GOAL DIRECTION OF SCIENTIFIC RESEARCH

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1. Introduction

That science, both as an institution and a body of knowledge, is neither invariant nor homogeneous is by now widely accepted. Thus Ravetz (1) has argued that three distinct varieties of science have been historically perceived and have been associated with particular interest groups:

(i) 'Pure, academic science' which was based on an ideology derived from nineteenth-century German universities:

> Here science is totally inward looking, its only offerings to the outside world are general contributions to knowledge and culture, unpredictable technological applications, and the example of its endeavour (2).

(ii) 'Ideologically engaged science', which is considered a bearer of truth and reason, standing against dogma, superstition and oppression, and a weapon in the struggle against a variety of material and spiritual ills:

> By its very nature science could not produce either error or evil, and so it had a privileged position among all sorts of ideologically engaged activities (3).

(iii) 'Useful Science' where 'the results and methods of science are applied directly to technical and practical problems; and those external tasks provide stimuli, goals and partial justification for scientific work' (4).

There is considerable evidence that it is the last of these which is most appropriate as a description of contemporary 'science'. Research has become concentrated in industrial and government laboratories (5), where the demands for profit and growth and accountability, respectively, require that the research be directed, at least in the long term and more

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often in the short term, to practical ends. Furthermore, it is directed primarily towards the general objectives of economic development and national security (6).

This orientation towards 'useful science' has had a considerable effect on the status and self-images of those engaged in scientific research, whether they call themselves scientists, research workers or technicians. The growth of unionisation among scientific workers (7), reflecting an increased awareness of their loss of status can be seen as a response to the directed nature of modern research. Furthermore, this direction is not restricted to the environment of government or industrial laboratories, as shown by the organisational constraints operating in 'big science' institutions such as CERN (8).

In spite of the evidence that research has become a much more highly controlled and directed activity, academic scientists and in particular the elite who represent the scientific community in negotiation with the paymasters and political interests, continue to project the image of science as autonomous and apolitical, concerned solely with the objective pursuit of truth, i.e., as 'pure academic science'. A clear illustration of the solidarity with which this position is held is provided by the response of British scientists to the Rothschild reorganisation (9). Such a view can be considered a self-serving ideology, protecting the interests of scientists from external control (10):

> The theory that scientists follow only the internal rules of science would seem to reinforce their efforts to prevent the subordination of their work to standards extrinsic to science and to protect themselves from external political influence (11).

We would wish to argue that the continuation of this misleading view of science represents a dangerous mystification which can serve only to obscure the role of science in modern society, confuse the scientist and science administrator, and alienate the public.

The extent to which this protective self-image has influenced the study of science and its institutions has been shown by the pervasiveness of the analytical dichotomy between 'internalist' and 'externalist' explanations which reinforces the notion of science as a social system separated from, but occasionally influenced by, other social forces (12). It is also evident in the concentration of studies on precisely that small sector which most nearly approximates this model – that of academic, university-based, 'pure' research (13).

This disjunction between 'pure' and 'useful' models of science is reflected in the conceptual distinction between 'pure' and 'applied' science (14) which has provided the basis for most attempts to relate scientific knowledge to socio-economic objectives. In this model, certain 'pure' kinds of research involve the objective pursuit of truth, and should be conducted in entirely autonomous fashion, i.e., according to the regulatives of science only. Other 'applied' research is directed to the achievement of specific and practical objectives and may therefore be expected to be administered and held accountable, in more or less the same way as any other production or social function (15).

The establishment and subsequent growth of science policy, with its emphasis on mechanisms for evaluating claims for research support, and the form of institution most suitable to administer research funds, reflected a concern to more efficiently direct science to desired ends (16). However, once again the self-image of science appears to have been accepted:

> The underlying model for science policy organisation is based on the transaction concept drawn from political science; its aim is the establishment of effective institutionalised transaction processes between an independent science institution and society, via society's representatives in government. In this model there is no mechanism permitting society's interest to operate on the scientific institution, and analysis, planning and one might add, responsibility, is limited to the areas of *application* of scientific knowledge (17).

