UNIVERSITY OF GHANA
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50th Anniversary
Aggrey-Fraser-Guggisberg Memorial Lectures

BEYOND THE MARKET
Universities and Society in the 21st Century

MICHAEL GIBBONS

UNIVERSITIES AND SOCIETY

BEYOND THE MARKET: UNIVERSITIES AND SOCIETY IN THE 21ST CENTURY

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Aggrey-Fraser-Guggisberg Lectures delivered at the University of Ghana on March, 1999 on the occasion of the 50th Anniversary of the University

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To the staff, students and friends of the University of Ghana on the occasion of the University's 50th anniversary

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PREFACE

I was deeply honoured to participate in the celebration of the 50th anniversary of the University of Ghana and to be invited to give the Aggrey-Fraser-Guggisberg Memorial Lectures. These lectures recall the memory of Joseph Aggrey, the great African spokesman for racial harmony and equality; Alexander Fraser, the first principal of Achimota College, a far-sighted educationalist who saw clearly the potential of an educated Africa; and the administrator, Gordon Guggisberg, who was responsible for the growth and development of excellence in Achimota College. These three individuals between them set both the structure and the standards of excellence for higher education in Ghana. Being innovators, they would have known that innovation is not a one-off adjustment but a commitment to a process of continual change, and so it is appropriate that, from time to time, we come together to review progress and to consider what changes still need to be made. The distinguished speakers who have preceded me have, in one way or another, addressed this theme of innovation in the university and in society more generally, albeit from very different perspectives. I hope that at the end of these lectures you will agree that I have kept to this tradition.

I should perhaps say something about the provenance of the ideas presented here. Lecture 1 and the part of Lecture 2 concerned with the role of universities in economic development have been drawn from previously published work, notably from The *New Production of Knowledge: Science and Research in Contemporary Societies,* by M. Gibbons, C. Limoges, H. Nowotny, S. Schwartzman, P. Scott and M. Trow, published by Sage in 1994. The parts of Lecture 2 concerned with the emergence of Mode 2 society and much of Lecture 3 draw upon as yet unpublished work being carried out by M. Gibbons, H. Nowotny and P. Scott. As these ideas are still being developed, it is possible that they may have been modified when a final text is ready for publication. I want to acknowledge the contributions of my colleagues, H. Nowotny and P. Scott, to the substance of these lectures. Of course, I accept full responsibility for what I have written, but I ask their indulgence if I have in any way misrepresented or inadequately presented the ideas which they have allowed me to share.

My wife Gillian and I want to express our special gratitude to Ivan and Nana Addae-Mensah and to George and Teresa Daniel. For the Vice-Chancellor and Registrar, in particular, the 50th anniversary celebrations must have been among the busiest of times. Yet, they found time to spend with us and saw that we were introduced to the truly wonderful country that Ghana is. We thank them for this experience and for the memories of Ghana which will remain with us always.

March 1999 *Michael Gibbons*

PROLOGUE

It is an accepted part of contemporary discourse to speak of scientific revolutions. The first one, by common consent, began sometime in the 16th and 17th centuries and is most frequently associated with the names of Copernicus, Kepler, Galileo, and Newton. Since that first revolution, there have of course been many others. They too are associated with particular names: Harvey, Lyell, Boyle and Lavoisier; and, more recently, Heisenberg, Einstein, Crick and Watson. The contributions of each of these, and many more besides, have been described in terms of revolutions because they have transformed our ways of thinking about some aspect of the physical universe. In the 1960s, Thomas Kuhn generated a minor academic industry when, in his book, The *Structure of Scientific Revolutions*, he drew attention to the fact that scientific revolutions were discontinuous jumps — paradigm shifts in our ways of viewing the world. Kuhn's pioneering work did much to increase our understanding of scientific change and, in particular, taught us to explore more fully the distinction between revolutionary and normal science.

By contrast with scientific revolutions, it is much less common to speak of research revolutions. Research commonly refers to what scientists do and how they do it. A revolution, under this description, would be a shift of research practices and methods or techniques, rather than a change in how we think about the physical universe. However, the situation is further complicated by the conjunction of two terms science and research to create the term 'scientific research'. Scientific research refers to a particular way of 'doing' science — particular ways scientists generate knowledge using the accepted canons of empirical method. Unfortunately, the phrase 'scientific research' also carries the implication that other methods of identifying and solving problems are, or might in some way be, 'unscientific'; and in our society to be labelled unscientific is to be consigned to the outer fringes of respectability.

Despite these terminological difficulties, it will be argued in these lectures that we are in the midst of a research revolution. Using terms that will become more familiar in due course, we are witnessing the emergence of new forms of knowledge production; that is to say, new research practices and new forms of collaboration are transforming what 'scientists' do and how they do it. The new mode of knowledge production is transforming what it means to be a scientist and what is involved in doing 'good science'. As such, the research revolution touches the core beliefs and organizational structures of all the social institutions concerned with knowledge production — and none more so than the universities which from the end of the Second World War have become the primary institutions involved in the production of that particular kind of research known as pure science. It is to be expected, then, that any change in research practices, or in what it means to do good science, will be vigorously contested in the universities which have invested so much in a particular way of carrying out research. It is for this reason that these lectures will concentrate on the impact of changing research practices on academics and universities respectively. Though the research revolution is affecting the structure and organization of industrial laboratories and government research establishments as well, it is only the universities that have organized themselves to pursue and defend the values of one particular way of generating knowledge, while at the same time providing training for future generations of researchers. Other organizations can generate particular types of knowledge internally if they wish, for example by setting up R&D departments. But neither government laboratories nor industrial corporations have, so far at least, taken on the burden of training the next generations of researchers. And, since the organization of teaching and research are interconnected in universities in the contemporary definition of a university, changes in the way research is carried out which might move it away from the existing disciplinary structure are bound to create tensions between the — heretofore — symbiotic relationship between teaching and research.

