Part V: Towards self-managed science

The most fundamental presuppositions underlying science are assumptions which are so basic that only by drastically changing science could they be altered. One way to determine what such presuppositions underlie science is simply to analyse features of science, as has been done in part IV.

But there is still a basic difficulty in fully comprehending the presuppositions underlying science: getting beyond the feeling that the current features of science are natural and inevitable. One way to overcome this problem is to imagine how science and the society with which it is inextricably intertwined might be structured in an entirely different way.

However, it is very difficult, at least for me, to maintain a continual feeling of what the world could be and might be, of the potential of the world. While one is living in the world that currently exists, one is being continually cued, encouraged and led to perceive and believe that the world *necessarily* is the way it is. Yet to be able to see that the presuppositions underlying science are to a certain extent arbitrary, one must be able to imagine alternatives, to imagine that things could be different.

In this chapter, I sketch my own conception of how science might be organised. There are at least two reasons for doing this. First, I wish to highlight some of my own value assumptions, to make clear those features of present-day science which I think could be different and should be different. This will make it clear that the analysis in part IV of the presuppositions underlying science is biased towards revealing those features of science, and of the society with which it is interlinked, which I would wish to see changed. Second, the perspective to which I subscribe is based on values radically different from those underlying current science. Therefore, it provides a useful basis for perceiving many of the otherwise unnoticed presuppositions underlying science.

I will approach the idea of self-managed science and its implications for understanding the presuppositions underlying current science in the following way. First I will summarise the presuppositions treated in part IV, and spell out some of the implications of these presuppositions for a critique of science as it is. Then I will discuss some experiences, arguments and ideas which point towards the possibility of an alternative science. This will lead into a discussion of a particular alternative science: self-managed science in a self-managed society, and the implications of this perspective for understanding present-day science.

Presuppositions underlying present-day science

The following summary of the presuppositions underlying science necessarily will include a large number of generalisations and statements without accompanying evidence and arguments. Fuller treatment is found in part IV.

Why is scientific research done? Scientific research is not done solely for the purpose of understanding the operation of nature, or any such 'pure' purpose. Instead, human interests always have an impact on the direction and content of scientifc research. There are several ways in which this impact occurs.

The most direct influence is the funding of scientific research in particular areas and in order to obtain particular types of results. Most of the financial support for scientific research today comes from big corporations and from the state. Hence the direction of scientific development is strongly oriented towards the needs of those groups in society most served by big corporations and by the state. Examples of research so influenced are ballistic missile control system theory, the study of pain-killing drugs for mass distribution and the search for cheap and safe methods for treating the problem of long-lived radioactive waste.

A less direct but very important influence on the direction of scientific research operates through the general awareness in society of what are important problems to be solved. These problems and the awareness of them are a product of the way society is organised. For example, the emphasis on scientific research into the origins of cancer and heart disease is affected by the prevalence of these diseases in modern industrial societies. And the orientation of scientific research relating to these diseases is conditioned by political and economic constraints on the types of solutions to them that are acceptable. One of the economic constraints is the high rate of profit obtainable from goods such as food additives, asbestos and automobiles which introduce cancerous materials into the environment and encourage a sedentary life style. Although some scientific research may be 'independent' in the sense that it is not funded directly by the companies involved, most of such research is more likely than not to be concerned with what are seen as pressing problems in society which can be solved within the existing social, economic and political framework.

The interests of different groups in society which affect scientific development obviously are not neutral. The impact of big corporations and the state on science makes the results of scientific research selectively useful to the interests served by big corporations and the state. These interests seldom if ever coincide precisely with the interests of the populace as a whole. The impact of the organisation of society on the general research climate also makes the results of scientific research selectively useful to those groups which benefit most from the particular current organisation of society. Thus it might be said that science is one means by which society reproduces itself. That is, it is a means by which those groups in society which have the greatest control over the development of society maintain and perpetuate their control and use it to serve their own interests.

The particular presuppositions underlying the answer to the question, "why is scientific research done?", could quite conceivably be different. Groups other than the current powerful groups in society, with aims different from these groups, would promote a science different from present science. For example, a world dictatorship might be interested mainly in scientific results which would technically and ideologically reinforce the dictatorship. On the other hand, worker collectives or community groups, with the power to commission research or undertake their own research into problems decided upon by the collective or group, would be interested in different sorts of scientific problems and results. Obviously, there are many possible political and economic bases for an alternative science.

Who can use scientific research? Scientific research in practice is selectively accessible, selectively understandable and selectively exploitable by particular groups in society. This selective usefulness of scientific research can be seen as a direct result of the impact of human interests on scientific development. The scientific community has developed in the context of the various societal influences on scientific research. Its research techniques, methods of communication and interaction, and its organisational forms have developed to enable it to effectively serve the interests which promote it (especially today, big corporations and the state) as well as scientific goals and the vested interests of the scientific community itself. As a result, the scientific communication system makes it difficult for outsiders to get hold of relevant materials; some scientific research is more difficult for outsiders to understand than it might otherwise be; and much scientific research can only be exploited by powerful organisations. One extreme example of the selective usefulness of scientific research is military research into nuclear weapons: the outsider would have a difficult time indeed getting access to the research, understanding it and exploiting it.