Blume (18) has argued for the establishment of a political sociology of science directed towards the explanation of the contemporary politically directed, occupationally differentiated and institutionally disparate form of science, but as yet there has been little direct response to this challenge. There is, of course, a well established Marxist tradition of relating science to social needs which can be traced back to Hessen (19) and has included within its ranks such notables as J. D. Bernal (20) and Joseph Needham (21), but its major contemporary expression is in detailed historical studies of the way in which particular scientific theories reflect the socio-economic and cultural context (22).

One promising development has been the work of the project group 'Alternativen in der Wissenschaft' at the Max-Planck-Institut, Starnberg, and Weingart at Bielefeld, who have attempted to develop the concept of 'finalisation' to establish theoretically the conditions for effective direction of scientific knowledge towards politically determined goals (23). This approach has been developed over the past five years and in the most recent paper (24) takes the form of a sophisticated and fruitful model for the formation and transformation of research objectives, and the limitations placed on the achievement of such objectives by the state of development of relevant knowledge fields.

However, although the supporting case studies consider a range of specialties (25), we wish to argue that 'finalisation' represents only one extreme, and rather unusual type of externally directed science, taking as its implicit model the U.S. crash programmes to land a man on the moon (the Apollo project) and to find a cure for cancer (the 'cancer moonshot'). There may be a very wide spectrum of goal-orientation within science, ranging from the directly politically motivated programme to a much more general and pervasive shaping of cognitive goals in accord with social or economic needs.

Thus there is a need to develop a more general analysis of the establishment and operation of goals both within the scientific community and between it and its paymasters. Such an analysis should take account of the fact that scientists are themselves involved in the process of goal formation, and that it is determined, at least in part, by the state of knowledge perceived or claimed to be relevant. Furthermore goals, at least at an operational level, may be in a state of continual transition and redefinition. Such an analysis of the function of goals in science is seen as part of a programme to develop a flexible theory of mediation between socio-economic and cognitive aspects of the social reality which constitutes and conditions science. Previous papers have explored the need for a contextual model of scientific development (26) and the roles of occupational and cognitive differentiation in shaping the knowledge structure (27).

2. The Common-Sense Notion of Goals for Scientific Research

All scientific work can be regarded as goal-directed, at least in the sense of Habermas (28) who argues that all work is 'purposive rational action', in that it is either instrumental action, or rational choice, or their conjunction. Thus,

> science is oriented towards goals which may be directly or indirectly perceived, which are expressed at varying levels of generality, which are developed and transformed by social processes and which are dynamically linked to scientific practice and the state of knowledge in such a way that the goals and science are only analytically separable (29).

However, the fact that *all* action is directed to goals would appear to have led students of science to treat goals as a common-sense phenomenon. As a consequence the 'low-level' goal of problem-solution has been the primary focus of investigation, and other levels or kinds of goals which may shape the research process have been neglected. Moreoever, the existence of 'problems' has been taken for granted; in the positivist model of science, problems are posed by the external reality. It is only with the development of the post-Kuhnian sociology of scientific knowledge that the perception of a scientific problem has been considered in need of sociological explanation. Furthermore, the acceptance of goals as a common-sense phenomenon has entailed a common-sense relationship between goals and the means used in the attempts to realise them. Consequently the relationship between means and goals (or ends) has not been an issue in science studies. The dominant approach has been a functionalist analysis of the evolutionary movement of means towards 'immaculately conceived' goals.

The analysis of goals by sociologists, at least in the sense used in this paper, has in general been quite limited, with the marked exception of organisation theorists. Within this literature, there are a number of distinct traditions, including of relevance to this paper, studies of the range of goals pursued by industrial firms, the evolution of goals within organisations, and means of changing goals in normative institutions (30). We will draw on some of these concepts in subsequent arguments.