In these lectures, the term 'research revolution' will be used heuristically to help throw light on the changing relations between science and research, on the one hand, and between universities and other knowledge-producing institutions, on the other. Broadly, we envisage a transition from a culture of science to a culture of research and, as we will see, this shift requires profound changes in the nature of knowledge production and of the institutions in which it is carried out. In terms which will be explored more fully later, the research revolution, in so far as it affects universities, can be described in terms of three phases or aspects of a more pervasive research revolution.

The first phase of the research revolution begins with the institutionalization of discipline-based science in universities which occurred massively after the end of the Second World War and which has continued to the present day. However, this process contained an instability — a heavy dependence on the state for funding. However, when the external conditions began to alter, that is, as the Cold War came to an end and governments began to question afresh the relation of science to the state, many academics responded by taking a more 'experimental' approach to their participation in research. This expansion of experimental behaviour and the greater variety of research practices to which it has by now given rise underpin a new culture which may be more accurately called a culture of research than a culture of science. The emerging research culture is characterized by a new mode of knowledge production which we have labelled Mode 2, to distinguish it from the more familiar research practices associated with disciplinary science, labelled Mode 1.

The second phase refers to that development which began in earnest in the 1970s when universities moved progressively from consultancy, through technology transfer, to taking equity, with others, in the capitalization of the knowledge generated through their own research. In becoming involved in the capitalization of knowledge, universities have indicated their intention to play a more direct role in economic development, a role that takes them beyond the provision of qualified manpower, on the one hand, or the provision of fundamental knowledge, on the other. To help understand the implications of this, the notion of 'Mode 2 society' is introduced. In line with the general characteristics of Mode 2 society, universities have adopted forms of organization and research practices which resemble those which can also be found in many industrial laboratories. Change, however, has not been in one direction only, from industry to the universities. Industry, too, has now adopted some of the forms of research and patterns of research behaviour which have been found successful in universities. Both types of organization have become more open and permeable to one another as their common interests in knowledge production have begun to converge.

The third phase traces the implications of the changes taking place in the second phase of the research revolution on the wider relationship between universities and society. It is argued that as universities open up and begin to play a more participative role in society as evidenced, for example, in the case of economic development, they are furthering a much larger social process in which institutional boundaries, in general, are becoming more permeable, scientific identities more blurred, and, as a consequence, research practices more diverse. In the third phase of the research revolution, universities are becoming more closely intertwined not only with industry but with society at many different levels. This means that many more academics now work in one, or perhaps several, problem contexts and have begun to adopt a variety of research practices. Both Mode 2 knowledge production and Mode 2 society are shown to exhibit similar characteristics of uncertainty, openness, flexibility and reflexivity, and this is used to support the contention that research and society have become linked in a coevolutionary process. One outcome, then, of the research revolution, so far, is the emergence of a new mode of knowledge production, linked in a coevolutionary process to parallel changes in society. This coevolutionary relationship yields no longer disinterested knowledge, nor merely useful knowledge, but socially-robust knowledge, which researchers and society produce jointly. The joint production of knowledge requires a new vision of science and new types of universities to promote it. Scientists who adopt this vision will be active in the *agora* and will take their universities not only into the market but beyond it.

Lecture 1

THE RESEARCH REVOLUTION — PHASE 1: FROM A CULTURE OF SCIENCE TO A CULTURE OF RESEARCH

Summary

In this lecture, we describe how universities took on the mantle of research. Of course, it was a special kind of research, the kind now identified with basic science. The outcome was the institutionalization within universities of a disciplinary structure which has continued in existence up to the present. The structure of disciplinary knowledge, which is labelled Mode 1, is contrasted with that of a new mode of knowledge production, called Mode 2. The purpose of this distinction is to set the stage for a description of a larger research revolution around which the three lectures are organized. The research revolution has proceeded, so far at least, in three phases. The first phase which brought research of a particular kind — basic research — into universities reflected the conditions of its inception: the Cold War and a social structure characterized by three largely distinct institutional formations that governed the funding and execution of research — the state, industry and the universities. These initial conditions have now largely disappeared. Research in support of military goals has been replaced by research aimed at improving international competitiveness and the quality of life in a large number of dimensions. This large scale shift in political and social priorities has meant that traditional institutional sources for the support of university research have either disappeared or have changed their orientation and launched out onto new programmes. Not surprisingly, these structural changes have provoked changes in the behaviour of many academics. Generally, they have adopted a wider range of experimental approaches to the types of research in which they are prepared to become involved. The cumulative result of this experimentation has been a shift in

research practices amongst scientists. In particular, research practices are no longer governed solely by the norms of discipline-based science. The emergence of new research practices underpins our argument that a new mode of knowledge production has come into existence.

INTRODUCTION

It is hardly controversial to assert that it is only recently that universities have organized themselves to carry out research. Although individual research activities can be found in universities going back to the 19th century and beyond, it is really only since the end of the Second World War that research – particularly basic research – has been institutionalized in the universities and become one of their core values. Throughout the 20th century, universities have added the function of generating new knowledge to their previous ones of preserving knowledge and transmitting it.