The selective usefulness of scientific research is only occasionally due to a conscious conspiracy by scientists to exclude the public from the business of the scientific community. Instead, selective usefulness has mainly resulted from the attempts by scientists and their patrons to develop an efficient system for promoting scientific research in service of their respective goals. The scientific communication system, for example, may be relatively impermeable to outsiders. But it is a quite effective system for professional researchers and for those (especially big corporations and the state) who benefit from a relatively exclusive ability to use the results of scientific research.

Once again, it is quite conceivable that scientific research could be selectively useful to groups in society different from the groups it is selectively useful to at present. Take solar energy as an example. Scientific knowledge about massive orbiting solar collectors beaming microwaves back to earth is exploitable by quite different groups than scientific knowledge about building design and small-scale collection of solar energy for buildings.

What is scientific research used to justify? Current scientific research often serves to justify policies or practices, usually those of powerful groups in society. This can occur in at least two ways.

A scientific theory or hypothesis or the conclusion of a panel of scientists may serve as a direct or indirect justification for a policy or practice. For example, social Darwinism was used in the past to justify ruthless business practices; today, sociobiology is used to justify sexual and racial discrimination. The hypothesis of a threshold for radiation exposure has been used to justify releases of radioactivity from nuclear power plants. And the authority of scientific experts has been used to justify saturation bombing, the arms race, the use of herbicides such as 2,4,5-T, the use of food additives and many other policies.

A second way in which scientific research serves to justify policies or practices is through the very existence of particular types of scientific knowledge. The existence of knowledge always affects the evaluation of a situation. For example, knowledge of an even superficial testing of a cosmetic for cancer-inducing properties can serve to justify its release, with the assurance that "there is no evidence that our product is harmful". Knowledge of a new potent type of weapon can be used to justify escalation of the arms race. And lack of knowledge of alternative technologies can be used to justify a lack of effort to develop them.

The use of science to justify practices or policies in many cases is due to straightforward manipulation of scientists and their work, usually by powerful vested interests such as the former U.S. Atomic Energy Commission. Aside from this, scientific research is often selectively useful for justifying practices and policies as a result of the influences of political, economic and social interests on scientific development. These influences affect the choice of research topics, the assumptions underlying the research projects (such as the assumption of competition underlying evolutionary theory) and the idea that scientific research is independent of these very influences. The effect of human interests on scientific development thus makes scientific research selectively useful to particular groups in society both for practical purposes (exploitability) and for ideological purposes (justifying policies and practices).

What is scientific knowledge? Scientific knowledge is not identical with the natural world. Instead, it is a human interpretation of that world, a humanly conceived way of understanding the natural world. There is an infinite number of ways of conceptualising the world or any part of it, and therefore the choice of a way to do this always reflects human interests. As a result, the effect of the interests of groups in society on scientific development also affects scientific knowledge and thereby makes this knowledge selectively useful to the various different groups both materially and ideologically.

Of course, scientific knowledge is not solely the product of the quest for profit or the need to justify war. Rather, scientific knowledge — like the organisation of the scientific community and the way scientific research is carried out — is selectively oriented towards these types of ends. In doing research, there are many areas which may be studied. Scientific knowledge is mainly developed in those areas and in those ways which show promise of benefiting powerful groups in society. For example, in electronics, scientific knowledge is organised to help promote communications efficiency (usually one directional communication) and profit rather than ease of general access and local control.

Finally, the concepts involved in any scientific knowledge and the way these concepts are related to each other are shaped by human interests. Take for example the types of instructions used in a computer language, which is after all the embodiment of a certain kind of knowledge. The instructions are partly a result of direct economics, being influenced for example by the current capital and labour costs of different electronic operations. Computer instructions also reflect the likely applications of the language, such as business or scientific applications, and as well the intrinsic capabilities of electronics and symbolism for computation and communication.

Once again, it is conceivable that scientific knowledge could be different. If different groups in society, with different aims, provided the motivating forces behind scientific research, scientific knowledge would develop in different areas, be selectively useful for different purposes and to some extent be composed out of different concepts. If the content and design of computer languages had been developed by people interested in promoting easy understanding and use of computer facilities, the result might have been less oriented towards business and scientific applications and less suited for the increasingly strict division of labour in the computer area. Scientific knowledge is not a unique product, isomorphic with nature. It is a product of humans and human society interacting with nature, a product that is stamped with its origins.

Who does scientific research? Scientific research is done predominantly by professional scientists. The vast majority of scientists work for government, big business or universities, and much of university science is oriented towards the needs of government and big business. This is once again mainly a result of the historical development of science. Powerful groups in society have been interested in scientific research which is selectively geared to their needs. The interests of these groups have been promoted by the gradual transformation of the scientific community into a group of professionals working for large organisations linked to economic and political vested interests. These professionals find their own collective self-interest promoted by exclusiveness in recruitment and employment. They find their needs met by a scientific communications system oriented towards the needs of professionals. They succeed by accepting a high degree of specialisation. And they prosper by unthinkingly working on research problems as dictated by funding, or on current problems in society as defined and limited by existing political, economic and social structures. All these characteristics of life spent doing scientific research are very useful to the powerful groups who selectively benefit from science. And understandably so, if the development of the scientific research community has been heavily influenced by these very same powerful groups.