As already noted references to goals within science are in general sparse, or made, in passing, as part of a more general anslysis. Thus Merton (31) sees the goal of science as 'the rational pursuit of truth'. For Sklair (32), 'the charter or purpose of science' is of three types *viz.*, the quest for knowledge for its own sake, for alleviating human suffering and satisfying the needs of mankind, or to provide an economically rewarding career. Richter suggests:

> The goal of science, as commonly recognised today, involves the acquisition of systematic, generalised knowledge concerning the natural world; knowledge which helps man to understand nature, to predict natural events and to control natural forces (33).

Ravetz has made a considerable effort to clarify the notion of goal by developing a hierarchy of 'final causes' that determines the goals of the research task. He distinguishes between goal, function and purpose:

> the task itself has a goal, which is conditioned more or less strictly by the function which will be performed by the result of the accomplished task; and this in turn is governed by the ultimate human purposes which are expected to be served by the performance of that function (34).

The goal is the solution of the research problem.

The most detailed analysis of goal-direction in science is offered by Hagstrom (35) but in general the concept is used in a common-sense way to explain structural change, the role of fashion and the processes of disciplinary differentiation and social control. Thus, although Hagstrom observes that:

> Segmentation begins with cultural change, the appearance of new goals in the scientific community. Of course, new goals do not spontaneously appear: scientists actively seek them (36),

he provides few indications of the origin of the goals and continues by examining the way scientists respond to cultural change once it has occurred. The uncritical use of the concept is highlighted by the conflation of 'goals' with 'problems'. Thus, the above quotation continues,

> Those who discover important problems upon which few others are engaged are less likely to be anticipated and more likely to be rewarded with recognition (37).

Where do these goals come from, and how are they formed? Hagstrom, adhering to the internal/external demarcation, distinguishes between goals arising inside and outside science:

When the relative importance of goals is easily ascertained by generally accepted criteria, or when the goals are given by non-scientists, there will be little play of fashion. In many of the applied sciences, where the goals arise outside of science and the criteria of success are usually given by non-scientists, scientific fashion is perhaps least important. In the empirical sciences, especially those with a more or less rigorous theoretical framework, the goals arise within science, but in many respects they appear to be 'given' in the confrontation of theories by 'nature' (38).

The change of goals directed from within science is due primarily to the actions of leaders:

The orderly succession of goals in a discipline is the sum of individual responses to a situation being changed by discoveries. Changes in the goals of individuals are facilitated by the tendency of scientists both to seek social validation of their goals and to follow the lead of outstanding men . . . . The ease with which physicists can change the goals of their discipline is linked with the structure of leadership in the discipline. While the ease of determining the really important problems makes it easier to spot leaders, the existence of leaders facilitates the orderly succession of goals (39).

Hagstrom makes other distinctions between types of goals, but not in any systematic fashion. Thus goals may be 'short term', i.e., specific problems being researched (40), 'traditional' disciplinary goals, as for example the purely biological goal of understanding life as a function of the cell (41), 'applied goals' such as the pursuits of industrial and government laboratories (42) and motivational goals such as incentives, particularly recognition (43). Implicitly, all the objects of competition between individuals and organisations are treated as goals. For example, position, promotion, research facilities and graduate students are scarce resources to be competed for, i.e., goals to be achieved (44).

The recognition of different levels and types of goals represents a considerable advance, but by failing to distinguish between goals and problems, and even more by linking this analysis with Merton's (45) five ideal types of scientific performer Hagstrom is committed to a static analysis which cannot comprehend interpenetrating goals and means. More fundamentally the analysis of goals, in terms of purposes to be achieved, is hindered by the adoption of a functionalist stance, whereby goals and changes in them can be interpreted only in terms of maintenance of the institution and correspondence with the means for achieving them.