The research enterprise that has gradually been put in place in universities is guided by a set of research practices — a system of behavioural and institutional norms — which ensures that results are sound. These research practices set the terms of what shall count as knowledge, who shall be allowed to participate in its production, and how accreditation shall be organized. These practices have generated what is known as the disciplinary structure of science and this structure, in turn, has come to govern the management and organization of universities today. In particular, it should be noted that the disciplinary structure is specialist. Whether in sciences, the social sciences, or the humanities, specialism has been seen as a secure way to advance knowledge.

The disciplinary structure also organizes teaching by providing a framework for the curriculum. The disciplinary structure is the essential link which connects teaching and research and which underpins the argument that in universities they properly belong together. Of course, research not only adds to the stock of specialist knowledge but transforms it as well. The research enterprise is dynamic. Its research practices articulate the disciplinary structure and, over time, change what is regarded as the essential ideas, techniques and methods to be learned.

CHANGING RESEARCH PRACTICES: MODE 1 AND MODE 2

It is a characteristic of the research enterprise to break out of existing cognitive structures. But, today, the mode of knowledge production is also changing as new research practices are being introduced to cope with the complexities of the research questions which need to be addressed. Two modes of knowledge production — Mode 1 and Mode 2 — can be distinguished, each associated with a distinctive set of research practices. As indicated, most universities make use of a model of knowledge production that has a disciplinary basis. This structure provides the guidelines about what the important problems are, how they should be tackled, who should tackle them, and what should be regarded as a contribution to the field. In brief, the disciplinary structure defines what shall count as 'good science'. Because the disciplinary structure has been institutionalized in universities, naturally they have become the primary legitimators of this form of excellence. The currently-institutionalized mode of knowledge production is, for the purposes of this paper, labelled Mode 1. But a new mode of knowledge production may be emerging. The new mode of research production is appearing across the board in the sciences, the social sciences and the humanities. It is labelled Mode 2, and its characteristics are an essential ingredient to understanding the role of knowledge and curricula in the universities of the future.

Above all, the principal differences between Mode 1 and Mode 2 need to be clarified. The term Mode 1 refers to a form of knowledge production — a complex of ideas, methods, values, norms — that has grown up to control the diffusion of the Newtonian ideal of mathematical science to more and more fields of enquiry and ensure its compliance with what is considered sound scientific practice. Mode 1 is meant to summarize in a single phrase the cognitive and social norms which must be followed in the production, legitimation and diffusion of knowledge of this kind. For many, Mode 1 is identical with what is meant by science. Its cognitive and social norms determine what shall count as significant problems, who shall be allowed to practice science and what constitutes good science. Forms of practice which adhere to these rules are by definition 'scientific', while those that violate them are not. It is partly for these reasons that whereas in Mode 1 it is conventional to speak of science and scientists, it has been necessary to use the more general terms — knowledge and practitioners — when describing Mode 2. This is intended merely to highlight differences and not to suggest that practitioners of Mode 2 are not behaving according to the norms of scientific method.

The argument being developed in this lecture is that there is sufficient empirical evidence to indicate that a distinct set of cognitive and social practices is beginning to emerge and that they are different from those that govern Mode 1. The only question may be whether they are sufficiently different to require a new label, or whether they can be regarded simply as developments that can be accommodated within existing practices. The final answer to this question depends, in part, on how Mode 1 adapts to changing conditions in the economic and political environment of research.

Changes in practice provide an empirical starting point. They can be described in terms of a number of attributes which when taken together have sufficient coherence to suggest the emergence of a new mode of knowledge production. Analytically, the set of attributes are used to allow the differences between Mode 1 and Mode 2 to be specified. We summarize using terms which will be explored more fully below: in Mode 1, problems are set and solved in a context governed by the (largely academic) interests of a specific community. By contrast, Mode 2 knowledge is carried out in a context of application. Mode 1 is disciplinary while Mode 2 is transdisciplinary. Mode 1 is characterized by homogeneity, Mode 2 by heterogeneity. Organizationally, Mode 1 is hierarchical and tends to preserve its form, while Mode 2 is more heterarchical and transient. Each employs a different type of quality control. In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localized context. As such, it involves a much-expanded system of quality control.

SOME ATTRIBUTES OF KNOWLEDGE PRODUCTION IN MODE 2

In summary, then, Mode 2 is characterized by:

1. Knowledge produced in the context of application.
2. Transdisciplinarity.
3. Heterogeneity and organizational diversity.
4. Enhanced social accountability.
5 More broadly-based system of quality control.

Let us consider each of these characteristics in greater detail.

Knowledge Produced in the Context of Application

The relevant contrast here is between problem-solving which is carried out following the codes of practice relevant to a particular discipline, and problem-solving which is organized around a particular application. In the former, the context is defined in relation to the cognitive and social norms that govern basic research or academic science. Latterly, this has tended to imply knowledge production carried out in the absence of some practical goal. In Mode 2, by contrast, knowledge results from a broader range of considerations. Such knowledge is intended to be useful to someone, whether in industry or government, or society more generally, and this imperative is present from the beginning. Knowledge thus produced is always produced under an aspect of continuous negotiation, i.e. it will not be produced unless and until the interests of the various actors are included. Such is the context of application. Application, in this sense, is not product development carried out for industry, and the processes or markets that operate to determine what knowledge is produced are much broader than what is normally implied when one speaks about taking ideas to the market place. Nonetheless, knowledge production in Mode 2 is the outcome of a process in which supply-and-demand factors can be said to operate, but the sources of supply are increasingly diverse, as are the demands for differentiated forms of specialist knowledge. Such processes or markets specify what we mean by the context of application. Because they include much more than commercial considerations, it might be said that, in Mode 2, science is both in the market but also gone beyond it! In the process, knowledge production becomes diffused throughout society. That is why we also speak of socially-distributed knowledge.