There is no intrinsic necessity that almost all scientific research be done by full-time professionals working mainly for large organisations, as at present. Quite conceivably, it might be done mainly by self-employed free-lancers, or mainly by amateurs as in the early days of modern science, or mainly by self-organised citizen groups. The composition and organisation of the scientific community is a result of the particular interests in society promoting and using science, including the scientific community itself. Therefore, it would be different, to a greater or lesser degree, in a differently organised society.

Presuppositions in SST-NO_x-ozone research

All of the presuppositions mentioned above can be illustrated through the scientific research done concerning the influence of nitrogen oxides, emitted as part of the exhausts from supersonic transport aircraft, on ozone in the stratosphere. To begin with, the Concorde, the Tupolev-144 and the planned U.S. SST are products of particular vested interests, most notably aircraft corporations seeking profit and governments seeking national prestige. The sources of opposition to the SST are less easily pinpointed. They range from concern by some economists over the possibility of making a poor investment choice, through genuine concern by public interest scientists and citizens about environmental effects, to protest by some citizen groups perhaps motivated in part by their lack of say in decision-making.

The particular technological project of the SST happened to interact with the newly developing public and political consciousness of the environment and human impacts on it. As a part of this consciousness, many scientists had become aware of environmental problems. Their awareness kept them sensitive in their research work to possible environmental impacts and ways of overcoming them. The SST is of course the source of many environmental impacts, such as the sonic boom. Therefore the environmental impacts of the SST provided a fertile ground for scientific study motivated directly or indirectly by political and economic interests. The studies by Johnston and by Goldsmith et al. can be seen in this context.

Johnston drew attention to an environmental impact of the SST previously considered unimportant. The possibility he studied was that the nitrogen oxides (NO_x) in SST exhausts might interact with and reduce the stratospheric ozone layer. This would in turn cause a number of effects, in particular an increase in skin cancer due to increased transmission of ultraviolet light through the ozone layer. The doing of Johnston's work on SST-NO_x thus depended on the existence of interests promoting the SST, on the existence of environmental concerns as a possible reason for opposing the SST and on Johnston's own particular research interests.

Goldsmith et al. studied the impact upon the ozone layer of NO_x earlier introduced into the stratosphere by atmospheric nuclear weapons testing. They also compared the amount of NO_x from these weapons tests with the likely amount of NO_x from Concordes. From this they drew conclusions about the likely impact of NO_x from Concordes upon stratospheric ozone. The doing of Goldsmith et al.'s work also depended upon the existence of interests promoting the SST, of environmental concerns and of Goldsmith et al.'s particular research interests.

The detailed motivations of Johnston and of Goldsmith et al. cannot be determined directly. But it can be determined that scientists typically hold strong opinions about their scientific ideas as well as about social and political questions (chapter 7). It can be determined that scientific papers on SST-NO_x-ozone type problems fall pretty much into two categories in terms of the way they treat evidence, promoting either the idea of the safety or of the danger of SST exhaust products (chapter 6). And it can be determined that the scientific arguments of Johnston and of Goldsmith et al. are each unified, to a considerable degree, around promoting a particular conclusion about the safety or danger of SST-NO_x (chapter 5). Seen only in the context of their scientific papers, the arguments of Johnston and of Goldsmith et al. appear to be 'pushed'. The conclusions reached are promoted by the technical assumptions which are made, by the way evidence is used, by the way results are used, and by the way alternative arguments are referred to (chapters 1 to 4). From a wider perspective, this pushing can be seen as a result of presuppositions by these authors about what they are trying to prove, either the lack of safety or the lack of danger of SST-NO_x. And from a wider perspective yet, these presuppositions can be seen as an aspect of the social and political promotion of and opposition to the SST, of the use of scientific environmental arguments to justify political decisions, and of the role of professional scientific research in providing and bolstering these scientific environmental arguments.

If society had been organised differently, the SST might never have been promoted, or its environmental impacts might never have been of concern. As a result, the scientific study of the effects of NO_x on stratospheric ozone would have taken on a different significance and course.

As noted above, the research areas opened up by the environmental impacts of the SST provided a fertile ground for the relatively overt intrusion of political and economic factors into science. It is for this reason that Johnston's and Goldsmith et al.'s papers provide a useful basis for analysing presuppositions in scientific research: the presuppositions are much easier to detect and study than in many other research areas. Concerning presuppositions in other research areas, I argue (chapter 8) that presuppositions are usually still important but that they are more hidden and less easy to recognise by being embedded in the context of the research.

Learning about the bias of science

A first step towards conceiving of and promoting an alternative science is creating awareness of the biases underlying present science. But creating such an awareness is not easy. For a scientist, writing about the political motivations of one's research in a research paper is very likely to make that paper editorially unacceptable. An alternative, taking matters to the public through the media or the educational system, is likely to be difficult and also rather bad for one's career.

