to use), its stability under testing and repetition, and its invariance under the changes in conceptual objects which inevitably occur as new problems are investigated. Of all the facts which are so established, the great majority remain within the descendant-lattice of problems deriving from their original, and sink into oblivion when that field is exhausted and forgotten. Those facts which survive to become scientific knowledge have a different path of evolution. Rather like successful tools, they are also extended to other fields, in standardized versions performing a variety of functions and taking diverse forms. When such facts have survived the demise of their original problem and its descendants, and remain alive through their many uses, they are recognizable as knowledge. It is paradoxical that the different extant versions will be incapable of being reduced to a single, standard statement; and that the obscurities latent in the original formulation will frequently remain unresolved. It is also paradoxical that the whole process of evolution and selection is accomplished by fallible individuals, and governed by a craft knowledge of methods. Such a conception of the nature and origins of genuine knowledge runs counter to the hitherto dominant traditions of the philosophy of science and epistemology. But in them, the basic problem was how an individual could quickly achieve truth or the best substitute. Here, the guiding principle is 'veritas temporis filia'; and as the daughter of time, transformed and tested by a great variety of contacts with the external world, recognizable scientific knowledge emerges from a complex and lengthy social endeavour.

For simplicity this first analysis was restricted to matured fields of 'pure' scientific inquiry, and it presupposed the presence of social mechanisms whereby the private purposes of individuals would be harmonized with the collective goals of the endeavour. An examination of these mechanisms was necessary as a preliminary to any analysis of the conditions under which the health and vitality of science can be maintained. We saw that in the protection of the intellectual property embodied in an authenticated research report, the inherited formal system of journals and citations must be operated by an informal etiquette if it is not to be abused and destroyed; and the introduction of new forms of property lacking the controls of the journals requires a most refined etiquette if they are not to lead to a degeneration of the work. The management of novelty has in the past presented some of the most severe practical problems for science. We saw that neither the assimilation of old materials to new, nor the choice between competing research strategies, can be accomplished on the basis of general rules; but that destruction and conflict are inevitable in science, and the social organization and style of work in each particular area will determine whether the outcome of a 'revolution' will be renewed vitality or stagnation. The social task of quality control in science bears most directly on ethics, for the immediate private purposes of most individual agents are served by skimping, however slightly, on the quality of their accomplished tasks. No formal system of imposed penalties and rewards will guarantee the maintenance of quality, for the tasks of scientific inquiry are generally too subtle to be so crudely assessed; nor will the advantages to an individual of a good reputation of his group be sufficient to induce a self-interested individual to make sacrifices to maintain it. Only the identification with his colleagues, and the pride in his work, both requiring good morale, will ensure good work. Science possesses a hierarchy of quality control, informal except at the lowest level where research reports are assessed for publication; and the controllers are controlled by rewards of prestige in various ways. At the top of the pyramid of control are the leading scientists at the leading universities, who control each other and their fields by the most informal of techniques. They are neither answerable to their inferiors, nor strictly accountable to those who provide their support; and their work of direction and control requires both wisdom and the highest ethical commitment if it is not to degenerate. The ideology and social context of this ethical commitment are inherited from an earlier age; and the conditions of industrialized science present them with problems and temptations for which their inherited 'scientific ethic' is totally inadequate.

Science becomes directly involved with society at large when it is applied to the solution of technical problems, involving the production of the means for the performance of a function, or practical problems, involving the achievement of the purposes of individuals or groups of people. Each of these other sorts of problems have their characteristic cycles of investigation, their appropriate criteria of quality, and their particular pitfalls. The most sophisticated technical problems, in which the scientific component is strongest, are encountered in those industries where the automatic mechanisms of quality control through a competitive market are weakest; in them there is the danger, not merely of runaway technology advanced without regard for human welfare, but the corruption of the activity of technical problem-solving itself. The investigation of practical problems, and their solution through large-scale practical projects, encounters every pitfall of scientific and technical problems, and then some peculiar to itself. Conflicting ideologies and purposes are at the heart of every urgent practical problem; they lack the accepted criteria of quality for their solution; the sciences involved in them are usually immature; and in their execution they are prone to distortion by the natural tendencies of bureaucratic operation. Because of the increasing recognition of new practical problems, immature sciences are assigned tasks which they are not strong enough to accomplish properly; to their internal difficulties (aggravated by the necessary pretence of maturity) are then added those of hypertrophy. When involved in the solution of practical problems, they also function as folk-sciences; and the resulting confusion of the different sorts of problems and their appropriate styles of work can result in total demoralization and corruption. These difficulties and dangers are directly relevant to the future health of the traditional, established, matured natural sciences. For their internal difficulties of recruitment and morale, as well as those of their relations with society at large, are practical problems of the sort analysed here. Their resolution is urgent, because of the delicacy and vulnerability of scientific inquiry; but the pitfalls to be encountered here are no less dangerous than on any other practical problem.

*Science in History*

Our analysis of genuine scientific knowledge showed that it is the outcome of a lengthy process operating through history; and we have also indicated various ways in which scientific inquiry as a whole is an historical phenomenon: conditioned by its social and cultural environment, and subject to cycles of growth and decline. The very long period of the flourishing of the matured natural sciences was plausible evidence for the comforting belief that science, in its academic and positive period, had truly reached evolution's end, and would thenceforth experience a simple progress onwards and upwards indefinitely. The 'idea of progress' with which the rise of modern science was intimately associated received its mortal blow in the First World War and its aftermath; but in science itself the assumption survived for nearly another half-century. Appreciating that that long 'golden age' of science is now definitely ended, we can see it as one temporary phase in the history of man's attempts at understanding and control of the perceptible world around himself. Extending back to remote antiquity, this history has the common pattern of continuity and change, and gains and losses, as its successive phases appear. Seeing ourselves in a new phase of this history, we can face its problems as inherent in its conditions, and not as merely accidental difficulties to be removed by exhortations or by administrative devices.

While recognizing the novelty of the problems of industrialized science, we would be quite mistaken to think that the whole social activity of science has been completely transformed in the last two decades. A large part of scientific research proceeds as before, in a social context which is still mainly 'academic' rather than industrialized. The radical difference is that certain new tendencies resulting from industrialization are developing rapidly, and that the self-consciousness of science, as reflected in the pronouncements of its leaders, has changed from a simple optimism to a troubled uncertainty. Even if these developments continue and intensify, one cannot predict with any assurance just how serious their effects will be within any given time. The work of scientific inquiry is now embedded in a very large social institution which performs other essential functions in an advanced society, including higher education and the investigation of technical and practical problems. Even if all these sectors encounter increasingly serious problems they will continue to receive support from society so long as they are considered as performing these functions better than any feasible alternatives. Historical change can take a long time to work itself out; and we must avoid the naïve rationalism characteristic of radical reformers, who believe that once the insoluble problems of an institution have been exposed it will soon pass away. We might recall that the Catholic Church was conscious of a deep internal crisis as early as the later twelfth century; the incompetence and corruption of the clergy had already led to powerful movements of reform and schism. Yet several centuries were to pass before 'Reformation' achieved a permanent, independent base; and the Church survived that, to continue as a powerful force up to the present. Of course, the Church had coherence, wealth, and power in a way that the social institution of science does not; but if we are assessing the prospects for science over a period of a few decades to come, we must keep in mind the enormous inertia of any established institution in all but the most revolutionary of contexts.