3. An Exposition of Goal-Direction in Scientific Research

Before proceeding further it is important to clarify the meaning to be applied to the concept of goal. It has been noted previously that this concept has not been rigorously developed, in part because almost any sequence of behaviour can be divided into segments of varying 'size', each of which can be said to be goal-directed:

> Since there is only a relative distinction between means and ends, and since, therefore, any end or goal can be seen as a means to another goal, one is free to enter the hierarchy of means and ends at any point (46).

While precise semantic definition may be difficult, in this paper we will attempt to restrict the usage of the term goal to an over-arching objective or end which serves in part to direct one or more fields of research and of which individual, or groups of, scientists need not be explicitly aware.

It is important to recognise that we are not here considering the goal of 'science'. Along with Richter (47) we reject the notion that the concept of goal can be fruitfully applied to the whole enterprise of science. Recent developments within the sociology of scientific knowledge (48) emphasise the distinctive cognitive and social structure of different *sciences*. However, whether science is examined from a cognitive perspective, be it discipline, specialty or research area, or from an occupational standpoint, in industry, government or university, we would argue that the concept of goal can provide a very useful insight into the ways in which the modern sciences reflect and can be directed to the needs of industralised society.

Furthermore the distinction that Ravetz (49) makes between goal and purpose can be accounted for, in that each scientist may structure his or her research in order to achieve particular individual purposes, but goals form an important, and so far unconsidered, element of the cognitive, and hence social, structure, which shape the possibilities of achieving particular purposes.

In this paper, a clear distinction is made between goals and research tasks or problems. It can be argued that much of the sociology of science has been directed to an examination of the cognitive and social means of achieving the low-level objective of problem solution. Considerable progress has been made in explaining how cognitive and social structures, in part determined by the elite members of a research community (49a), shape the range of appropriate research tasks open to the 'autonomous' academic scientist. The way in which the apprentice, from student to post-doctoral fellow, is presented with a research 'package' which closely defines an appropriate set of research problems has been usefully explored by Whitley (50) and others. Less attention has been applied to the work of scientists in industrial and government environments, though here it is clear that the research tasks are equally prescribed, though in a more overtly hierarchical or bureaucratic manner and with a more immediate orientation to the objectives of the organisation. While studies of the research task are of undoubted value, we are concerned here with the extent to which high level goals form part of the structure determining these research tasks.

Particular goals may vary greatly in type, level of application and origin. The development of Kuhn's models suggest that cognitive structures operate at different levels and thus it appears reasonable to infer that goals, which to a large extent will express themselves through the cognitive structures, may also operate at different levels. Using Whitley's categorisation, at the highest level goals form part of the 'metaphysical' component of scientific knowledge – 'the overall system of values and beliefs which serves to justify and integrate the scientific activity with other systems of production . . . and provides a general world view' (51). Such high-level goals need not be consciously associated with all phases of scientific work; they may form part of a tacit background knowledge internalised through socialisation processes of which the scientist or administrator may be unaware. Nevertheless they may, in a highly mediated form, provide a powerful directing influence on scientific research. To illustrate, Mullins has identified the high level goal of the phage group as determining 'the secret of life' (52). On the basis of a detailed examination of solar energy research Jagtenberg has argued that the consensual high level goal has been "making the sun work for mankind by extracting large amounts of useful energy from solar radiation" (53).

Goals may also be formulated directly at the next level of cognitive structure, i.e., specialty concerns, described as: "the general problems or purposes of conducting the activity seen in terms of a particular definition of reality which may incorporate a number of evaluative frameworks" (54). At this level goals may take a rather more concrete, and explicit form as, continuing the phage group example, the determination of "the mechanisms by which genetic information is transferred" (55). Other examples include plasma physics, where the goal is one of understanding the properties of plasma sufficiently to allow continued controlled fusion with a positive energy balance, or biotechnology, where the goal is the artificial mutation of microorganisms suitable for the manufacture of industrial products (56). Cognitive structures at lower levels, namely explanatory models, techniques and research practices, may contain expressions of the higher level goals but the latter are unlikely to operate directly at these levels.