Furthermore, the way science is taught in most schools and universities promotes the idea that science is neutral. This is done for example by teaching almost exclusively the content of scientific theories and ignoring the context in which scientific research is actually carried out and used. The situation is similar in the media's portrayal of science, which emphasises discoveries and breakthroughs and ignores the social forces underlying the direction and use of scientific research. There have been some attempts to change this state of affairs, for example by promoting a more realistic view of the history of science. However, more important may be attempts to change education and the media themselves. In the long run this might allow people to learn about science and its biases in a way that doesn't need to be sanctioned by the educational and media establishments.

One response to the bias of science has been the development of anti-science and anti-technology attitudes in certain circles. This disillusionment with science and technology because of its selective development to serve the interests of powerful groups in society is understandable, but inadequate. Rejecting science would not get rid of the powerful groups which shape the development and use of science. To say that science is neutral, as done by those who are 'pro-science', is to ignore the political and economic forces behind its development. To say science is bad, or out of control, as done by those who are 'anti-science', is also to ignore these forces. What this attitude lacks is any political analysis of science.

A different response to the bias of science is political critique. This is most easily done in scientific areas where political issues are a matter of public debate, such as the race/IQ controversy or research into techniques for social control. It is inevitable that any serious investigation into the bias of science will be political. This is because the bias — or at least the bias that is of most concern in terms of human interests — is a result of the exercise of power in society.

The main problem with political critique lies in its very success in emphasising the political nature of science. This often makes it unacceptable to educational authorities and media censors. Also, it is rejected by the majority of scientists, who cannot afford to become aware of the political aspects of their own work. Nevertheless, the political critique of science, at least if directed towards the public rather than into academic journals, seems to hold the greatest opportunity for increasing awareness of the values underlying scientific research. It is perhaps most effective in areas of public debate, where the political nature of scientific questions is most apparent already.

Towards a different motivation for scientific research

Even though a large majority of scientific research is oriented towards the needs of big corporations and the state, not all of it is. Individual scientists and small groups of scientists sometimes see it as their task to undertake research to serve other groups. In recent years this has been most apparent in the case of 'public interest science': scientific research undertaken to serve the interests of the public and often in opposition to the interests of powerful groups. This research is most heavily concentrated in the area of environmental impacts of new technologies, such as nuclear power, SSTs, pesticides and food additives.

Johnston's work on the effects of SST-NO_x on ozone can be considered to be an example of this sort of science, especially since he actively promoted awareness of his results at a critical time in the U.S. congressional decision-making process over further federal funding for SST research and development. Other most institutionalised examples are the Union of Concerned Scientists, which has studied the issues involved in the safety of nuclear power reactors, and the Committee for Nuclear Information, which for example has promoted research in and public awareness of environmental threats to health, going back as far as the controversy over the safety of radioactive fallout.

The best example today of scientific research which reflects a motivation based in interests other than those currently dominant is part of what goes by the name of alternative technology. Much of this technology and the science associated with it is designed to give independence to the user and to foster self-reliance. On the one hand is conventional, 'hard' technology. For example, nuclear power and related scientific knowledge is power requiring for its production massive amounts of capital, dependence on expertise and centralised control for safety purposes. Therefore it is power and knowledge useable only through the medium of large organisations. On the other hand is alternative, 'soft' technology. For example, diffusely generated solar energy, and some of the related knowledge, is energy and knowledge useable by the individual and small groups.

Much of alternative technology is motivated by its potential for making individuals and groups more independent of the institutions now dominating society. This is quite a reversal of the previous development of technology. Historically, much of modern technology has been designed specifically to make the worker and consumer more dependent, controlled or otherwise hooked into the established system. It is not surprising then that many aspects of alternative technology are closely linked with groups and ideas critical of existing arrangements in society and are opposed or ridiculed by supporters of the status quo.

Another way in which the motivations for scientific research would be changed would be through greater public participation in major decisions about the funding of scientific research. This is already happening in small ways, for example through the support of the Union of Concerned Scientists through donations from the public. It is also happening in indirect ways, as when major development projects such as Plowshare (use of nuclear explosives for digging canals or stimulating production of natural gas) or the SST are halted or partially restrained through adverse public opinion or the opposition of citizen groups. On the positive side, increasing public concern for the environment and public health has been an indirect but important reason for the increasing scientific interest in areas such as solar energy, biological control of crop pests and exercise physiology.

In principle, it is immediately possible to involve the public in decisions about what scientific research should be done. For example, members of the public could learn about research proposals through much greater coverage in the mass media, and a citizen voice in scientific planning could operate through citizen representation on decision-making bodies.

The proposal that the community at large could be and should be involved in decisions about the funding of major scientific projects has been ably expounded by Leslie Sklair in his excellent book *Organized knowledge*. Sklair presents a view of participatory democracy which includes public involvement and debate about the major development decisions in science which affect the wider public. In the course of his argument he makes the obvious replies to various objections to such involvement. For example, the idea of informed public debate does not require that everyone should know everything about everything. Sklair finds that most obstacles to public involvement are not unchangeable — such as genetic limits to understanding science — but are institutional — such as the nature of the mass media and the education system. Finally, Sklair points out how the lack of public participation in decision-making about science is very useful to various vested interests, from scientists to the economic beneficiaries of SST development.