We must also remember that the world of science is a very variegated one. Some fields are capital-intensive, and so very vulnerable to the effects of industrialization; while others can produce outstanding work with small investments for each project. Again, some are closely related to technical problems, while others can proceed in peaceful uselessness. National styles in science, which were very marked even among the successful nations before the complete domination of academic science, may emerge again so strongly as to condition the sort of work which is successfully done in different places. It is well known that the greatest strength of America lies in technical problems: both the development of physical devices and the organization of work and management. But American science is particularly prone to the dangers of entrepreneurial, shoddy, and dirty science. By contrast, British science is sufficiently small and poor (in comparison) to be led by an institution (the Royal Society) still resembling a club; and in this context the problems of contraction, and accommodation to industry, may be managed with more finesse. Again, in the Soviet Union the political pressures on intellectuals are so crude, that the leaders of science have a natural social and political role as spokesmen for an Enlightenment in classic eighteenth-century terms.[1]

The history of science provides yet another caution against over-simple predictions of the effects on science of the changes in its context. While it is relatively easy to give plausible explanations of the gross features of scientific activity in terms of its social and cultural environment, this becomes progressively more difficult as one tries to account for work of lasting quality, and the productions of genius. We have mentioned earlier that some of the greatest scientific work of all time was conducted within a metaphysical framework which would now be rejected as superstitious and anti-scientific. Yet even those who were searching for the divine harmonies of the celestial motions, or for the material location of the world-soul (as Kepler and Gilbert, for example) could, by talent and discipline, achieve results which became incorporated into the body of genuine scientific knowledge. Similarly, although men of ability will generally do better work when they are part of a vigorous community, enjoying prestige and leisure for their researches, some of the greatest advances have come from men working under difficult conditions in nearly complete isolation: such men as Copernicus, Mendel, Galois, and Lobachewski are cases in point. Hence, even if the goals of 'positive science' are totally displaced in scientific inquiry, and the major communities of science experience crises of finance and morale, there may yet be scientific achievements which will last for centuries to come. However, there is no known means of encouraging genius through adversity; and it would be dangerous in the extreme to conclude that the quality of scientific work would improve if scientists were left to starve in garrets.

### *Science in Society: the Problems of Morality*

With all due caution in the face of the complexities of historical change, we can proceed to indicate the deepest problems that science will face as the process of industrialization develops, and to speculate on how they might be resolved. For this we will first need to analyse the inherent tensions in the relations between scientific inquiry and the society at large which supports it.

[1] See A. Vucinich, 'Science and Morality, a Soviet Dilemma', *Science*, 159 (15 March 1968), 1208–12, for a discussion of the current movements for autonomy of science, in the context of the Russian traditions. For an example of this style of work, see A. D. Sakharov, *Progress, Coexistence and Intellectual Freedom* (Norton, New York; Deutsch, London, 1968; Penguin, London, 1969).

Of itself, scientific inquiry is not a self-sustaining social institution; neither wealth nor power are derived directly from the activity. It requires support from society at large, or at least some wealthy and powerful section of it, if it is to exist. From lay supporters, then, science requires first of all 'legitimization', if its practitioners are not to be relegated to a despised or abhorred fringe of society. More than mere tolerance is required; resources must be invested in scientific work, both in providing paid research time for the practitioners, and in supplying their specialized equipment. Finally, an increasing flow of recruits, drawn from the adolescent population, is necessary if the work is not to stagnate and die. In exchange, science can offer the promise of assistance in the solution of technical and practical problems. This may be direct, or indirect; thus high-level teaching, which in recent generations has been considered to depend on an association with research, contributes to technique; and the contribution of science to national prestige, or to the strengthening of the nation's official ideology, helps in the solution of practical problems. But we notice that these return offerings of science to society are not, and cannot be, dominant components of the general goals of the work, and still less of particular research projects. Some of them may well be present, in varying degrees, in the work of particular individuals or schools, especially in the conditions of immaturity and in the endeavours of a genius. But should a large, established field, depending on the efforts of many research workers, allow its criteria of value (and hence of adequacy as well) to be dominated by such external functions, the work which results will not be science. It may have excellence of a different sort, or it may be quite corrupt, depending on conditions; but it will contribute to the advancement of knowledge only very incidentally.

Thus the social position of science is really quite precarious. Scientists are not professionals of the traditional sort, who can justify their position by the serving of the purposes of clients; nor can science be conducted on a large scale in a social context analogous to that of the fine arts, providing prestige to particular patrons. Science not merely requires very tangible support in return for quite intangible returns; but the different components of its support will in general derive from different sections of society. Each of these will need to be furnished with propaganda appropriate to its tastes; and this internal complexity, together with the great variety of social contexts within which science has operated, have produced a great variety of themes in the literature of justification and defence of science. The dominant themes from earlier times relate to the ideological functions (and dysfunctions) of science or of natural philosophy; for until the middle of the nineteenth century only a very few fields (as chemistry, itself only recently established as a science rather than a craft) could make any plausible claim to contribute to industrial production. In the later nineteenth century an accommodation with industry was recognized as necessary; and in the present period there is a strange mixture of 'images of science' purveyed to its different audiences.

In earlier times, the principal threats to the autonomy of science, or rather natural philosophy, have occurred when some fields were considered as ideologically sensitive, endangering the established religion; and in this respect they were involved in the practical problems of their age. Those with responsibility for the spiritual welfare of the lay public would use all the means at their disposal to contain or eliminate the dangerous doctrines and their perpetrators. Such measures would be more successful in places where the Church had an established machinery for handling doctrinal crimes, and the power to enforce its decisions; hence the Catholic Church has had an unfair reputation of outstanding enmity to free inquiry. As a result, there developed a belief in a close association between scientific inquiry and independent, rational, or free thinking in general. Propagandists for any of these traditions have assimilated the martyrs of science (most notably, the very complex figure of Galileo) to their cause; and some important traditions within the folk-history of science have imagined the community of science as necessarily composed of individuals who are selflessly and fearlessly devoted to Truth, against Authority and Superstition.

This identification rests on several basic fallacies. Scientific inquiry must have a subtle and complex assessment of the strength of evidence deriving from accepted authority; and in this it is similar to any other work where partly new problems are being solved. Only in sectarian religion and in teaching can the work continue successfully for any length of time without encountering the problems of the management of authority; and of course the total rejection of authority, whereby every assertion must be examined as an equal claim to truth, quickly yields chaos. Also, scientific inquiry is ideologically sensitive only accidentally and occasionally. In England, for example, the propaganda for science, purveyed from the seventeenth through the nineteenth centuries, argued that the contemplation of God's creation could not but induce to true religion. Of course, in England hardly anything gets really sensitive ideologically; and English divines could use the persecution of Galileo as evidence for the wickedness of Rome. And when English scientists were confronted with the practical problems of uncomfortable theological implications of their work, they were far more likely to devote their energies to a reconciliation than to make some specialized results a fulcrum on which they would move all heaven and earth.

Towards the end of the nineteenth century, the applications of science to technical problems were increasing in number and in power. Spokesmen for science had the delicate task of securing ever-increasing support from the community on the basis of such usefulness, while still preserving the autonomy of science itself. We recall the brilliant speech of Helmholtz (quoted on p. 39 above), where he reminded his audience of the apparent 'uselessness' of Galvani's experiments on animal electricity, which yielded the electric telegraph; but then warned them that the scientist himself must not be expected to search for anything but new knowledge about nature. This sincere plea for the social support of science, on the grounds of its accidental social benefits, is characteristic of the period of matured academic science.

With the advent of industrialization in science the claim of the technical applicability of science in general did not need to be pressed (although particular fields still need to justify their requests for support in these terms). Although there have been continuing discussions about the proportion of resources which should be devoted to 'pure' or 'basic' or 'undirected' research, there is a general recognition among policy-makers of science that it performs a variety of useful functions and so deserves some minor share of the budget. However, another audience has suddenly become crucial for the continued well-being and expansion of science: its potential recruits. Among them, there is a significant fraction who see the applications of science quite differently from the nineteenth-century optimists such as Helmholtz. Not the telegraph, but the Bomb, has become the type-example of the leading technical problems in which science is engaged. Hence a new, negative, and defensive theme has been developed in the propaganda for science: its neutrality. Of course, this will be purveyed to lay and juvenile audiences, in the hope that they are unaware of the firmly realistic terms in which 'science policy' is now cast.

