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What is happening to science?

The dark cavern in the mountain rang with the merry hammering of the Dwarves.

1.1 The shape of science today

Imagine a space–time traveller, returning after 30 of our earthly years. For Dr Winkel van Rip, it seems only a few months since she hurtled off at nearly the velocity of light in a secret biotest of General Relativity. Now she has come back to her job as lecturer in astrophysics at Loamshire University. Until now she has been a dedicated researcher, entirely uninterested in any aspect of science beyond her textbooks and laboratory bench. What features of contemporary science might catch her innocent eye? What account would she give of scientific life and work in Britain today?

At first, she would be delighted and overwhelmed by all the good science that had been done in her absence. She would enjoy learning about the theoretical explanations of old mysteries, and getting her hands on to marvellously powerful new observational techniques. She would also soon realise that many of the old questions had still not been answered, and that many exciting new questions were emerging. Astrophysics happens to have made conspicuous progress in the last thirty years, but it is not unique. In almost every other field of the natural sciences she would find

the same buzz of activity, immense technical achievements, and ever widening challenges and opportunities.

She would also note that science and its technological products was highly prized in society generally, especially as a source of national economic achievement. She would see scientists using incredibly refined techniques to acquire quite remarkably powerful understanding of every aspect of the natural world. She might feel slightly uneasy at the attention given to the voices of intellectual dissent, and to ethical concerns about the effects of technological innovation. Nevertheless, her 1960s vision of unabated and beneficial scientific progress would still seem to be alive and well in the 1990s.

But as she began to work again at her profession she would begin to realize that the whole scene had subtly changed. Being a wise person, she would not take too seriously the perennial grumbles about lack of research funds, inept decisions by ill-informed bureaucrats, political incomprehension of the value of science to the nation, etc. Scientists have always felt inadequately appreciated by those who do not share their peculiar, esoteric missions and have always complained that they deserved far more resources and social recognition. She might have noted, however, that these discontents were now being articulated more precisely, and backed by facts and figures. Responsible people were questioning the future of British science, if not of science as a whole. Even in their table talk, scientists would seem to be much more politically anxious and self-conscious than they used to be.

Moreover, in listening to this table talk, the good Dr van Rip would frequently hear words that seemed quite out of place in the academic world – words such as 'management', 'outputs', 'accountability', and 'evaluation'. Piecing these buzzwords together, and puzzling out the meaning of various unfamiliar terms such as 'critical mass' and 'intellectual property rights', she would begin to see the science of today in quite a new light.

First of all, and most importantly, she would find herself involved in a single, loosely articulated but essentially indivisible, **'R&D' (research and development) system**, where very

diverse activities, ranging from basic scientific research to near-market technological development, interpenetrate and combine within a bewildering variety of institutions. She would note references to an elaborate apparatus of committees and administrators designed to provide a **policy** for this system. This policy would include such matters as: formulating national **priorities** in deciding how research should be funded; achieving early identification of **exploitable** areas of academic science; increasing the emphasis on **strategic** and **pre-competitive** research; initiating national programmes of **directed** research in fields such as information technology and biotechnology; fostering direct *industrial/academic* linkages; negotiating transnational programmes of research and technological development through international organizations such as the European Community.

Her academic colleagues would provide her with a running commentary on some of the characteristics of the national machinery for the allocation of **resources**. They would tell her about the fierce **competition** between scientists to get funds for research, the insistence on increased **accountability** for the inputs and outputs of science, and on systematic accountancy for the **overheads** incurred in carrying out research. She would also learn about the politics of setting up and arranging the shared use of **facilities**, often on a multinational basis, such as particle accelerators, synchrotron radiation sources, computer networks, etc.

Our innocent friend would also note the development of all sorts of procedures for the systematic evaluation of the performance of every element of the research system: research units, laboratories, research establishments, university departments, Higher Educational Institutions of various kinds, and even whole nations. She would observe that the work of **individual** academic scientists was subject to periodic **appraisal**, and that various performance **indicators** had been developed to monitor **efficiency** and facilitate **selectivity** in the allocation of resources according to presumed quality. Although the term triage would not be used publicly, she would become aware of various administrative devices for killing off weak research units to enhance the survival of the others.

In the same context, she would hear of various measures designed to concentrate scientific activities, in order to achieve a **critical mass** of effort. These measures might include the establishment of national **centres of excellence** designed to compete internationally in particular subjects, the agglomeration of scientists and equipment into **multidisciplinary** centres to attack particular practical problems, and the development of research **networks** linking scientists in different institutions.

In considering her own further career prospects as a scientist, she would realise with alarm that she could no longer rely upon permanent tenure in her university post, and might find herself among the ranks of **contract researchers** on short-term appointments supported by **soft money**. She would also become conscious of a number of other features of the system, including concern about the efficiency of professional research **training**, a trend towards the separation of **teaching** from research, and the association of **managerial** functions with scientific leadership roles.