Towards a different 'scientific community'

My own position is different from Sklair's in that I do not believe public participation in science policy will be achieved in any meaningful sense until a large fraction of people are actually involved in helping to do scientific research themselves. If experts have the power to judge which choices are feasible and can be presented for public evaluation, this power very likely will be used to determine the direction of social development, to the detriment of the community as a whole.

Before considering some examples of how more people may be involved in scientific research, let me first tackle the question of whether it is even possible for very many people, besides the fraction who now become professional scientists, to participate in scientific research in any real sense.

Often it is claimed that members of the general public are incapable of understanding science to a sufficient degree to make valid judgements about what sort of research should be done, much less to do research themselves. Such claims have never been put to the test. Practical experiments, such as directly involving the public in scientific activities, promoting an understanding of science through the mass media or truncating the length and compulsion of scientific training, are seldom attempted. Generally such possibilities are rejected without trial on the basis of spurious inference from limited evidence.

There is considerable evidence that people can learn many skills and abilities without the lengthy training or background knowledge normally considered necessary. Examples are the skills learned by trainee doctors or mechanics under wartime necessity. A programme run by Huber since before 1970 has shown that high school students and others, with little or no background knowledge in subjects such as physics or chemistry, can learn the essentials of doing medical research in a matter of months. My own limited experience with young apprentice researchers agrees with the results of Huber's programme. Johnston has involved undergraduate students in his research to a considerable degree. Indicative of this is the fact that undergraduate students are co-authors on quite a number of his papers and research reports. Also, Johnston has attempted to get non-specialists to reproduce at least some of his work, and thereby to gain a deeper understanding of what it is all about. An example is the presentation in the *Science* paper of data and techniques for the amateur who wishes to get a feel for the calculational procedure involved (pages 519-520).

These examples indicate that the non-scientist is perfectly capable of being involved in scientific research and of contributing to the research. They also suggest some ways in which this involvement could be promoted.

On a wider scale, local people in Japan have been involved in scientific studies of pollution problems under the supervision of 'public interest scientists'. Furthermore, the studies carried out by these citizen research teams have been much more successful in finding the sources of problems (such as the source of Minamata disease) than studies made by teams of government or business sponsored scientists.

These experiences strongly suggest that scientific research carried out by non-professionals will be different from conventional scientific research in a number of significant ways. It will be concerned more with problems of interest to the public, it will be interested in different sorts of results and it will be carried out using different methods and styles. In particular, the Japanese studies by citizen teams have been more integrative, less dependent on expensive apparatus, and more strongly focussed on the problem at hand (as opposed to following academic byways) when compared to the research carried out by the professionals.

The best description I know of more widespread participation in scientific research is Science for the People's account of science in China. Some of the features of science described in this account are: a drastic reduction in the duration of specialist scientific training, and a reduction in prerequisites for scientific training; despecialisation — the involvement of scientists in non-scientific tasks; commune research groups, working on problems of local interest; the interlinking of scientific research and practical knowledge of people; communities carrying out practical projects (often judged impossible by experts); workers learning about the organisation of the factories in which they work; and students learning from all available resources. This description is not necessarily completely accurate. Nor is the situation it describes necessarily ideal. What it does show is that the possibility of a much more widespread understanding of science in the community and much greater community involvement in scientific research is a very real possibility. The Chinese experience shows that the question, "who does scientific research?", could be answered in quite a different way.

How is scientific research to be oriented to serve the public interest?

Many people will agree that scientific research ought to be oriented more towards the public interest. The question is how this is to come about.

One vision is that of the socially responsible scientist who, through personal concern for and consideration of the consequences of particular types of scientific research, brings about a redirection of research policies. The implication of this vision is that in order to alter the direction of scientific research, efforts should be aimed at scientists and their awareness.

But this is to expect too much from individuals, and to underrate the influence of structures. Scientists are a product of society; they are shaped by their upbringing, education and work situation. As long as institutions which promote 'irresponsible science' predominate in society, only a relatively few scientists will be found who will actively reject or resist the research done in the service of these institutions. Because of their immense power and resources, big corporations and the state need only attract a fraction of potential scientists to satisfy their requirements.

Social responsibility by scientists is highly desirable but not sufficient in itself. The success of public interest science, for instance, depends as much or more on the awareness, support and mobilisation of the public as it does on the awareness of the scientists doing the research.

Another vision is that of control of the direction of scientific research by representatives of the people in a socialist society of the bureaucratic type. In this vision, science will be done by professional scientists as at present, but in a responsible manner because science funding and important problems in society will be defined by the people through their representatives, namely the ruling socialist or communist party. The implication of this vision is that all efforts should be directed towards changes in political and economic structures rather than towards scientific research and its implications.

This view, oriented as it is towards changing those features of society which fundamentally shape the form and content of scientific development, overcomes some of the shortcomings of the vision of the socially responsible scientist. However, it also has several deficiencies.