Since the claim of 'neutrality' is the last defence against recognition of the political and moral problems of science consequent upon its industrialization, we can expect it to be advanced for some time to come; and it is worth closer analysis. The attempt to disclaim moral responsibility for the effects of scientific work has been made, not merely for 'pure' science, but even for work on technical problems with a military function. This extension of the domain of moral isolation of science is too implausible to survive. To be sure, one can agree that in one sense 'it is the height of folly to blame the weapon for the crime',[2] if for nothing else than that inanimate things are not appropriate objects of moral judgements. But those who are engaged in making weapons in the knowledge that their main function will be in the commission of a crime are subject to moral judgements and sometimes to legal proceedings as well. If this were not the case, then the defence of Adolf Eichmann, that he was merely engaged on a technical problem of transport, indifferent to the fact that it was a one-way transport of Jews and others to the gas-chambers, would be a valid one.

It is more plausible to assert the neutrality of science for that work which is governed by purely internal criteria of value, so that in the choice of problems the possible technical functions are either unknown or irrelevant. Even here, there is an area of ambiguity; for a particular research worker may choose to work on a problem for its functions in the advancement of the field, and for its political functions for his own career, while being aware that the investing agency is interested in the problem for its possible technical functions. If these technical functions are morally dubious or bad, can he claim immunity? The ignorance of consequences is not always a valid defence in law, and the mere absence of deliberate intent to malefaction is an even weaker defence.

However, there are severe difficulties in the way of making precise and fair moral judgements on scientists, individually or collectively. If nothing else, our experience of these problems is extremely short, and we possess neither general principles nor case-law for their interpretation, whereby responsibility and blame can be assigned in any but the most blatant cases of dirty science. Also, the division of

[2] See Sir Peter Medawar, 'On the Effecting of All Things Possible', Presidential Address to the British Association, 1969, *New Scientist* (4 September 1969), 465–7.

labour in large-scale technical problems is extremely fine; so that the scientist who publishes a result generally has no more knowledge of its possible functions than does a process-worker assembling a standard component of a device. This does not mean that the position of the agent is one of moral neutrality; rather that it is morally indeterminate. However, to the extent that his research is related to technical applications, the area of indeterminacy decreases, and the scientist's responsibility becomes defined. Once the scientist is aware of the likely consequences of his work, his sole disclaimer of responsibility can be along the lines of, 'I was only following orders.' This is no longer likely to be acceptable as a defence, in science as anywhere else.

These considerations apply strongly to scientists who are employees of a 'mission-oriented' research establishment; but for those whose experience is in a community of science still enjoying an academic style these moral problems are remote and philosophical rather than immediate and personal. There, research problems and personal achievements are evaluated by internal criteria, regardless of the motives of those supporting the work; the hard work and strict self-discipline are supported by a refined ethic; and results are shared with colleagues independently of all the boundaries which divide mankind. There, it seems, worthwhile work can be done, insulated from the moral squalor of ordinary life.

But even to the extent that the moral neutrality of academic science is real, it creates moral problems on its own; and the deep connection of science with the culture in which it is embedded involves science in its basic problems of justification and survival. The practical irrelevance of most of the results of scientific inquiry is a blessing to some, but an agony to others. What can be more selfish than to turn one's back on the sufferings of humanity, devoting one's talents to narrow tasks which will bring immediate rewards to oneself and only the most remote and unknowable benefits to one's fellow man? For a young scientist with a strong social conscience it requires an extremely strong faith in the human value of scientific knowledge to justify such a career.[3] Once this moral dilemma is recognized, it can be alleviated by various sorts of good works, but

[3] J. G. Crowther, *The Social Relations of Science* (MacMillan, London, 1941), has some sharp words on this problem: 'Young scientists who abandon science for politics often prove to be mentally unstable, and after a few years of bohemian agitation become conspicuously conservative. Conduct and opinions that appear to be based purely on moral sentiments are nearly all suspect' (p. 644).

never completely resolved. Moreover, the remoteness of academic science from human concerns is itself a result of its own traditions, deriving from its particular niche in a particular society. The openness and internationalism of science are admirable and valuable in themselves; but they are not the same thing as a sharing with all humanity. Rather, they are methods of social behaviour of a small group operating within European literate culture. Now that national boundaries within that culture are of decreasing emotional significance, the transcending of them is correspondingly less impressive. And to the extent that this culture as a whole is subjected to moral judgement, for its involvement in various sorts of colonial and class oppression, and for its creation of a runaway technology, academic science will be inescapably implicated as well.

It is quite likely that those of the present generation of elder statesmen of science who invoke its 'neutrality' are trying to reassure themselves as much as any audience of potential recruits. Consciousness always lags behind reality, and its adjustments are usually abrupt and painful. The conception of science as an essentially academic enterprise, and of 'the scientist' as an academic researcher, has persisted unchallenged in all the literature about science until very recently, in spite of the traditional industrial connections of several major fields (particularly chemistry, but also physics and biology), and in spite of the fact that the great majority of those who have ever earned their living through their scientific skills, have done so in technical work.[4] Even the interpenetration of science and industry can be traced back to the later nineteenth century, and can be seen as growing continuously since then. An awareness of a new condition of science came only when a series of dramatic events, such as nuclear weapons, and new technical problems, such as the planning of large-scale scientific research, obtruded themselves. The self-consciousness of science is still trying to cope with these changes; the purely technical problems of decision and control are difficult enough in themselves, and the deeper practical problems of responsibility and morality are only beginning to be grasped.

In the short run, the easiest response to such problems is to hope

[4] N. D. Ellis, in *The Scientific Worker*, has shown that the Royal Institute of Chemistry and the later Institutes of Physics and of Biology were created with the co-operation of the major employers of scientists; and their ethical principles were framed for the 'professional employee'. The academic scientist was not their concern; and these institutes are now subject to some strain because the majority of 'Q.S.E.'s' in industry have no professional status, but are rather 'scientific workers'.

that they will go away, and in the meantime to try to get the best of all worlds. Such a course of action, which was almost certainly not the result of a conscious policy, was taken by British university science teachers in the post-war period. Still believing in science as a genuinely liberal education, they expanded their departments with State funds intended to provide more units of trained manpower, and in practice taught Honours degree courses designed for that small fraction who could proceed to research. The instability of such an arrangement was revealed after only a decade or so; and whatever the outcome of the pressures for its alteration, the world of science has suffered no public discredit thereby. But the same sort of convenient wishful thinking, applied to the understanding of science as a whole, can have dangerous consequences, including a corruption of the whole work.

The sort of corruption which can occur in science has little in common, superficially, with that which is recognized in public life. Hence it is necessary for us to analyse the concept briefly, to show why it is relevant to the problem of science.[5] We can say that an activity is corrupt when the actual goals of the tasks accomplished are contrary to the professed social functions to a degree that a public trust is betrayed. Corruption is occasionally flagrant, but more commonly it exists in a penumbra of ambiguity; both the divergence between the final causes, and the awareness of that divergence, are ill-defined. Because of this, a man may work in a corrupt situation without himself being corrupted.[6] If he is ignorant of the state of

[5] The only worthwhile analytical study of corruption is *The Autobiography of Lincoln Steffens* (Harcourt, Brace, New York, 1931). Steffens was able to gain experience of corruption in American public life through his work as a journalist; but he could rise above mere 'muckraking' because he had previously spent years of (informal) study and thought on the problems of ethics. Although he never achieved a coherent solution to the problem of corruption (which is an interesting problem because, as Steffens found, the corruptors frequently have more honesty and personal integrity than muckrakers and reformers), his book is a mine of experiences and insights. My attempted formal definition derives from his interview with 'a dying boss', where Steffens told him why corruption is evil (see Part III, ch. VIII, p. 419).