Forgive me for the above paragraphs. They lampoon policy prose to make a serious point. Of course, the table talk would mostly be taken up with other, more familiar topics. Within a few weeks, for sure, our time traveller would find herself entirely at home again in the interminable gossip of a peculiarly individualistic profession. She would soon be discussing the merits and demerits of the latest professorial appointment, the rights and wrongs of a notoriously critical referee's report, the slightly dubious circumstances surrounding the decision of Dr A to go to America, the advantages and disadvantages of collaborating with the rather snooty group at X, the choice of invited speakers for the next international conference, the selection of suitable themes for a forthcoming Summer School, or the prospects for next year's Nobel Prize. Most of the strong and abiding traditions of the scientific life would still seem reassuringly alive. But was this perhaps a superficial view? How was the whole world of science and scholarship being affected by the practices, procedures and attitudes signalled by those peculiar words that kept buzzing into the conversation?

1.2 Radical, irreversible, structural change

Like most of her fellow scientists, Dr van Rip would not have a deep historical perspective on the scientific enterprise as a whole. She would probably have some difficulty in fitting her findings together into a coherent picture of that enterprise today. But being very observant, she would note certain common characteristics of the changes that had taken place since she had started on her journey.

In the first place, the novel features are *widespread and penetrating*. Within a few weeks of entering the scientific world, at any point, our observer would have encountered most of them. They are not just the commonplaces of coffee-break chat, or the subject matter of government reports, or editorials in *Nature* or *New Scientist*. They affect the everyday decisions and working practices of researchers in universities, government establishments and industrial laboratories. They motivate committee agendas and give professors ulcers. They are deeply embedded in the *culture* of research: they form the *climate* in which scientists have to live.

They have *many different aspects*. Each of those cryptic phrases, tagged with its buzzword, stands for an ill-defined complex of procedures and principles, policies and practices. Take, for example, the requirement that the **overheads** of academic research must be accounted for. This obviously includes expendable items such as laboratory reagents, or the materials used in making research apparatus in the departmental workshop. It has to cover secretarial facilities and libraries; but what about the central university administration? At what rate should expensive scientific instruments be written off for obsolescence? How much should be set aside for the putative rent of that grand new, or decrepit old building? It looks like a standard exercise in accountancy, but conceals an infinite source of unproductive institutional toil and moil.

The novel features are *interconnected in many different ways*. Take again the apparently innocuous theme of **overheads**. The whole calculation depends on the degree to which **teaching** is

separated from research. It is affected by economies of scale achieved by the **concentration** of resources into larger units, and by the **networking** of facilities. It must be a consideration in the **competition** between research groups, and in their relative **evaluation**. And so on. These features are so interlaced that every time she tried to break the list down into separate categories she would have come out with a different scheme!

The same changes would be seen to have occurred, to a greater or lesser degree, in *most other scientifically developed countries*. The verification of this proposition would be a major task, beyond her personal capacity. But if she were to test her list on an audience of senior scientists and policymakers from most of Western Europe, North America and Australasia, she would not be seriously contradicted. The countries of Central and Eastern Europe, including the successor states to the Soviet Union, are working hard to restructure their science along similar lines. Communications from OECD (Organization for Economic Cooperation and Development) and UNESCO (United Nations Educational, Scientific and Cultural Organization) suggest that many of the Less Developed Countries are moving, or are being pushed by their advisers, in the same direction. In Japan, perhaps, the situation is rather different, although not at certain significant points such as the focus on **exploitation**.

Finally, our quantum leaper would sense that most people now believed that these new features were *unlikely to disappear in the foreseeable future*. However regrettable some of them may seem to many of the people affected by them, the general thrust of communal effort, from ginger groups as much as from establishment circles, is to accept them as permanent features of scientific activity and do their best to 'make them work', and 'get them right'. In many countries, particularly the UK, any call for these changes to be reversed is swamped by the demand for additional resources. Science everywhere is agonised by a thirst for money, both for positive new developments and to meet the cost of installing all these features into its existing institutions.

Now let Dr van Rip cast her mind back to the time of her apprenticeship to research – little more than a human generation ago. Let her refresh her memory of the scientific life in a country

such as Britain in the early 1960s. Let her read the autobiographies, listen to the reminiscences, and skim through old professional journals, newspapers and documents. She would surely be nonplussed by the realisation that *most of the features that are now so dominant would then have been scarcely noticeable.*

A serious historical scholar could, of course trace some of the basic themes, such as public pronouncements on the desirability of links between industry and academia, back to Francis Bacon. 'Evaluation' and 'selectivity', in one form or another, have been key factors in the building of scientific institutions and scientific careers since research went professional in the nineteenth century. But they were not highlighted and trumpeted around as indispensable tools of 'management' – a word that would never have been heard in academic circles. And other present-day features, such as job appraisal and abolition of tenure for university staffs, would have been quite inconceivable at that time.

It is not necessary to give a detailed historical account of each one of all the novel features that have emerged or evolved into prominence in this short period. They are so numerous, so pervasive, and so interconnected, that they amount to convincing empirical evidence of a profound structural change. In less than a generation we have witnessed a *radical, irreversible, world-wide transformation* in the way that science is organized and performed.