Firstly, the procedure by which the public interest is turned into policy seems open to abuse, at least if we go by the experiences of formally 'socialist' societies. And secondly, as long as scientific research is left to professional scientists, the professional scientists are likely to promote courses of action which serve their own interests as well as the interests of those other groups in society which make the privileged decision-making role of the scientists possible. The essential problem for the 'socialism from the top' vision is that of controlling the experts and decision-makers, whether these are political bureaucrats or scientists.

Two other stances have been mentioned earlier: the 'pro-science' attitude that science is neutral (the most common attitude among scientists), and the 'anti-science' attitude that science is bad. Neither of these can begin to handle the question of the reorientation of scientific research, since they are based on the premise that science is independent of social and political concerns.

In presenting short descriptions of these different approaches to the question of orienting science to serve the public interest, it should be obvious that I have not tried to cover all the issues and arguments. As a consequence, my description of the different approaches is incomplete and biased. My aim has been to put into perspective my own vision of how science may be best oriented to serve the public interest, and not to treat these other perspectives in detail. And so to my own vision: the involvement of as many people as possible in decision-making about science and in doing scientific research, in the context of a society where widespread decision-making and participation is the norm in all activities.

Self-managed science

The ultimate extension of public participation in decision-making about science and public involvement in doing scientific research may be called 'self-managed science'. Self-managed science is not something that could develop on its own within current society; it would have to develop as part of a self-managed society. The short description of self-managed science here — and a full exposition is ultimately a task for the people doing it anyway — is meant to throw light on the presuppositions that underlie current science.

Self-managed scientific research would be done by nearly everyone, in the same way that in present society nearly everyone purchases goods, reads and participates in community organisations, or has the opportunity to do these things.

Research groups and facilities would be organised so that entering into scientific research on a minor scale requiring relatively little training is attractive. Involvement in organising research programmes and in carrying out research would be open to all interested persons. Education, communication and decision-making would be organised so that as many people as possible were involved in doing research and making decisions about what research is worthwhile.

Since everyone would have an opportunity to contribute towards making decisions about what scientific research is done, there would be more emphasis on studying problems thought to be important for the communal welfare. The equipment and labour to support the research would be provided by the community, and the important problems to be solved would arise from the needs of the society at large. Thus the motivation for scientific research would arise in the same general way as at present, but would have its source in the collectively decided priorities of the whole populace rather than of the vested interests of powerful groups. As a result, the problems tackled by self-managed science would be inspired by aims such as providing adequate shelter for all without exploiting or degrading people, rather than aims such as producing more effective means for killing.

General accessibility of the results of scientific research to all interested parties would be a prerequisite of the practice of self-managed science. A much greater attention to understandability similarly would be the norm. As much as possible, researchers would attempt to communicate their ideas and results in ways that could be understood by others who wished to commit a reasonable amount of effort to the task. The use of apparently value-neutral sets of concepts and writing styles would be superseded by concepts and styles which highlighted the value assumptions entering into the research. Finally, research projects would be undertaken with close attention to the exploitability of the results. Projects which promised knowledge or applications which would foster ends such as equality and self-reliance would be especially encouraged.

As a result of research being done on topics of communal concern, of research findings and methods being made more understandable and of research being done by a large fraction of the populace, scientific knowledge would take on a different character than it does today. Its central topics would be in areas of vital social concern or interest. Its concepts and their relationships would facilitate understanding and use of the knowledge by all interested individuals and groups. And the values inherent in the content and formulation of the scientific knowledge would be readily apparent. In other words, there would be a visible bias in scientific knowledge: a bias towards the needs and wishes of the populace as a whole.

In discussions of self-management, there is sometimes seen to be a conflict between the importance of the people as a whole deciding collectively what is good for the community, and the importance of individuals or small groups being free to do what they wish as long as they don't infringe on the freedom of others. On the one hand, the collective may become just as dictatorial or socially irresponsible as the powerful groups in society at present. On the other, small groups might use their freedom to promote a system of unequal power and privilege.

Here I have emphasised the side of collective decision-making rather than individual freedom. There is a reason for this. The current mode of scientific development is dominated by the interests of big corporations and the state. However, although the organisation of society strongly conditions the form, content and inspiration for scientific research, the traditional idea that scientists are 'free' to pursue whatever they wish is still powerful. By emphasising the aspect of collective decision-making, I have tried to avoid confusing my view with the position that scientists should be 'free' — a position which falsely assumes that scientific development can occur in a political and economic vacuum.

Actually, I agree that there should be freedom for individuals to pursue lines of inquiry of their choosing, often in a spontaneous way. In a self-managed society, there actually would be *more* freedom for most people doing science than for present-day scientists. However, science would still be 'managed' in the wider sense of being bound by society-wide constraints. These constraints might include an obligation to protect the ecosystem, to help those in distress and to permit the involvement of interested people in all activities affecting the society as a whole. There have always been constraints on science. In any humane sort of society, research into more effective means for child-bashing or into the construction of plastic pellet bombs would be almost unimaginable, whatever the implications of this for the 'freedom' of research. In a self-managed society, individual and collective acceptance of such constraints — in other words, social control — might be exercised through socialisation or through new structures for human interaction; certainly it would not be through police. My own preference is for the collective aspects of society to be very tolerant of individual experiments. But this stance is quite different from the belief that scientific research today is 'free' in any fundamental sense.