Goals may also be of rather different types. Thus some goals may take the form of very highly mediated expressions of socio-economic and cultural context such as operate in physics and biology (57). At the other extreme goals may be much more direct expressions of non-scientific interest groups such as sectors of government, industry, or the public, as seen in the development and direction of fields such as computer science, geology, tribology, toxicology and environmental science. We emphatically reject the adherence to the internal/external dichotomy which leads van den Daele *et al.* (58) to restrict the concept of goal to an objective developed outside the scientific community. In accord with the view of scientific knowledge as the highly mediated expression of socio-economic as well as ontological constraints, the analysis of goal-direction should be sufficiently general to apply to all sciences.

The major argument of this paper is that all modern science can be understood as a goal-directed activity. That is, scientists and those concerned with directing and influencing research operate according to goals which are

(1) Established as the result of social and political processes which involve dynamic interaction between interest groups both involving and excluding direct scientific interests and which may be directly or indirectly perceived by scientists.

(2) Mediated by scientific, socio-economic and political considerations and expressed at varying levels of generality; (59) these mediated versions may be expressed within 'official' statements of research programmes or

they may be deeply embedded in the cognitive structure of the relevant sciences.

(3) Dynamically linked to an evolving body or bodies of scientific knowledge in such a way that goals and science are only analytically separable; both cognitive and social aspects of research are directed and constrained by orientation to goals which are posited and potentially continually redefinable in terms of changing theory, techniques and socio-economic conditions.

In summary, three characteristic features of the goal-direction of scientific research can be identified: goal establishment, goal mediation and goal evolution. It is important to recognise that these are only analytically distinct; it would be very unusual for them to follow each other as three distinct phases. In the subsequent sections we will examine these features and illustrate them with examples drawn from a number of case studies in order to assess the utility of the concept of goal-direction in science and to develop a model which provides the basis for a clearer and more practical understanding for both scientists and science administrators of the ways in which modern science is, and can be, directed.

4 Goal Establishment

Van den Daele *et al.* have pointed out with considerable clarity that the establishment of goals – or as they describe it, "the transformation of political into scientific goals" (60) – can involve a varying degree of determination by political and scientific authority. The establishment of goals for scientific research programmes have been thoroughly documented for such classic cases as the Manhattan Project (61), the Apollo Mission (62) and the U.S. Cancer Programme (63). However, below are presented studies of goal establishment in less spectacular and possibly more typical cases of goal-directed scientific research.

Tribology (64)

Concern with the problems of friction and the means of eradicating it is not new. The American Society of Lubrication Engineers was formed in

1944, and by 1954 the subject of lubrication engineering was being taught to undergraduates at Imperial College, London (65). However, Dowson (66) has argued that the industrial developments of the post-war period posed a series of qualitatively new questions for mechanical engineers. High speed rotating machinery, more severely loaded reciprocating machinery and hostile working environments were increasingly causing breakdown and failure in production hardware. In 1962, a special committee was set up by the U.K. Department of Scientific and Industrial Research (DSIR), under the chairmanship of Mr. G. B. R. Fielden to investigate 'the problem' of design within mechanical engineering. At the time, the engineering industries accounted for 35% of manufacturing industry, nearly half of the United Kingdom's total exports and was the main supplier of domestic plant and machinery. The Fielden Report (67) argued that the industry was not modernising sufficiently quickly, and that it was particularly lagging in the fastest growing, technically more advanced sectors. Vig has argued that the

> Fielden Committee's frank report and DSIR's follow-up campaign received much public attention and contributed to a growing consensus on need for further reform of education, management, and State support programs (68).