The problems of corruption in post-colonial societies are discussed by S. Andreski, *The African Predicament* (Michael Joseph, London, 1968). Although the author discusses the problem with sympathy and insight, and even offers the technical term 'kleptocracy', his analysis lacks the depth of Steffens' (of which he seems unaware), and it suffers from his assumption that in advanced societies corruption is minor in its scale and effects.

[6] It is important to realize that even the practice of a legislator actively promoting measures for his direct financial benefit is not necessarily corrupt; this was a common and accepted state of affairs in Victorian England. See R. A. Lewis, *Edwin Chadwick and the Public Health Movement 1832–1854* (Longmans, Green, 1952), ch. 15, 'Reaction'' which

affairs, or completely cynical, or capable of some sort of double morality, he may maintain his personal integrity. But more commonly, a shadowy awareness that things are not quite as they must be claimed to be, will force the individual agent to recognize the possibility of his complicity in something culpable. Such recognition tends to preserve and intensify the corrupted state of the activity: fear of exposure comes to dominate the purposes of the agent, and the group as a whole is held together by mutual blackmail. In such a situation, the worst elements gain power over the better, and the performance of the professed social functions is the least of the considerations affecting individual and collective decisions.

It is easy to see that this sketched analysis applies to cases of corruption in public life, where the private goals are the venal ones of personal gain. On the other hand, it is by no means necessary that every bureaucracy in which the defining functions have been displaced is corrupt; if there is no significant public which had some trust in it to begin with, there has been no betrayal. But again, it is possible for officials of a voluntary or political organization to become corrupted without desiring or achieving any personal benefit, merely by finding it impossible to achieve the purposes of their members and also finding it impossible to confess their failures. And most tragically, it is possible for a man to discover in retrospect, after years of service to an organization, that he had all along been corrupt.[7]

Cases of corruption in technical projects can be quite straightforward: a public contract for a device is sought and procured, on the basis of promised operating characteristics which the contractor has neither the ability nor the intention of achieving, but where the failure of the project will not affect his interests adversely. To protect his interests, the contractor may find it necessary to corrupt the State agencies of control, so that they will merely pretend to

describes the successful campaign in Parliament to defend the privileges of the London water companies against the needs of the population. Even in the early twentieth century Lincoln Steffens found English politicians who denied the existence of corruption in England calmly describing practices which in America are certainly considered corrupt. In trying to explain the differences between Europe and America he invoked the idea of the 'old' and the 'new' civilizations, with 'corruption' as a natural historical process. See *Autobiography*, Part IV, ch. VIII.

[7] The type-case of unwitting corruption is Steffens's Captain Schmittberger, a German immigrant who simply never knew that the policeman's job does *not* include protecting rackets and taking bribes, until the Lexow investigation exposed the truth about the system, to himself. See *Autobiography*, Part II, chs. XII and XIII, pp. 266–84.

scrutinize his operations.[8] The situation is similar in practical projects: the construction of a research empire may be publicly justified by its function in the solution of urgent practical problems, while the effective goals of the project are the provision of jobs, the securing of an academic base, and the production of titles of publications. Even in academic science, the production and publication of shoddy work involves an element of corruption, since both author and referee are participating in a deception, albeit an ambiguous one before a largely anonymous public. Entrepreneurial science is by its very nature corrupt in this sense, and an immature field in a hypertrophic state can scarcely avoid corruption. We notice, however, that as we move away from the straightforward situations where bank-notes are passed in return for favours, the subtlety and ambiguity of corruption become more pronounced. Indeed, it is possible for one person to denounce a project as corrupt, and another indignantly and sincerely to deny it, the disagreement resting on questions of whether there is an interested public, a trust, and a betrayal.

A failure to come to terms with the new problems resulting from the industrialization of science can bring about a very subtle but none the less corrosive form of corruption within science as a whole. For science, as a part of academic scholarship, has long claimed to be discharging a public trust in the advancement and diffusion of knowledge; and it has claimed a variety of privileges and immunities for its members (not shared by other teachers or research workers) on the basis of its ethic of autonomy and integrity. These claims are different in character from those claimed by a learned profession, and in some ways more extreme: a professional is expected to use his judgement in solving the problem set by the welfare of the client, while the scientist or scholar claims the freedom to choose the problem itself. If it were possible to make a neat separation between the sections of the scientific or academic community which are devoted to scientific problems on the one hand, and technical and practical problems on the other, then each section could develop its distinct identity, with appropriate public justification of its position and appropriate methods of social behaviour. But the industrialization of science brings the different sorts of problems into ever closer connection, in institutions and in the work of individuals. There is naturally a great temptation for the leaders of science to attempt to

[8] See Nieburg, *In the Name of Science*, for a discussion of this process.

gain the best of both worlds for as long as possible: to extol the virtues of the free search for truth to one audience, and to promise useful services to another. Except in those happy coincidences when the different criteria of value yield identical choices in a field, such a situation is liable to produce corruption. The most easily identifiable situation with such tendencies is what Americans call 'bootleg' research, where resources obtained for one project are partly, at least, diverted to another of more interest to the investigator. If this is something that 'everyone does' in a particular community, the equivalent of 'fiddling', then it is not corrupting to those involved.[9] On a large scale, however, as in big entrepreneurial science it can have serious consequences.

A more subtle but more dangerous sort of corruption can occur when the balance of real and professed final causes is tipped the other way: when scientists claim the privileges appropriate to the heirs of Helmholtz, while accumulating personal wealth and institutional power through the regular contracting of mission-oriented research. Again, the corrupting effects of such a situation may be latent, until it is exposed and challenged. The natural response is then to hide what can still be hidden and to explain away what cannot. Up to now, such exposures, and their attendant crises, have occurred only in connection with dirty science in American universities. Once the dangers of this situation were recognized, the response of many leaders of the scientific community was admirable. They disengaged from the State in military scientific establishment, doubtless at considerable personal cost, when the Vietnam war became politically and morally indefensible, and even before militant students forced the issue at leading universities. However, such a move, although welcome and heartening in itself, does not resolve the underlying dilemma of the external relations of industrialized science, with its tendency to corruption.[10]

[9] See D. S. Greenberg, '"Bootlegging": it Holds a Firm Place in Conduct of Research', *Science*, 153 (19 September 1966), 848–9. With characteristically American sophistication, some large industrial research laboratories become worried if their scientists work only on the projects formally agreed upon.

[10] Some scientific communities maintain their independence and integrity by astonishingly direct means. In Japan, physicists who associate themselves with the Japan Defence Agency are ostracized by the Japan Physical Society, not being permitted to present papers at its conferences. Military personnel sent to graduate schools by the armed forces are failed on their exams, either on entrance or on completion of their course. In these circumstances, it is not surprising that 'Japanese defence officials have also privately admitted to American colleagues that they have difficulty getting scientists

The State, and industry, need an expertise more sophisticated and prestigious than can be provided by narrowly technical institutions and personnel; it must come from the world of science based on academic institutions.[11] And if it is to continue to receive support on the present large scale, science must provide this service. To do so effectively, in the Anglo-American institutional structure, requires science to maintain a plausible semblance of its autonomy and integrity; yet the autonomy of science cannot be more than a semblance, especially as its accountability to its paymasters becomes increasingly close and obvious. The world of science will then need to half-believe itself to be still academic, free and autonomous, while half-knowing itself to be industrialized, dependent, and responsible to the State and industry. The traditional professed functions of science are internal and under its control: a means to the ultimate goal of the advancement of knowledge, as conceived and guided by itself. But the actual goals of the work are increasingly subordinate to functions that are externally defined: a means to the fostering of civil and military industry, through the provision of particularly applicable results and trained experts, on demand. When and whether this divergence will become a part of the self-consciousness of science, and by whom it could then be considered as a betrayal of a public trust, depends entirely on the complex circumstances of history and society. In this connection, one may revise Lord Acton's aphorism, 'all power corrupts, and absolute power corrupts absolutely', and substitute, 'responsibility tends to corrupt, and responsibility without power corrupts absolutely'.[12]

## *Critical Science: Politics and Philosophy*

We can now permit ourselves some final speculations on possible trends in the future of the natural sciences. The process of industri-

to perform defence research'. See P. M. Boffey, 'Japan (I): On the Threshold of Big Science?', *Science*, 167 (1970), 31–5.