Research carried out in the context of application might be said to characterize a number of disciplines in the applied sciences and engineering — e.g. chemical engineering, aeronautical engineering or, more recently, computer science. Historically, these sciences became established in universities but, strictly speaking, they cannot be called applied sciences, because it was precisely the lack of the relevant science that called them into being. They were genuinely new forms of knowledge, though not necessarily of knowledge production, because they too soon became the sites of disciplinary-based knowledge production in the style of Mode 1. These applied disciplines share with Mode 2 some aspects of the attributes of knowledge produced in the context of application. But, in Mode 2, the context is more complex. It is shaped by a more diverse set of intellectual and social demands than was the case in many applied sciences, and it may give rise to genuine basic research.

Transdisciplinarity

Mode 2 does more than assemble a diverse range of specialists to work in teams on problems in a complex applications-oriented environment. To qualify as a specific form of knowledge production it is essential that inquiry be guided by specifiable consensus as to appropriate cognitive and social practice. In Mode 2, the consensus is conditioned by the context of application and evolves with it.

The determinants of a potential solution involve the integration of different skills in a framework of action, but the consensus may be only temporary depending on how well it conforms to the requirements set by the specific context of application. In Mode 2, the shape of the final solution will normally be beyond that of any single contributing discipline. It will be transdisciplinary.

Transdisciplinarity has four distinct features. Firstly, it develops a distinct but evolving framework to guide problem-solving efforts. This is generated and sustained in the context of application and not developed first and then applied to that context later by a different group of practitioners. The solution does not arise solely, or even mainly, from the application of knowledge that already exists. Although elements of existing knowledge must have entered into it, genuine creativity is involved and the theoretical consensus, once attained, cannot easily be reduced to disciplinary parts.

Secondly, because the solution comprises both empirical and theoretical components, it is undeniably a contribution to knowledge, though not necessarily disciplinary knowledge. Though it has emerged from a particular context of application, transdisciplinary knowledge develops its own distinct theoretical structures, research methods, and modes of practice, though they may not be located on the prevalent disciplinary map. The effort is cumulative, though the direction of accumulation may travel in a number of different directions after a major problem has been solved.

Thirdly, unlike Mode 1, where results are communicated through institutional channels, the results are communicated to those who have participated as they participate and so, in a sense, the diffusion of the results is initially accomplished in the process of their production. Subsequent diffusion occurs primarily as the original practitioners move to new problem contexts, rather than through reporting results in professional journals or at conferences. Communication links are maintained partly through formal and partly through informal channels.

Fourthly, transdisciplinarity is dynamic. It is problem-solving capability on the move. A particular solution can become the cognitive site from which further advances can be made, but where this knowledge will be used next and how it will develop are as difficult to predict as are the possible applications that might arise from discipline-based research. Mode 2 is marked especially, but not exclusively, by the ever-closer interaction of knowledge production with a succession of problem contexts. Even though problem contexts are transient, and problem-solvers highly mobile, communication networks tend to persist, and the knowledge contained in them is available to enter into further configurations.

Heterogeneity and Organizational Diversity

Mode 2 knowledge production is heterogeneous in terms of the skills and experience people bring to it. The composition of a problem-solving team changes over time as requirements evolve. This is not planned or co-ordinated by any central body. As with Mode 1, challenging problems emerge, if not randomly, then in a way which makes their anticipation very difficult. Accordingly, it is marked by:

i. an increase in the number of potential sites where knowledge can be created: no longer only universities and colleges, but also non-university institutes, research centres, government agencies, industrial laboratories, think-tanks, consultancies — and in the interaction of all of these;

ii. the linking of sites together in a variety of ways — electronically, organizationally, socially, informally — through functioning networks of communication;

iii the simultaneous differentiation, at these sites, of fields and areas of study into finer and finer specialities. The recombination and reconfiguration of these subfields form the bases for new forms of useful knowledge. Over time, knowledge production moves increasingly away from traditional disciplinary activity into new societal contexts.

In Mode 2, flexibility and response time are the crucial factors and because of this the types of organization used to tackle these problems may vary greatly. New forms of organization have emerged to accommodate the changing and transitory nature of the problems Mode 2 addresses. Characteristically, in Mode 2, research groups are less firmly institutionalized: people come together in temporary work teams and networks which dissolve when a problem is solved or redefined. Members may then reassemble in different groups involving different people, often in different locations, around different problems. The experience gathered in this process creates a competence which becomes highly valued and which is transferred to new contexts. Though problems may be transient and groups short-lived, the organization and communication pattern persists as a matrix from which further groups and networks, dedicated to different problems, will be formed. Mode 2 knowledge is thus created in a great variety of organizations and institutions, including multinational firms, network firms, small hi-tech firms based on a particular technology, government institutions, research universities, laboratories and institutes, as well as national and international research programmes. In such environments, the patterns of funding exhibit a similar diversity, being assembled from a variety of organizations with a diverse range of requirements and expectations which, in turn, enter into the context of application.

Enhanced Social Accountability

In recent years, growing public concern about issues to do with the environment, health, communications, privacy and procreation, and so forth, have had the effect of stimulating the growth of knowledge production in Mode 2. Growing awareness about the variety of ways in which advances in science and technology can affect the public interest has increased the numbers of groups who wish to influence the outcome of the research process. This is reflected in the varied composition of the research teams. Social scientists work alongside natural scientists, engineers, lawyers and businessmen, because the nature of the problems requires it. Social accountability permeates the whole knowledge-production process. It is reflected not only in interpretation and diffusion of results, but in the definition of the problem and the setting of research priorities, as well. An expanding number of interest, and so-called concerned groups are demanding representation in the setting of the policy agenda as well as in the subsequent decision-making process. In Mode 2, sensitivity to the impact of the research is built in from the start. It forms part of the context of application.