What are the implications of the idea of self-managed science in terms of bringing about change in science and in society? Here is my assessment. Primary emphasis should be placed on changing political and economic structures. However, this should not be the concern of only a small elite. Instead, there needs to be a broad-based involvement in a movement for social change. The struggle for a 'people's science' is a part of this wider struggle. It includes exposure of the political nature of science, promotion of technology and knowledge selectively useable by the public (such as some alternative technologies), research efforts involving those who are currently non-scientists and avoidance of dependence only on experts in decision-making. Perhaps the most effective arena for many of today's professional scientists in such a movement is in countering the claims of establishment authorities and in broadening technical understanding in citizens' movements, whether women's groups, workers' self-management groups, anti-war groups, environmental groups or political parties.

Reference notes

The reason why the possibility of a decent society seems so remote is at least partly due to the existence of powerful entrenched vested interests. But there may be more prosaic causes, such as the good citizen's reluctance to jeopardise a stake in the prevailing order — see Moore (1967) for an illuminating analysis.

Perceptive analyses of attempts to create alternative educational structures are given by Graubard (1972) and Kozol (1972).

The author most identified with 'anti-science' is Roszak (1969, 1973). A brief survey of counter-cultural grievances against science is presented by Naess (1975). The best expression of the idea that science is out of control is by Ellul (1965).

For the political critique of science see Rose and Rose (1976, 1976a) and the magazines *Science for the people, Science for people* and *Radical science journal* (see bibliography for addresses).

Some organisations concerned with public interest science are the Union of Concerned Scientists (1208 Massachusetts Avenue, Cambridge, Massachusetts, U.S.A. 02138), Scientists' Institute for Public Information (560 Trinity Avenue, St Louis, Missouri, U.S.A. 63130), Center for Science in the Public Interest (1757 S Street N.W., Washington, D.C., U.S.A. 20009), Public Interest Research Group (1346 Connecticut Avenue N.W., Washington, D.C., U.S.A. 20036), and the British Society for Social Responsibility in Science (9 Poland Street, London, U.K. W1V 3DG). Some of the early work of the Committee for Nuclear Information is discussed by Commoner (1966). The idea of 'critical science' expounded by Ravetz (1971) is close to the idea of 'public interest science'.

On alternative technology see Clarke (1973) and Schumacher

(1973). While alternative technology suggests how science can reflect and help promote a decentralised and self-managed society, adoption of alternative technologies does not automatically lead to such a society. In my opinion, alternative technology is valuable in as much as it is developed and applied under the control of people who also have control of their political and economic institutions, and in as much as it is used to maintain and increase control by people over decisions and actions affecting their own lives, to promote development of the individual within an interactive and supportive social group and to promote life styles in harmony with the environment. On the other hand, alternative technologies can be 'given' by experts in industrialised countries to rural communities in a context which helps to reduce the possibility of radically transforming repressive institutional structures (Dickson, 1974). By far the best single work on alternative technology and its social and political implications is Boyle and Harper (1976). The material in this book is selectively accessible, understandable and exploitable by those organising a self-managed society. I highly recommend it.

A practical example of the linking of people's control of technology and alternative technology is the construction of the world's currently largest windmill in Denmark: see Jamison (1978).

On the social and political implications of nuclear power, see A. Roberts (1976).

As indicated in the text, Sklair (1973) is excellent in rebutting arguments that the public cannot be involved in decision-making about science.

Gary L. Huber's programme for training people in medical research is described in *Newsweek*, 10 January 1972, p. 26, and this article is quoted and discussed in Holt (1973). Johnston has informed me of several ways in which he involves undergraduate students in his research. These activities show that the ability of the typical person to do scientific research is much greater than most scientists want to recognise or permit.

The point that scientists are, on average, no more innately talented than people in any other occupational group is made by a number of authors, such as Barzun (1964, p. 75) and Nieburg (1966, p. 106). A most delightful presentation of this idea is by van den Berghe (1970).

Ui (1977) describes the involvement of local people in Japan in research projects which are simple, resourceful and highly successful compared with projects carried out by government or business sponsored professional scientists.

The Science for the People (1974) account of science in China is for me the best source of ideas and inspiration about what science could be like or should be like in a radically transformed society. According to their description, Chinese science has been characterised by many of the features that might be expected in a self-managed society: involvement of peasants and workers in posing scientific problems and offering solutions; involvement of scientists in practical problems of the common people, rather than problems of elites; use of expertise and material equipment for spreading learning at all times, rather than for mystification; fostering of and serious consideration of traditional wisdom. Chinese science is still constrained in many ways. For example, the national 'necessity' for developing a nuclear weapons capability encourages the training of elite groups of nuclear chemists and physicists. Also the Science for the People account is no doubt selective for several reasons, and to some extent based on the authors' seeing what they wanted to see. Still, that does not mean that their description is any less useful as a source of ideas about what the role of science could be in a radically different society.