By the early 1960s a Lubrication and Wear Group had been formed within the Institution of Mechanical Engineers, and it was within this group that some of the aforementioned problems were highlighted. Moreover it was at this time that science and technology became important issues in British politics (69). Two of the more strategic battle-cries of the successful Labour Party were the welding of science and socialism and the modernisation of Britain's industrial structure. The latter argument was particularly resonant with the state of affairs which mechanical engineers were facing in the fields of friction, lubrication and wear and the development and use of such knowledge in design procedures.

The crucial factor in the emergence of tribology as a distinct field of research was the generous support it received from the government. Mr. Peter Jost, a prominent member within the Lubrication and Wear Group of the Institute of Mechanical Engineers, was acquainted with, or at least 'had the ear of' Lord Bowden who was then Minister of State at the Department of Education and Science. Given the Labour government's manifesto, Bowden was probably sufficiently swayed by Jost's arguments that a lot of money could be saved in this crucial industrial sector if appropriate steps were taken and that this would, simultaneously, be a concrete realisation of one of the major promises in that manifesto. At any rate, whatever happened in this respect, Bowden *did* ask Jost to establish a committee of experts to examine the position of British lubrication education and research and to opine on the needs of industry in this field. A working group was established in late 1964 and eventually published the Jost Report (70) in February 1966.

This report justified the importance of its subject area in two ways which were obviously deeply resonant with Labour's electoral pledges:

(1) Potential savings were estimated at £515m per annum;

(2) Longer term economic, industrial and commercial benefits would accrue if the rate of technological progress was improved by recognition of this important problem. The barriers to this progress could be removed and the reputation of British engineering goods would be enhanced.

To effect these goals, the working group argued that more research and education, and the development of a general awareness of the important potential of the subject throughout industry was required. They also argued that these benefits had not been realised because of the subjects multidisciplinary nature and 'oil-can' associations. In an attempt to remove the latter fetter, the working group thought it necessary to devise a new name. So, following consultations with the editors of the Supplement of the *Oxford English Dictionary*, 'tribology' – from the Greek 'tribos', meaning 'rubbing' – was decided upon and defined as: 'the science and technology of interacting surfaces in relative motion and of the practices related thereto'.

In February 1966, responsibility for the mechanical engineering industries was assumed by the Ministry of Technology (71). This explains why it was Mr. Wedgewood Benn, the then Minister of Technology, who announced to the House of Commons, on 11 August 1966, the formation of a Committee on Tribology under the chairmanship of Mr. Peter Jost. Essentially, it was set up to advise the Ministry as to how the recommendations of The Jost Report could be most effectively implemented. The major results were the establishment of an Education and Training Committee, three Centres of Tribology research, and a Research and

Liaison Committee which, among other functions, assessed research proposals for the Science Research Council.

Thus by a detailed political process involving engineers, industrialists and civil servants the high level research goal of understanding interacting surfaces in relative motion was established. While the goal of 'understanding', it may be argued, is no different from that of science in general, it should be noted that the conditions and justifications for the programme focus the desired understanding within a particular set of constraints which can be best described as goal-oriented. A further point, and this marks a considerable distinction from the model of van den Daele *et al.* (72), is that the goal is not directed to or emergent from one 'finalised' science. Rather is has been adopted by specialists whose interests are or have become directed within the area of tribology from such a wide range of more traditional specialties such as crystallography, metallurgy, fluid mechanics, and various branches of chemistry and physics. Thus, the high-level, 'metaphysical' goal was transformed into a more immediate 'specialty concern' goal by a process of mediation for each of the relevant specialities – a process we will examine in more detail in the next section. But first, another example of goal establishment.

Environmental Goals (73)

In the early 1960s, the first rumblings of discontent over the despoliation of the environment in the industrialised countries were beginning to make themselves heard. The environment movement originated in the U.S.A., characterised by the appearance of such books as Rachel Carson's *Silent Spring* (74) and Barry Commoner's *Science and Survival* (75). Carson's book, in particular, caught the imagination of the public with an emotive discussion of the damage inflicted upon wildlife by the organochlorine insecticides. Subsequently, the destruction of the environment became an increasingly popular theme for discussion, and in mid-1969 the 'environmental crisis' arrived. This arrival was accompanied by a publication explosion and the flood of books and journal and newspaper articles focussed upon the 'crisis' has still not completely abated. Similarly, there was a sudden upsurge in the formation of environmental action groups in America and Europe.