[11] 'Precisely the indiscipline of relatively free intellectual activity attracts the powerful as guaranteeing the relative disinterestedness and novelty they hope to find in the ideas of intellectual counsellors. It is one of the ironies of our time that so many intellectuals strive to identify with the perspectives of kings, whilst their rulers value them for their activity as philosophers.' See N. Birnbaum, 'On the Idea of a Political Avant-garde in Contemporary Politics: the Intellectuals and Technical Intelligentsia', *Praxis* (Zagreb, 1969), Nos. 1–2, p. 243.

[12] This aspect of corruption is discussed in my papers on 'Power, Responsibility, Answerability'. The context there was the problem of participation in university government; but it could be interesting to relate it to the position of scientists responsible to the State described by the American cliché, 'on tap but not on top'.

alization is irreversible; and the innocence of academic science cannot be regained. The resolution of the social problems of science created by its industrialization will depend very strongly on the particular circumstances and traditions of each field in each nation. Where morale and effective leadership can be maintained under the new conditions, we may see entire fields adjusting successfully to them, and producing work which is both worthwhile as science and useful as a contribution to technology. Recruits to this sort of science will see it as a career only marginally different from any other open to them; and it is not impossible for men of ability and integrity to rise to leadership in such an environment. This thoroughly industrialized science will necessarily become the major part of the scientific enterprise, sharing resources with a few high-prestige fields of 'undirected' research, and allowing some crumbs for the remnants of small-scale individual research. A frank recognition of this situation will help in the solution of the problems of decision and control. Since the criteria of assessment of quality will be heavily biased towards possible technical functions of results, they will thereby be more easily applied, and less subject to abuse, than those which are based on the imponderable 'internal' components of value.

Thus, provided that the crises in recruitment and morale do not lead to the degeneration and corruption of whole fields, we can expect emergence of a stable, thoroughly industrialized natural science, responsible to society at large through its contribution to the solution of the technical problems set by industry and the State. Scientists, and their leaders and institutions, will be 'tame': accepting their dependence and their responsibilities, they will be unlikely to engage in, or encourage, public criticisms of the policies of those institutions that support their research and employ their graduates. Such a policy of prudence is not necessarily corruption; whether it becomes so will depend on many subtle factors in the self-consciousness of this new sort of science, and the claims made to its audiences. But not all the members of any group are easily tamed, and the emergence of a 'critical science', as a self-conscious and coherent force, is one of the most significant and hopeful developments of the present period.

There have always been natural scientists concerned with the sufferings of humanity; but with very few exceptions they have faced the alternatives of doing irrelevant academic research to gain the leisure and freedom for their social campaigns, or doing applied research which could benefit humanity only if it first produced profits for their industrial employer. The results of pharmaceutical research must pass through the cash nexus of that industry before being applied, and that process may be an unsavoury one. Only in the fields related to 'social medicine' could genuine scientific research make a direct contribution to the solution of practical problems, of protecting the health and welfare of an otherwise defenceless public. Now, however, the threats to human welfare and survival made by the runaway technology of the present provide opportunities for such beneficial research in a wide range of fields; and the problems there are as difficult and challenging as any in academic science. These new problems do more than provide opportunities for scientific research with humanitarian functions. For the response to this peril is rapidly creating a new sort of science: critical science. Instead of isolated individuals sacrificing their leisure and interrupting their regular research for engagement in practical problems, we now see the emergence of scientific schools of a new sort. In them, collaborative research of the highest quality is done, as part of practical projects involving the discovery, analysis and criticism of the different sorts of damage inflicted on man and nature by runaway technology, followed by their public exposure and campaigns for their abolition. The honour of creating the first school of 'critical science' belongs to Professor Barry Commoner and his colleagues at Washington University, St. Louis, together with the Committee for Environmental Information which publishes *Environment*.[13] For some years a Society for Social Responsibility in Science, based in America but with members and branches overseas, was the main voice of conscience in science; recently a British Society for Social Responsibility in Science, with a rather broader base among the leaders of the national scientific community, has been formed. As such societies gain strength and influence, the success of the St. Louis school of critical science should soon be emulated elsewhere.

The problem-situations which critical science investigates are not the result of deliberate attempts to poison the environment. But they result from practices whose correction will involve inconvenience and money cost; and the interests involved may be those of powerful groups of firms, or agencies of the State itself. The work

[13] The first statement of 'critical science' as distinct from ecological concern is B. Commoner, *Science and Survival* (Gollancz, London, 1966).

of enquiry is largely futile unless it is followed up by exposure and campaigning; and hence critical science is inevitably and essentially political.[14] Its style of politics is not that of the modern mass movements or even that of 'pressure groups' representing a particular constituency with a distinct set of interests; it is more like the politics of the Enlightenment, where a small minority uses reason, argument, and a mixture of political tactics to arouse a public concern on matters of human welfare.[15] The opponents of critical science will usually be bureaucratic institutions which try to remain faceless, pushing their tame experts, and hired advocates and image-projectors, into the line of battle; although occasionally a very distinguished man is exposed as more irresponsible than he would care to admit.[16]

In the struggles for the exposure and correction of practices damaging the environment the role of the State is ambiguous. On the one hand, every modern government is committed in principle to the protection of the health of its people and the conservation of its natural resources. But many of the agencies committing the worst outrages are State institutions, especially the military; and in any event the powerful interests which derive profit or convenience from polluting and degrading the environment have more political and economic power than a scattering of 'conservationists'. It sometimes occurs that two State agencies will be on opposite sides of an environmental struggle; but the natural tendency of regulatory agencies to come under the control of those they are supposed to regulate can make such a struggle a one-sided affair.

The presence of an effective critical science is naturally an embarrassment to the leadership of the responsible, industrialized,

[14] The most comprehensive analysis of 'critical science' yet published is Max Nicholson. *The Environmental Revolution* (Hodder & Stoughton, London, 1970). He is mainly concerned with 'conservation', but his healthy approach to modern bureaucratic politics is developed in his earlier book, *The System* (Hodder & Stoughton, London, 1967; McGraw-Hill, 1969).

[15] Support for this new style of politics has come from the Duke of Edinburgh. Speaking on the B.B.C. programme '24 Hours', on 17 February 1970, he discussed the proposition that 'tough action against the poisoners and wreckers' was essential for the promotion of conservation and the abatement of pollution, and said that people must 'be ruder and more direct to the people in political authority'.