Contrary to what one might expect, working in the context of application increases the sensitivity of scientists and technologists to the broader implications of what they are doing. Operating in Mode 2 makes all participants more reflexive. This is because the issues which forward the development of Mode 2 research cannot be specified in scientific and technical terms alone. The research towards the resolution of these types of problems has to incorporate options for the implementation of the solutions, and these are bound to touch the values and preferences of different individuals and groups which have been seen as traditionally outside the scientific and technological system. They can now become active agents in the definition and solution of problems as well as in the evaluation of performance. This is expressed partly in terms of the need for greater social accountability, but it also means that the individuals themselves cannot function effectively without reflecting — trying to operate from the standpoint of — all the actors involved. The deepening of understanding that this brings, in turn, has an effect on what is considered worthwhile doing and, hence, on the structure of the research itself. Reflection of the values implied in human aspirations and projects has been a traditional concern of the humanities. As reflexivity within the research process spreads, the humanities too are experiencing an increase in demand for the kinds of knowledge they have to offer.

Quality Control

Criteria to assess the quality of the work and the teams which carry out research in Mode 2 differ from those of more traditional disciplinary science. Quality in Mode 1 is determined essentially through the peer-review judgements about the contributions made by individuals. Control is maintained by careful selection of those judged competent to act as peers which is in part determined by their previous contributions to their discipline. So, the peer-review process is one in which quality and control mutually reinforce one another. It has both cognitive and social dimensions, in that there is professional control over what problems and techniques are deemed important to work on, as well as who is qualified to pursue their solution. In disciplinary science, peer review operates to channel individuals to work on problems judged to be central to the advance of the discipline. These problems are defined largely in terms of criteria which reflect the intellectual interests and preoccupations of the discipline and its gatekeepers.

In Mode 2, additional criteria are added through the context of application which now incorporates a diverse range of intellectual interests as well as other social, economic or political ones. To the criterion of intellectual interest and its interaction, further questions are posed: 'Will the solution, if found, be competitive in the market? Will it be cost-effective? Will it be socially acceptable?' Quality is determined by a wider set of criteria that reflects the broadening social composition of the review system. This implies that 'good science' is more difficult to determine. Since it is no longer limited strictly to the judgements of disciplinary peers, the fear is that control will be weaker and result in lower quality work. Although the quality control process in Mode 2 is more broadly based, it does not follow that because a wider range of expertise is brought to bear on a problem that it will necessarily be of lower quality. It is of a more composite, multidimensional kind.

THE COHERENCE OF MODE 2

These attributes, while not present in every instance of Mode 2, do, when they appear, together have a coherence which gives recognizable cognitive and organizational stability to the mode of production. Just as in Mode 1 cognitive and social norms are adjusted to one another and produce disciplinary knowledge, so in Mode 2 new norms are emerging that are appropriate to transdisciplinary knowledge. In all kinds of knowledge production, individual and collective creativity find themselves in a varying relationship of tension and balance. In Mode 1, individual creativity is emphasized as the driving force of development and quality control, operating through disciplinary structures organized to identify and enhance it; while the collective side, including its control aspects, is hidden under the consensual figure of the scientific community. In Mode 2, creativity is mainly manifest as a group phenomenon, with the individual's contributions seemingly subsumed as part of the process, and quality control being exercised as a socially-extended process which accommodates many interests in a given application process. Just as in Mode 1, knowledge was accumulated through the professionalization of specialization largely institutionalized in universities, so in Mode 2, knowledge is accumulated through the repeated configuration of human resources in flexible, essentially transient forms of organization. The loop from the context of application, through transdisciplinarity, heterogeneity and organizational diversity, is closed by new adaptive and contextual forms of quality control. The result is a more socially accountable and reflexive mode of science. Many examples of these phenomena could be drawn from the biomedical and environmental sciences.

Although Mode 1 and Mode 2 are distinct modes of production, they interact with each other. Specialists trained in the disciplinary sciences do enter Mode 2 knowledge production. While some may return to their original disciplinary base, others will choose to follow a trail of complex problem-solving that is set by a sequence of application contexts. Conversely, some outputs of transdisciplinary knowledge production, particularly new instruments, may enter into and fertilize any number of disciplinary sciences. Because of such interactions, there may be a temptation to reduce the new form to more familiar ones, to collapse Mode 2 into Mode 1, and thereby to minimize the significance of the changes outlined above. Though Mode 2 knowledge production interacts with Mode 1, it is different from it. Terms in common usage — such as pre-competitive research, strategic research, mission-oriented research, applied research, or industrial research and development — still carry many of the social preconceptions of the function of disciplinary science; in particular, the idea that disciplinary science provides the inexhaustible well for future applications. The beliefs that, if the disciplines do not flourish then fundamental insights will be missed, or that foundational theoretical knowledge cannot be produced and sustained outside of disciplinary structures, are deeply held and may account for the persistence of the linear model of innovation in policy debates. Yet, it is increasingly in computer, material, biomedical and environmental sciences that theories are developed in the context of application, and these continue to fertilize lines of intellectual advance that lie outside disciplinary frameworks. In Mode 2, things are done differently and when enough things are done differently, one is entitled to say that a new form has emerged.