1.3 A provisional analysis for practical guidance

This, in essence, is what an objective observer of the present-day scientific world might report. But those of us who are immersed in this world find it difficult to appreciate the magnitude of the transformation that has occurred. On the whole, it has been a continuous process, leading to a situation to which the older generation have adapted reluctantly and which the younger generation accept as normal. We are all aware that many significant changes have taken place, but we have tended to treat these as independent phenomena, generated almost accidentally by peculiar political or economic circumstances beyond our control. Until

quite recently, very little effort had been made to connect them up and locate them in a more general scheme.

What is it all about? Why has it happened? If this were a scholarly text in an academic course of science studies, there would now have to be a systematic analysis of the phenomena in question. Although there seems little doubt that a very significant change in the social structure of science has indeed taken place, a proper historical account would probably not make it seem quite so dramatic or abrupt as I have here suggested. There would be references to trends that were already under way between the World Wars, to the prophetic writings of J.D.Bernal and others, and to the profound effects of war-time developments on the scale and influence of the sciences and their associated technologies. Many items in the current vocabulary of science policy were being formulated in the 1950s by Alexander King, from his post in OECD, and so on.

My guess is, moreover, that the concept of a 'new regime' or a 'new model' for science was already in the air towards the end of the 1960s, even though the big changes did not begin to take place on the ground until about a decade later. I am quite deliberately evading any question about the nature of this consciousness or how it developed. Jerry Ravetz' notion of 'industrialization' and Jean-Jacques Salomon's concept of 'technoscience' come to mind, as well the sharply contrasting works on the 'politics' of science by Don Price and Daniel Greenberg; but we still lack a serious historical study of the process of change.

What we also lack is an agreed sociological account of science under these new conditions. Arie Rip (1989) and others are working on this, but it is obviously extremely complex, and likely to become very controversial. The transition tends to be treated from an 'externalist' viewpoint, as if all that had happened was an intensification of the political, economic, military and industrial forces to which science has – on this view – always been highly responsive. In my opinion, there is a lot of work to be done in developing an alternative 'internalist' account, in which a relatively self-contained institution would be seen as going through a traumatic cultural change under the impact of these

forces. But these are issues for the scholars, who are invited to dispute them as they will.

The purpose of the present book is much less exalted. The scientific world is in turmoil. Working scientists, scientific leaders, industrial managers, government officials, academic authorities, and many others are seeking guidance on how to carry out their duties in a rapidly changing landscape of institutions and procedures. The most valuable guidance in these circumstances has to be strategic rather than tactical. It has to come from a broad understanding of what is happening. The actors in the drama need a 'mental model' of their world, located inside their own heads and conceived in their own terms. In the end, this will have to be based on deeper theoretical principles: for the moment, all I have to offer is this provisional analysis in the everyday language of organization folk.

1.4 How did it happen?

As we shall see, the causes of the transformation are quite complex and vary from country to country. For example, in the UK, until the end of the 1980s most active scientists would have described the various changes that had taken place over the previous 15 years as the unfortunate side effects of harsh economic policies, imposed by governments who were essentially obtuse to the long-term benefits of research. They saw present conditions as essentially 'abnormal', even though they had little evidence to suggest that there would be an eventual return to 'normal' conditions. In other words, it was all a question of resources: the troubles of science – like the troubles of the poor, as Bernard Shaw remarked – were due to not having enough money!

This interpretation is not unfounded, but it lacks historical depth. In 1963, Derek de Solla Price published a famous graph, showing that scientific activity had been expanding exponentially at a very high rate for about 300 years. He pointed out that if the publication of scientific papers went on growing

like that, doubling every fifteen years, then soon every man, woman and child in the country would have to be spending all their time doing research and writing scientific papers. This was an absurdity: it was time to ask when the expansion would stop, and what would happen to science when it met its own limits to growth.

In simple terms, this is what we must have been seeing in recent years. Conventional econometric studies indicate that the R&D activity of a developed country now takes somewhere between 2 and 3 per cent of the national income. The precise figures, nation by nation, year upon year, sector by sector, are much in dispute, but with the possible exception of Japan they all began to stick at about this level in the mid 1970s and have risen very little since.

Some people argue that this was a pause associated with a world economic depression, and insist that scientific expansion has resumed, or will resume shortly, in some fortunate countries. The response to that must be that none of the optimists are seriously suggesting that scientific activity is set to double in the next fifteen years, let alone make up for the years when it stood still. Can they be expecting to reach a situation where, say, 10 per cent of the gross domestic product (GDP) goes on R&D, i.e. more than most countries are willing to spend on health, or defence? Tell that to the Financial Secretary to the Treasury, or his/her equivalent, in the next Public Expenditure Survey negotiations, or their equivalent. Explain that in your party manifesto, or even in your not-very-high-tech company prospectus!

There is no law of nature ruling out substantial further growth, but there are some pretty reliable principles of politics against it. The likely prospect is that science will have to exist for the future *within a fixed or slowly growing envelope of resources*. Some people are discouraged by this thought, or regard it as a damaging or disloyal admission of weakness. They point to this or that other country where a courageous, far-seeing government has raised the science budget by a few percentage points – and ignore a number of other countries where this item has (most reluctantly!) had to take the brunt of (absolutely unavoidable!) economies in public spending. In spite of considerable variations from place to