[16] On 22 March 1966, for example, the President of General Motors appeared before a Senate hearing to apologize to Mr. Ralph Nader, following revelations that General Motors' lawyers had hired an investigator to unearth details about Nader's private life. Nader's analysis of the defects of the 'Corvair' car was costing General Motors a lot of money.

tame scientific establishment.[17] Their natural (and sincere) reaction is to accuse the critics of being negative and irresponsible; and their defensive slogan is along the lines of 'technology creates problems, which technology can solve'. This is not strictly true in all cases, since nothing will solve the problems of the children already killed or deformed by radioactive fallout or by the drug Thalidomide.[18] Moreover, this claim carries the implication that 'technology' is an autonomous and self-correcting process. This is patent nonsense. We have already seen that a new device is produced and diffused only if it performs certain functions whereby human purposes can be served; and if the intended beneficiaries do not appreciate its use, or if those injured by its working can stop it, the device will be still-born. The distortions of technological development arise when the only effective 'purposes' in the situation are those of the people who believe themselves to derive pure benefit from the innovation. On the self-correcting tendency of technology, one might argue that no large and responsible institution would continue harmful practices once they had been recognized; but this generalization is analogous to the traditional denial of the cruelty of slavery, along the lines that no sensible man would maltreat such valuable pieces of property. And the history of the struggles for public health and against pollution, from their inception to the present, shows that the guilty institutions and groups of people will usually fight by every means available to prevent their immediate interests being sacrificed to some impalpable public benefit.[19] If the campaigns waged by critical science come to touch on some issue central to the convenience of the State or other very powerful institutions, we may experience a polarization of the community of natural science, along the same lines as has already occurred on the Vietnam issue in some of the human sciences in America. In such a situation, it will

[17] Thus *Nature* ridiculed the UNESCO conference on the biosphere of September 1968, comparing it to an earlier conference on 'communications satellites and under-developed countries'. See 'Bandwagon for UNESCO', *Nature*, 219 (7 September 1968), p. 999. There was no report on the conference itself.

[18] Up to the time of writing, *Nature* maintains a magnificent complacency, such as one hardly hopes to see in England in its epoch of imperial decline. Thus, criticizing Dr. Fraser Darling's first Reith Lecture, an editorial asserts, 'And in spite of quite proper concern for the need to make only decent use of new developments, it is hard to find contemporary illustrations of where technology has gone astray.' 'No Peace for the Wicked', *Nature*, 224 (1969), 631.

[19] The 'sanitary movement' in nineteenth-century England was involved in such struggles through its career. For a sample, see R. A. Lewis, *Edwin Chadwick and the Public Health Movement 1832-54* (Longmans, Green, 1952).

not be possible for a leader of science to be both honest and tame; and if the establishment of science chooses to serve its paymasters rather than truth, it will be recognizably corrupt.

Such extreme situations may be a long time in developing, if for nothing else than that critical science is still in its infancy. As it develops, it will be at risk of encountering many pitfalls, partly those characteristic of immature sciences applied to practical problems, and partly those of radical and reforming political movements. Perhaps the most obvious will be an accretion of cranks and congenital rebels, whose reforming zeal is not matched by their scientific skill. But there are others, arising from the contradictory relations between critical science and the relevant established institutions of society. As true intellectuals rather than a technical intelligentsia, individual members may find some 'sinecures within the interstices of bureaucratized intellectual systems';[20] but there will need to be some institutions providing a home for the nucleus of each school, and external sources of funds for research. Hence, especially as critical science grows in size and influence and society becomes more sophisticated about the problems of runaway technology, some accommodation between the critics and the criticized will inevitably develop. We can even expect to see critical research being supported, critical slogans being echoed, and leaders of critical science being rewarded, by institutions whose basic destructive policies still are unchanged.[21] Such phenomena have already occurred in America, in the politics of race; and on this issue, where the interests concerned are mainly major institutions which can hire talented and enlightened experts at will, it is even more likely. The movement of critical science would then face the pitfalls of corruption as soon as, or even before, it had skirted those of impotence.[22] But this is only a natural process, characteristic of

[20] '. . . the intellectuals' distance from certain kinds of material activity, their occupational repugnance for certain forms of bourgeois organizations, their attachment to abstract versions of bourgeois tradition rather than to the sub-stratum of bourgeois activity, their familiar quest for sinecures within the interstices of bureaucratized intellectual systems, combine to endow them with what was once an anticapitalist and is now an anti-bureaucratic ethos.' See N. Birnbaum, op. cit., p. 244.

[21] First prize in the 'enlightenment' stakes has been won by the Monsanto Chemical Company. The Scientific Division of the Committee for Environmental Information (which publishes *Environment*) included among its members for 1969 Mr. F. D. Wharton, Jr., St. Louis Development Manager, Life Sciences in the New Enterprise Division, Monsanto Company.

[22] On the corruption of good causes, the classic is G. B. Shaw, *Major Barbara*. The climax of the play comes when Mrs. Baines, the Salvation Army Commissioner who

all radical movements. It is easy to maintain one's integrity when one's words and actions are ineffective; but a long period of this can produce a sectarian or a crank. If one begins to achieve power, and one's policies affect the interests of many others, one must decide where one's responsibility lies. If it is to the ideal alone, then one is set on a course towards tyranny, until overthrown by the host of enemies one has raised up.[23] And if one accepts responsibility for the maintenance of a general welfare, including that of one's opponents, one is on the path to corruption and impotence. This may seem a gloomy prognosis; but a society which does not present such hazards to radical movements of every sort is not likely to retain its stability.

We can expect, then, that the future political history of critical science will be as complex and perhaps as tortured as that of any successful radical and reforming movement. But if it does survive the pitfalls of maturation, and so contributes to the survival of our species, it can also make a very important contribution to the development of science itself. For if the style of critical science, imposed by the very nature of its problems, becomes incorporated into a coherent philosophy of science, it will provide the basis for a transformation of scientific inquiry as

runs the shelter in West Ham, thanks God for the donation of £5,000 by Mr. Bodger, the distiller whose whiskey is the curse of the poor in their care. The Cockney Bill Walker, whose donation of a guinea in repentance for striking two women had just previously been indignantly rejected, utters the significant 'Wot prawce selvytion nah?' (Penguin Books, 1960; p. 106.) See also Shaw's Preface to the play.

[23] A cautionary tale that should be read by all who are embarking on political activism based on 'critical science' is the play by Ibsen, *The Enemy of the People*. Superficially, it is about an honest doctor who is hated by the corrupt forces of his town for his determination to expose the scandal of polluted waters being used in the town's profitable baths. But on closer reading, it can be seen that Dr. Stockmann's misfortunes were also due to his own naïvété and egoism. It is significant that in his own version of the play (Viking Press, New York, 1951), Arthur Miller strengthened the 'progressive' message by transferring the passage where the public meeting declares Dr. Stockmann to be 'an enemy of the people'. In his version it comes at the very beginning of the meeting, before he has spoken; while in the original it comes after the Doctor's harangue, concluding with, 'Let the whole country perish, let all these people be exterminated.' After studying the play with a class at Harvard, where this modification was discovered, it struck me that a worthwhile sequel could be written, entitled 'The People's Friend', in which the entrenched forces, if only a bit less stupid and venal than in the original, could corrupt the good Doctor without difficulty. Although Spa resorts are no longer an important focus of pollution, it is possible for an 'Enemy of the People' situation to be repeated in any of the seaside towns which dump their raw sewage into proximity to bathers. See J. A. Wakefield, 'Clean or Dirty Beaches—Which do you Prefer?' *Your Environment*, No. 1 (Winter 1969), pp. 29–31.

deep as that which occurred in early modern Europe. The problems, the methods, and the objects of inquiry of a matured and coherent critical science will be very different from those of academic science or technology as they have developed up to now; and together they can provide a practical foundation for a new conception of humanity in its relations with itself and the rest of nature.

The work of inquiry in critical science involves an awareness of craft skills at all levels, and the conscious effort of mastering new skills. The data itself is obtained in a great variety of ways, from the laboratory, from the field, and from searching through a varied literature, not all of it in the public domain. Much of it lacks soundness, and all of it requires sophisticated and imaginative treatment before it can function as information. Indeed, since the problem-situations are presented in the environment, and much of the crucial data must be produced under controlled conditions in the laboratory, work in critical science may overcome the dichotomy between field-work and lab-work which has developed in science, even in the biological fields, over the past century. In the later phases of investigations of problems, the same challenges of variety and novelty will always be present. The establishment of the strength and fit of each particular piece of evidence is a problem in itself; and the objects of inquiry (including the measures of various effects and processes, as well as conventional standards of acceptability in practice) are so patently artificial, that one is in little danger of being encased in them as a world of common sense. The establishment of criteria of adequacy for solved problems is possible, for the work will frequently be an extension and combination of established fields for new problems, and so critical science can escape the worst perils of immaturity. Also, any critical publication is bound to be scrutinized severely by experts on the other side, so high standards of adequacy are required because of the political context of the work. Indeed, a completely solved problem in critical science is more demanding than in either pure science or technology. In the former, it is usually sufficient to obtain a conclusion about those properties of the artificial objects of inquiry which can be derived from data obtained in the controlled conditions of experiment; in the latter it is sufficient for an artificial device to perform its functions without undue disturbance by its natural environment; while here the complex webs of causation between and within the artificial and natural systems must be understood sufficiently so that their harmony can be maintained.