The reasons for the emergence of this new mode of knowledge production at the present time are not hard to find. In the first place, Mode 1 has been eminently successful. Scientists long ago discovered that the most effective way to achieve this was through a process of specialization in the cognitive realm, of professionalization in the social realm, and institutionalization in the political realm. This pattern has governed the diffusion of science from one area of activity to another, and it has tended to treat harshly those who tried to circumvent its controls. The disciplinary structure of knowledge reflects the successful operation of this pattern of cognitive and social control. But over the years, the numbers of graduates grounded in the ethos of research, and holding some specialist skill, have been too large for them all to be absorbed within the disciplinary structure. Some of them have gone into government laboratories, others into industry, while others have established their own laboratories, think-tanks and consultancies. As a consequence, the number of sites where competent research can be carried out has increased. These constitute the intellectual resources for, and social underpinnings of, Mode 2. Seen from another perspective, one might also say that the creation of many new sites is an unintended result of the process of massification of education and research.

The development of rapid transportation, information and communication technologies has created a capability which allows these sites to interact. Mode 2 is critically dependent upon the emerging computer and telecommunication technologies and will favour those who can afford them. The interactions amongst these sites of knowledge have set the stage for an explosion in the numbers of interconnections and possible configurations of knowledge and skill. The outcome can be described as a socially-distributed knowledge production system. In this system, communication increasingly takes place across existing institutional boundaries. The outcome is a web whose nodes are now strung out across the globe and whose connectivity grows daily. Not surprisingly, when traditional scientists begin to participate in this, they are perceived to be weakening disciplinary loyalty and institutional control. But contexts of application are often the sites of challenging intellectual problems, and involvement in Mode 2 allows access to these and promises close collaboration with experts from a wide range of backgrounds. For many, this can be a very stimulating work environment. Mode 2 shows no particular inclination to become institutionalized in the conventional pattern. The established structure of science can be expected to be concerned about this and about how quality control will be assured in a socially-distributed knowledge production system, but it is now a fact of life. Mode 2 is a response to the needs of both science and society. It is irreversible. The problem is how to understand and manage it.

THE EMERGENCE OF A SOCIALLY-DISTRIBUTED KNOWLEDGE PRODUCTION SYSTEM

The key change to note is that knowledge production is becoming less and less a self-contained activity. As practised currently, it is neither the science of the 'universities' nor the 'technology' of industry. It is no longer the preserve of a special type of institution, from which knowledge is expected to spill over, or spin off, to the benefit of other sectors. Knowledge production, not only in its theories and models but also in its methods and techniques, has spread from academia to many different types of institutions. It is in this sense that knowledge production has become a socially-distributed process. At its base lies the expansion of the numbers of sites which form the sources for a continual combination and recombination of knowledge resources. What we are seeing is the 'multiplication of the nerve endings of knowledge'.

The socially-distributed knowledge production system has five principal characteristics:

1. There is an increasing number of places where recognizably-competent research is being carried out. This can easily be demonstrated by consulting the addresses of the authors of scientific publications, though change is taking place so rapidly that the full extent of the social distribution of knowledge production is probably no longer fully captured by the printed word.

2. These sites interact with one another and, thereby, broaden the base of effective interaction. Thus, contributions to the stock of knowledge are derived from an increasing number of tributarial flows from various types of institutions that both contribute to, and draw from, the stock of knowledge.

3. The dynamics of socially-distributed knowledge production lie in the flows of knowledge and in the shifting patterns of connectivity amongst these flows. The connections may appear to be random, but they move with the problem context rather than according either to disciplinary structures or the dictates of national science policy.

4. The number of interconnections is accelerating, so far apparently unchannelled by existing institutional structures, perhaps for the reason that these connections are intended to be functional and to survive only as long as they are useful. The ebb and flow of connections follow the paths of problem interest, and the paths of problem interest are no longer determined by the disciplinary structure of science.

5. The new mode of knowledge production exhibits heterogeneous, rather than homogeneous, growth. New sites of knowledge production are continually emerging which, in their turn, provide intellectual points of departure for further combinations or configurations of researchers. In this sense, the socially-distributed knowledge production system exhibits some of the properties that are often associated with self-organizing systems in which the communication density is increasing rapidly.

In summary, the distributed character of knowledge production constitutes a fundamental change both in terms of the *numbers* of possible sites of expertise and in their degree of *interactivity.* To it are linked other dimensions of change which cannot be explored here but which include: the increasing contextualization of knowledge (including its marketability); the blurring of boundaries between disciplines and institutions and across institutional boundaries; the fungibility of scientific careers; the transdisciplinarity of research (and not only of hot topics); and the increasing importance of hybrid *fora* — groups constituted through the interplay of experts and non-experts as social actors — in the shaping of knowledge. Of course, all of this has implications for the management of the knowledge-production process and for the maintenance of quality control within it. A discussion of these, however, will have to wait for another occasion.

SOME IMPLICATIONS OF MODE 2

The aim has been to draw attention to the existence of a number of attributes associated with the new kind of production of knowledge, and to show that these attributes possess sufficient coherence to be called a new mode of production. We argue that, as Mode 1 has become the mode of production characteristic of disciplinary research institutionalized largely in universities, so Mode 2 is characterized by transdisciplinarity and institutionalized in a more heterogeneous and flexible socially-distributed system. Having outlined its main features, we are now in a position to consider the implications of this development.

The massification of higher education and the appropriation, after the Second World War, by the universities of a distinct research function have produced increasing numbers of people familiar with the methods of research, many of whom are equipped with specialized knowledge and skills of various kinds. Massification is now a strongly entrenched phenomenon; it is international in scope and is unlikely ever to be reversed. On the supply side, the numbers of potential knowledge producers flowing out of higher education is increasing and will continue to do so.