Suttmeier (1974) analyses the alternative models used in post-revolutionary Chinese science and social development. Part of the time the 'organisational' model, based on hierarchy, specialisation and research chosen by professional scientists, has been favoured. In the periods following the Great Leap and the Cultural Revolution, the 'mobilisation' model has been favoured. It is based on decentralisation, despecialisation, and planning by 'revolutionary committees' (with representation from the masses, revolutionary cadres, and progressive scientists and technicians). It is this mobilisation model that so inspires the Science for the People account. The current (1978) Chinese regime obviously represents a return to the 'organisational' model.

There are many other accounts of Chinese science, such as Wheelwright and McFarlane (1970), Dean (1972) and Rifkin (1975).

The dangers of government by the experts have been argued by many authors, such as Bakunin (1971) and Laski (1931).

The case for self-managed science also has been put very briefly by Bakunin (1953, p. 80), Gorz (1976) and Lévy-Leblond (1976).

The most well-known advocate of deprofessionalisation in recent years has been Illich (1971, 1973, 1975). Illich is superb in describing the undesirable consequences of institutionalisation, in areas such as education, health, energy use, religion and defense. For a political critique of Illich, see Gintis (1972).

The idea of and the struggle for a self-managed society has a long history: for a good account and introduction, see Guérin (1970) and Ward (1973).

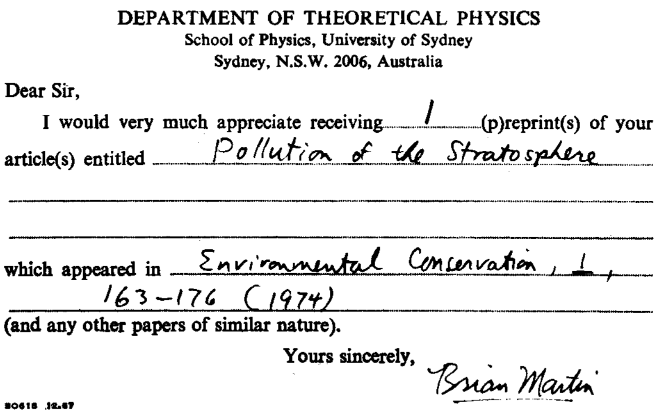
As to *how* to achieve a self-managed society, I am very much in sympathy with the approaches of Gorz (1967), Swomley (1972) and Lakey (1973), and present some of my own views in Martin (1979).

References

On getting hold of references

For the non-scientist I offer here a few notes on getting hold of references in the scientific literature.

Ask your librarian about finding articles published in scientific journals. Many journals are found only in specialist libraries. You may wish to have your own copy of some articles. Buying the journal is usually out of the question. Photocopying is the usual practice. Although most scientific articles are copyrighted as are Johnston's and Goldsmith et al.'s, it is generally acceptable to make a single photocopy, "for purposes of research or private study". Photocopying can be expensive. It is also common and accepted practice to write to the author of any published or unpublished paper and request a reprint. A reprint is a copy of the article. Reprints usually are nicely printed as in the journal, often in booklet form, although sometimes they are only photocopies. Reprints require no payment (that is, the author's institution or the journal pays for


DEPARTMENT OF THEORETICAL PHYSICS
School of Physics, University of Sydney
Sydney, N.S.W. 2006, Australia

Dear Sir,

I would very much appreciate receiving 1 (p)reprint(s) of your article(s) entitled Pollution of the Stratosphere

which appeared in Environmental Conservation, 1, 163-176 (1974)

(and any other papers of similar nature).

Yours sincerely,
Brian Martin

80618 12.67

Figure E. One side of a typical reprint request postcard. On the other side, which is blank, the address of the author of the requested reprint is written.

the reprints). Since most scientific organisations have standard postcard request forms — see for example Figure E — and also pay postage, it may be convenient to impose on a friend who is a scientist. Sometimes authors may be unable to furnish reprints due to exhaustion of their supply. A more common difficulty, especially for older papers (say more than 2 to 5 years old), is that the author has changed institutions and so does not receive the request. Also, some authors do not respond to reprint requests. But in my experience the large majority of reprint requests are successful, and often authors send other articles of interest as well. If you have only a reference to the article and do not have the author's address, often the address can be found in abstracting journals or in special volumes listing names and addresses of scientists. Ask your librarian for help in these matters.

For the non-specialist it is more difficult to obtain scientific materials not published in journals. Examples are conference proceedings such as the CIAP conferences, internal reports such as the early version of Foley and Ruderman's paper, and preprints, which are usually photocopies of typed manuscripts of work submitted for publication or in an intermediate stage of preparation. Some conference proceedings and internal reports may be found in libraries. But in general, unless one has contacts in the appropriate research speciality, these sorts of materials are difficult to obtain. Even assuming knowledge of their very existence, which may not be easy to come by, it is often hard to find out the proper address for requesting the material. Then to top it off the material may be very expensive. Once again I can only suggest asking a scientist to order the material for you.

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