A number of key issues dominated the discussions on the environment, particularly the population explosion, the depletion of natural resources (mineral and energy), and the ever-increasing discharges of liquid, solid and gaseous pollutants into the environment. Less tangible worries included the increase in noise, the threat of nuclear war and fears for the general debasement of the quality of life. 'Ecology' quickly became a new watchword, despite that fact that it had originated as a biological concept in the latter half of the nineteenth century; it was seen by many to hold the key to the solution to the environmental crisis. The most important element of ecology lay in its emphasis upon the total interrelatedness and interdependence of all this planet's living matter, including man (76). Man is an integral part of the global ecosystem; his disregard of this fact was the cause of his environmental problems.

The environmental movement was by no means united. A large, predominantly youth-based faction was committed to the environmental cause because of its potential radical implications. This group's enthusiasm was probably responsible for the launching of the entire movement. In the prevalent counter-cultural spirit of the late 1960s, when the opposition to technocratic society was at its zenith, the environmental cause was another direction through which to channel anti-system energies and sentiments; the 'crisis' was seen as a damning indictment of the *status quo* and technological rationality.

The conservative version of the environmental campaign depicted the problems as technical rather than political. It has been suggested that this conservation ethos, predominantly middle-class, was based chiefly on a consumer's view of nature, which did not demand much reflection further than the recognition that the natural environment was undergoing a process of despoliation. In those days of relative affluence, having achieved the satisfaction of their more material needs, the middle classes had time to turn their attention to less immediate consumptions habits – e.g., the countryside.

The strength and persistence of this public concern necessarily required a response from governments and international bodies concerned to influence them. In 1968, UNESCO convened an international conference upon the use and conservation of the biosphere. It resulted in the drawing up of a four-point plan for a long-term 'Man and the Biosphere' research programme which can be outlines as follows (77):

(a) Natural environments – the description and classification of the world's ecosystems, and the measures required for their conservation.

(b) Rural environments – the study of 'domesticated' ecosystems, for example associated with agriculture and forestry, to ensure the suitability of techniques.

(c) Urban–industrial environments – the attempt to forecast and avoid harmful ecological and sociological side-effects associated with the use of technology.

(d) Pollution and related phenomena – the study of the effects of the many different sorts of pollution upon man.

In Britain, a Royal Commission on Environmental pollution was set up in 1970 under the chairmanship of Sir Eric Ashby, "to advise on matters, both national and international, concerning the pollution of the environment; on the adequacy of research in the field; and the future possibilities of danger to the environment" (78). In the first report, a general survey was made of the 'state of the natural environment' and it was concluded that although there was no cause for alarm measures it was essential to carry out research into certain areas, such as the pollution of estuaries and coastal waters. Four priorities for government action were recommended: the improvement of public water supply, the control of the disposal of toxic wastes on land, the control of dumping noxious materials at sea and the reduction of noise (79).

Finally, there was the much-publicised United Nations 'Conference on the Human Environment' in Stockholm in 1972. Amongst its lengthy list of proposals were several points which stressed the important role of science and technology in relation to the environment (80). For example:

(Item Number 18): Science and technology, as part of their contribution to economic and social development, must be applied to the identification, avoidance and control of environmental problems for the common good of mankind.

(Item Number 19): Education in environmental matters for the younger generation as well as adults . . . is essential to broaden the basis for enlightened opinion and responsible conduct . . . in protecting and improving the environment.

(Item Number 20): Scientific research and development in the context of environmental problems both national and multinational must be promoted in all countries.