However, this expansion of higher education has an implication that has so far been little examined. Not only are an increasing number of people familiar with science and competent in its methods, but also many of these are engaged in activities which have a research dimension. They have brought their knowledge and skills to bear on a wide range of problems, in contexts and situations often very remote from the universities where they were originally trained. Scientific and technological knowledge production are now pursued not only in universities but also in industry and government laboratories, in think-tanks, research institutions and consultancies, etc. The expansion of higher education, internationally, has meant that the numbers of potential sites where recognizably-competent research is being performed have increased. The implication, not yet fully grasped, is that to the extent that universities continue to produce quality graduates, they undermine their monopoly as knowledge producers. Many graduates have subsequently become competent to pass judgement on university research, and belong to organizations which might do the job just as well. Universities are coming to recognize that they are now only one player, albeit still a major one, in a vastly-expanded knowledge production process.

In parallel with this vast expansion in supply has been the expansion of the demand for specialist knowledge of all kinds. The interaction of supply and demand for specialist knowledge has many characteristics of a market, but there are some crucial differences. The function of a market is to bring supply and demand into balance and to establish the terms of exchange. Traditionally, markets are understood to establish the prices at which the supply and demand of particular commodities will be in equilibrium. A market is a mechanism for allocating resources — labour and capital — to the production of commodities. It works most effectively in cases for which there is already a clearly-specified demand and for which the factors of production are available. But markets also have a dynamic component. They can call forth new commodities the demand for which barely exists, or, conversely, they can stimulate demand for commodities whose features are as yet unclear. In dynamic markets, supply and demand mutually articulate one another.

Knowledge plays a crucial role in many dynamic markets. It is an important source of created comparative advantage for both its producers and users of all kinds, and not only in industry. In some of these markets, the terms of trade are more complex than may be indicated by comparative levels of costs and prices, and the medium of exchange more subtle than money. For example, in those markets which articulate the supply and demand for knowledge about the environment, there are many different kinds of exchanges amongst the many participants, but the medium is a more complex blend of individual and social values than could be captured by monetary values alone. Because comparative advantage cannot be reduced to economic criteria, such markets may be described as social rather than commercial markets, but they are markets nonetheless. Within such markets, the sources of demand are manifold: they come from society in the form of public enquiries of various kinds; from governments in regard to a wide range of issues, such as the adverse consequences of high-risk technologies; and from a whole spectrum of institutions, interest groups and individuals who need to know more about particular matters. This complex set of actors form hybrid *fora* which provide stimuli for both the supply and demand of specialized knowledge. Both theoretical and practical knowledge is generated in these *fora*.

The requirement of industry for knowledge, particularly for the results of scientific and technological research, is widely appreciated. The expansion of demand for a flow of specialist knowledge amongst firms is perhaps less well understood. Specialist knowledge is often a key factor in determining a firm's comparative advantage. As the pressures of international competition increase, firms have tried to meet the challenges presented through the introduction of new technologies. New technology is a necessary but not sufficient condition for successful innovative performance and, increasingly, technological innovation depends upon using specialized knowledge to develop technologies in directions dictated by competitive pressures. Specialist knowledge is used partly because it provides a constantly-replenishable source of created comparative advantage, and partly because it can be difficult to imitate, particularly by firms whose national culture does not yet support a well-articulated science and technology infrastructure. Since, in many sectors, these firms represent the spearhead of international competition, specialized knowledge is at a premium, but its acquisition is difficult and often too expensive for individual firms to replicate entirely in-house. To meet this exigency, firms have become involved in a complex array of collaborative arrangements involving universities, governments and other firms, sometimes from within the same sector. In each case, supply and demand are mediated by a market mechanism, but, again, it is not — or need not be — a narrowly commercial one.

In these markets, knowledge itself may continuously be sought, but more often than not, it is not readily available to be bought or sold, off the shelf, like other commodities. It is increasingly generated in the market nexus itself. In producing specialized knowledge, markets operate to configure human and physical resources in a particular context of application. As a consequence of intensifying competition, the numbers of these contexts is expanding but they are also transient. Markets are dynamic. They set new problems more or less continuously, and the sites of knowledge production and their associated networks of communication move on. Knowledge is produced by configuring human capital. However, unlike physical capital, human capital is potentially more malleable. Human resources can be configured again and again to generate new forms of specialized knowledge. The ability to do this lies at the heart of many economies of scope which are currently regarded as crucial to survival in the marketplace.

The core of our thesis is that the parallel expansion in the numbers of potential knowledge producers on the supply side, and the expansion of the requirement of specialist knowledge on the demand side, are creating the conditions for the emergence of a new mode of knowledge production. The new mode has implications for all the institutions — whether universities, government research establishments, or industrial laboratories — that have a stake in the production of knowledge. The emergence of markets for specialized knowledge means that, for each set of institutions, the game is changing, though not necessarily in the same ways or at the same speed. There is no imperative for all institutions to adopt the norms and values of the new mode of knowledge production. Some firms and universities are already a long way along the path of change, and this is manifested in the types of staff they recruit and in the complex range of collaborative agreements that they enter. However, for the institutional goals to be achieved, the rules governing professional development, and the social and technical determinants of competence, will all need to be modified according to the extent that the new mode of production becomes established.

The new mode — Mode 2 — is emerging alongside the traditional disciplinary structure of science and technology — Mode 1. Indeed, Mode 2 is an outgrowth of Mode 1. In order to make clear what is involved in the new mode of production, the attributes of Mode 2 have been contrasted with those of Mode 1. From this analysis it will be clear that Mode 2 is not supplanting but, rather, supplementing Mode 1. Mode 2 constitutes a distinct mode with its own set of cognitive and social norms. Some of these contrast sharply with deeply-held beliefs about how reliable theoretical and practical knowledge should be generated, but they should not for that reason be regarded as either superior or inferior to those operating in Mode 1. They are simply different. To some extent, however, the way in which Mode 2 becomes established in a particular context will be determined by the degree to which Mode 1 institutions wish to adapt themselves to the new situation.