The social aspects of inquiry in critical science are also conducive to the maintenance of its health and vitality, at least until such times as the response to its challenge becomes over-sophisticated. The ultimate purpose which governs the work is the protection of the welfare of humanity as a part of nature; and this is neither remote, nor vulgar. Critical science cannot be a permanent home for careerists and entrepreneurs of the ordinary sort; although it may well use the services of bright young men intending eventually to serve as enlightened experts. Those who want safe, routine work for the achievement of eminence by accumulation will not find its atmosphere congenial; for its inquiries are set by a succession of problem-situations, each presenting new challenges and difficulties. Hence although critical science will doubtless experience its periods of turbulence, political and scientific, it is well protected from stagnation and from the sort of creeping corruption that can easily come to afflict industrialized science.

Finally, the objects of inquiry of critical science will inevitably become different from those of traditional pure science or technology, for here the relation of the scientist to the external world is so fundamentally different. In traditional pure mathematical-experimental natural science, the external world is a passive object to be analysed, and only the more simple and abstract properties of the things and events are capable of study. In technology, the reactions of the uncontrolled real world on a constructed device must be taken into account, but only as perturbations of an ideal system; the task is to manipulate it or to shield the device from its effects. But when the problem is to achieve a harmonious interaction between man and nature, the real world must be treated with respect: both as a complex and subtle system in its own right, and as a heritage of which we are temporary stewards for future generations. Hence, even though studies of our interaction with the environment will necessarily use all the intellectually constructed apparatus of disciplined inquiry, their status and their content will inevitably be modified. They will be more easily recognized as imperfect tools, with which we attempt to live in harmony with the real world around us; and although this attitude may seem to conduce to scepticism, it will be the healthy one which recognizes that genuine knowledge arises from lengthy social experience, and that such knowledge depends for its existence on the continued survival of our civilization. The objects of inquiry themselves will include final causes among their essential attributes, not merely the limited functions appropriate to technology, but also the judgements of fitness and success already developed in classical biology and ecology. All this is work for the future; but if it is successful, the opposition between scientific knowledge and human concerns, characteristic of the sciences derived from the dehumanized natural philosophy of the seventeenth century, will be overcome.

With a new conception of the practice of science, there will come a new conception of the history of science and of the meaning of the scientific endeavour. It is possible, and it has been natural, to reconstruct the history of scientific inquiry as a success-story leading up to the triumph of the matured academic mathematical-experimental natural science of the later nineteenth century. One can identify the historical moments, and the great men associated with them, when the very conception of the inquiry itself was significantly advanced. Thus, the origins of our sort of science are rightly located in the earlier Greek civilization, when attempts were made to account for the world of sense experience without invoking personified divine agents. The heritage of the so-called 'pre-Socratic' philosophers was further developed by Aristotle, who not merely conducted disciplined inquiries over almost all areas of human experience, but also showed that such disciplined inquiry has conceptual and methodological problems that can and should be investigated. In a parallel tradition, the idea of mathematics as a body of proved results about conceptual objects developed to full maturity in the achievements of Euclid and Archimedes. The next great advance (according to this interpretation) came many centuries later, when the pioneers of the 'mechanical philosophy' of the seventeenth century achieved a powerful synthesis of experience and reason. Galileo's slogan, 'sense experience and necessary demonstration', stood for his appreciation of the need for closely controlled experience, which could serve as evidence of the appropriate strength, in an argument cast in mathematical language. All that was required to complete the body of methods of classic academic science was the development of institutions for organized, co-operative research; and this came by natural evolution through the nineteenth century. The dominant world-view of matured academic science was atomistic in several important senses. The real world underlying our sense experience was assumed to be devoid of the characteristically human attributes of intellectual and spiritual reality, and of value; final causes were excluded from scientific explanation; and all efficient causes were to be reduced to the material cause of insensibly small brute matter in motion. Correspondingly, knowledge itself was atomic: the achievement of individual facts about the external world, isolated from any philosophical and social context, was considered possible and valuable. This approach to natural knowledge achieved magnificent successes in many fields, and was also appropriate for the development of successful large-scale research.

It was natural to suppose that this particular style of scientific enquiry could be successfully extended to all disciplimes, and that it was internally stable. But both these optimistic assumptions proved incorrect. Ineffective and immature fields can be hindered rather than helped by a mechanical imitation of those whose objects and appropriate methods are very different; and the pretence of this sort of maturity only adds to the hazards of applying such fields to practical problems. On the other hand, academic natural science has been transformed by its very successes into industrialized science; and the unexpected problems and abuses of this new sort of science, ranging from shoddy science to runaway technology, present threats to the survival of science and of our whole civilization.

With the new perspective gained from our recent experience, we can look again at the long history of the human endeavour of understanding and controlling the external world. We can now see a positive significance in events and tendencies that have hitherto been considered as unfortunate aberrations. The dominant traditions in academic science have developed out of conflict with other styles of scientific work; and it can be distinguished from them by its objects of inquiry, its methods of work, and its social context. For 'our' science, the real world is devoid of human and spiritual qualities; and the scientist studies the smaller aggregations of matter, considering the most simple and mathematical properties that suffice for the successful investigation of problems. Its approach to its materials is appropriately depersonalized; any 'deeper' meaning that might be thought to inhere in its results is rigidly segregated from his reporting, and is left to amateur speculations. As a social activity, this science is necessarily élitist, presupposing a lengthy course of training and indoctrination for which only a minority have an appropriate cultural background.

To the extent that the traditional history of science has considered these aspects of scientific inquiry, it has been embarrassed by the presence of traditions and tendencies that achieved success in 'our' terms in spite of radical differences in one or more respects from the recently dominant academic style. The roots of astronomy in astrology, and of chemistry in alchemy, are cases in point. Some of the immortal ancestor-figures of the modern discipline are revealed, on unbiassed inspection, to have seen their work as contributing to what is now regarded as pseudo-science: Ptolemy and Tycho for astronomy, and Paracelsus and Glauber for chemistry. Indeed, when we look more closely at the period of the later sixteenth century, when the arts and sciences were developing quite rapidly *before* the incursion of the 'new philosophy' of dead matter, we find the very greatest scientists participating in the world-view of an animated nature: Gilbert investigating magnetism in the attempt to prove that the earth is the embodiment of the *anima mundi*, Kepler searching (with all rigour) for the divine harmonies of the celestial realm, and Harvey using 'spirit' and the macrocosm-microcosm analogy to guide his anatomical and physiological researches.[24]

It would be very misleading to imagine a simple succession of two sorts of science, each unified and coherent in itself, first that of the 'animated' world and then (since the seventeenth century) that of the 'dehumanized and disenchanted' world. History is more complex, and more interesting, than that; and within the 'old' conception of science there were many different tendencies in the interpretation of its appropriate objects, methods and social functions. I have previously referred to a 'romantic' philosophy of nature providing the vehicle for a politically radical folk-science that challenges the academic science of its time. In this tradition, the study of nature is explicitly seen as a social and also spiritual act; one dialogues rather than analyses; and there is no protective cover of belief in the 'neutrality' or 'objectivity' of the style adopted. Such a philosophy of nature will become articulated and advanced, as part of a general radical reaction against a formal, dry or bureaucratic style pervading social or cultural life. Looking back into history, we can find a similarity of doctrine or style, and sometimes a linking tradition, as

[24] Gilbert makes his programme plain; see *de Magnete* Book V, ch. 12: 'The magnetic force is animate, or imitates a soul; in many respects it surpasses the human soul while that is united to an organic body.' (tr. P. F. Mottelay; Dover, New York, 1958, p. 308.) Kepler is well-known; and for Harvey, see W. Pagel, *William Harvey's Biological Ideas* (Basel and New York, 1967).

far back as the Taoists of ancient China, through St. Francis of Assisi, to Paracelsus, William Blake, and Herbert Marcuse.[25]

Not every one of these figures would claim to be a natural scientist of any description; but as philosophers, poets or prophets, they must be recognized as participating in and shaping a tradition of a certain perception of nature and its relation to man. Granted all the variety of their messages and styles, certain themes recur. One is the 'romantic' striving for immediacy, of contact with the living things themselves rather than with book-learned descriptions. Another is 'philanthropy'; the quest is not for a private realization, but for the benefit of all men and nature. And, related to these is a radical criticism of existing institutions, their rules and their personnel. Looked at from the outside, each upward thrust of the romantic philosophy of nature is doomed to failure. Mankind will not be transfigured overnight; and the romantic style has its own destructive contradictions. Whereas the 'classic' style degenerates gradually into an ossified form and a sterile content, the 'romantic' style goes off much more quickly, through chaos of form and corruption of content. But this study of ours has shown that even in disciplined scientific inquiry, the categories of 'success' and 'failure' are neither so absolutely opposed, nor so assuredly assignable in particular cases, as the traditional ideology of science assumed. And the failure to achieve Utopian dreams, in science as well as in social reform, is not at all the same thing as futility.

The dreams of the romantic, philanthropic, radical philosopher-prophets cannot move towards realization by the accumulation of facts or of battalions. Rather, they exist through a discontinuous, perhaps erratic, series of crises and responses. Sometimes they have the good fortune of producing a creative tension in a man brave enough to attempt the synthesis of a prophet's vision with a world

[25] On Taoism, see J. Needham, *Science and Civilisation in China*, 2, 88–132. In his magisterial fashion, Needham provides more materials on the analogous movements in early modern Europe than is available in any general history of science. For a discussion of the limitations of his view, see note 35 on p. 394 above. See Lynn White, Jr., 'The Historical Roots of our Ecological Crisis', *Machine ex Deo* (M.I.T. Press, 1968), Chapter 5, for St. Francis.

Francis A. Yates, in 'The Hermetic Tradition in Renaissance Science' in *Art, Science and History in the Renaissance*, ed. C. S. Singleton (John Hopkins Press, Baltimore, 1968), discusses the 'Rosicrucian' style of science in considerable depth. The theme of 'philanthropy' is most clearly developed in the German alchemical philosophers in the Paracelsian tradition; and their influence on Francis Bacon is clear.

On Marcuse, see his *One-Dimensional Man* (Beacon Press, Boston, 1964).

managed by priests. He too will fail, almost certainly; some problems are insoluble. But his message, perhaps in a particular science or walk of life, perhaps of a generalized wisdom, will speak to men in later ages, coming alive whenever it has insights to offer. In this present period, we may find Francis Bacon speaking to us more than Descartes the metaphysician-geometer or Galileo the engineer-cosmologist. As deeply as any of his pietistic, alchemical forerunners, he felt the love of God's creation, the pity for the sufferings of man, and the striving for innocence, humility, and charity; and he recognized vanity as the deadliest of sins.[26] To this last he ascribed the evil state of the arts and sciences:

> For we copy the sin of our first parents while we suffer for it. They wished to be like God, but their posterity wish to be even greater. For we create worlds, we direct and domineer over nature, we will have it that all things *are* as in our folly we think they should be, not as seems fittest to the Divine wisdom, or as they are found to be in fact.[27]

The punishment for all this, as Bacon saw it, was ignorance and impotence. It might seem that the problem is different now, for we have so much scientific knowledge and merely face the task of applying it for good rather than evil. But Bacon assumed his readers to believe themselves in possession of great knowledge; and much of his writing was devoted to disabusing them of this illusion. Perhaps the daily reports of 'insufficient knowledge' of the effects of this or that aspect of the rape of the earth, and our sense of insufficient understanding of what our social and spiritual crises are all about, indicate that in spite of the magnificent edifice of genuine scientific knowledge bequeathed to us, we are only at the beginning of learning the things, and the ways, necessary for the human life.

Bacon was a shrewd man, fully sensitive to the weaknesses of the human intellect and spirit. He was aware of the superficiality of ordinary thought and discourse, at whatever educational level; and he also distrusted the extraordinary enthusiast, in religion or politics, for the damage he could cause. His life's endeavour was to overcome

[26] For a detailed interpretation of Bacon's programme for science in terms of a vision of moral and spiritual reform, see J. R. Ravetz, 'Francis Bacon and the Reform of Philosophy', in *Science, Medicine and Society in the Renaissance* (Walter Pagel Festschrift), ed. A. Debus (University of Chicago Press and Oldbourne Press, London, 1972). This is an elaboration of certain themes in Benjamin Farrington's, *The Philosophy of Francis Bacon*, and I am indebted to him for my first insights into this aspect of Bacon.

[27] See *The Natural and Experimental History for the Foundation of Philosophy* (*Works*, vol. v; translation p. 132).

this contradiction somehow, and to bring about a true and effective reformation in the arts and sciences of nature. For him, this was a holy work, a work of practical charity inseparable from spiritual redemption.[28] His audience was inevitably among the literate; and so he tried, by scattering hints and half-concealed invitations, to call together his brothers, who would gently and silently show by their example that a good and pure way into Nature is also the practically effective way. Of course he failed, in his philosophical reform as in his political career. There was no English audience for his particular message during his lifetime, and at his death he was alone and neglected.

Shortly after his death, however, there was a stirring; and Bacon's message of 'philanthropic' science began a career of its own. For a while, his followers knew what he was about; but with the passage of decades and disillusion, this was forgotten, and only the vulgar fact-finding Bácon survived. Yet when we now come back to read Bacon, perplexed and worried as we are by the sudden transformation that science has wrought upon itself as well as upon the world, we can find relevance in passages like the following:

> Lastly, I would address one general admonition to all; that they consider what are the true ends of knowledge, and that they seek it not either for pleasure of mind, or for contention, or for superiority to others, or for profit, or fame, or power, or any of these inferior things; but for the benefit and use of life; and that they perfect and govern it in charity. For it was from lust of power that the angels fell, from lust of knowledge that men fell; but of charity there can be no excess, neither did angel or man ever come in danger by it.[30]

[28] See the *Meditationes Sacrae* (*Works*, vol. vii; translation pp. 243–4). Bacon contrasts the miracles of punishment wrought by the prophets of the Old Testament, with those of Jesus: 'Jesus was the Lamb of God, without wrath or judgment. All his miracles were for the benefit of the human body, his doctrine for the benefit of the human soul.' After a list of instances, Bacon comments, 'There was no miracle of judgment, but all of mercy, and all upon the human body.' Later, in the essay 'Of Hypocrites', he comments, 'The way to convict a hypocrite therefore is to send him from the works of sacrifice, to the works of mercy. Whence the text: *Pure religion and undefiled before God and the Father is this, to visit the orphans and widows in their affliction . . .*' (p. 249).

[29] On the influence of Bacon, see Charles Webster, *Samuel Hartlib and the Advancement of Learning* (Cambridge University Press, 1970).

[30] Bacon, *The Great Instauration, Preface* (*Works*, vol. iv; translation pp. 20–21).