The emergence of a socially-distributed knowledge production system means that this type of knowledge is both supplied by, and distributed to, individuals and groups across the social spectrum. Communications at institutional levels tend to be bypassed because of the need for rapid, flexible responses to problems. Although one may expect variety to the extent that Mode 2 becomes dominant, it is a correlate to the socially-distributed knowledge production system which is now emerging. To the extent that institutions become permeable, then Mode 2 can operate. The degree to which current knowledge-producing institutions become more permeable will not alter the fundamental fact that knowledge production is becoming more widely distributed. That is to say: it takes place in many more types of social setting; it is no longer concentrated in a relatively-small number of institutions; and it involves many different types of individuals and organizations in a vast array of different relationships. Such behaviour will simply cause other linkages to become established which in the end may leave them scientifically and technically isolated from some intellectual developments.

Socially-distributed knowledge production is tending towards the form of a global web whose numbers of interconnections are being continuously expanded by the creation of new sites of production. As a consequence, in Mode 2 communications are crucial. At present, this is maintained partly through formal collaborative agreements and strategic alliances, and partly through informal networks backed-up by rapid transportation and electronic communications. But this is only the tip of the iceberg. To function, the new mode needs to be supported by the latest that telecommunications and computer technologies have to offer. Mode 2, then, is both a cause and a consumer of innovations which enhance the flow and transformation of information.

It is one of the imperatives of Mode 2 that exploitation of knowledge requires participation in its generation. In socially distributed knowledge production, the organization of that participation becomes a crucial factor. The goals of participation are no longer simply to secure some national advantage, commercial or otherwise. Indeed, the very notion of what constitutes an economic benefit, and for whom, is at the root of many debates not only in environmental science but also in biotechnology and the medical sciences as well. For example, the current push towards 'clean' technologies is about more than just economic benefit. It is also about stabilizing collapsing ecological systems, the health and well-being of populations, as well as commercial gain. This is to say that although Mode 2 has been exemplified here only in relation to knowledge production, it has coevolutionary effects in other areas — for example in economics, the prevailing division of labour, and our sense of community.

The appearance of Mode 2 is creating new challenges for governments. National institutions need to be decentralized — to be made more permeable — and governments through their policies can promote change in this direction. These policies will be more effective if, concurrently, they become more proactive brokers in a knowledge-production game which includes, in addition to the interests and ambitions of other nations, the policies of supranational institutions, such as the European Union. The effectiveness of governments' brokering abilities now underlies the competitiveness of their national innovation systems. This will be reflected both in their ability to participate in knowledge production that may be taking place anywhere in the world, and in their ingenuity in appropriating that knowledge with their innovation system.

Ingenuity is required because sooner or later collaboration must turn into competition. This is in the nature of the wealth-creating process as it is presently constituted. Simply to monitor the interface between competition and collaboration would be a difficult enough task. To manage it to national advantage is a challenge that governments will neglect to their cost. As with scientists and technologists, governments too need to learn to operate in the context of application, and increasingly this involves working with supranational institutions. Some of these have political, social and economic dimensions as in the case of the EU in Western Europe; others are more narrowly economic in their aims as with the North American Free Trade Agreement (NAFTA), or the General Agreement on Trade and Tariffs (GATT). A key question is whether these supranational institutions can play a role in the socially-distributed knowledge production and, correlatively, how individual nations ought to position themselves relative to these larger systems.

It is perhaps ironic that it should fall to governments to punch holes in the very institutions that in an earlier day were established to maintain its science and technology capability. But along with many other apparently fixed notions, the purpose and function of these institutions need to be rethought in the light of the emergence of Mode 2. This will reveal the need for a different approach to policy, particularly for the integration of education, science and technology and competition policy into a comprehensive innovation policy that is sensitive to the fact that knowledge production is socially distributed. In Europe, particularly, national policies that will enhance the potential of national institutions need to be developed in concert with those of the EU. The developing countries, too, need to take stock. For many of them, access will continue to be a problem, not only because capability is lacking, but also because governments there still model their scientific and technological institutions on assumptions that no longer apply to the kinds of scientific and technological activities on which their aspirations depend.

CONCLUSIONS

In the new mode of knowledge production, research in many important areas is cutting loose from the disciplinary structure and generating knowledge which, so far at least, does not seem to be drawn to institutionalize itself in university departments and faculties in the conventional way. At times, it often seems that research centres, institutes and 'think-tanks' are multiplying on the periphery of universities, while faculties and departments are becoming the internal locus of teaching provision. What, then, are the implications of Mode 2 for research in universities?

Leading-edge Research

Universities are now confronted with the challenge of how to accommodate the emergence of socially-distributed knowledge production. The establishment of the research agenda and its funding are increasingly the outcome of a dialogue between researchers and users, regulators, interest groups, etc.; and unless that dialogue produces a consensus, no research will be done. Leading-edge research has become a more participative exercise, involving many actors and experts who move less according to the dynamics of their original disciplines and more according to problem interest. Important intellectual problems are emerging in a 'context of application', and scientists want to work on them. Pursuing problem interest means that academics will be away from the university, working in teams, with experts from a wide range of intellectual backgrounds, in a variety of organizational settings. They will contribute problems solutions that cannot be easily reduced to a recognizable 'disciplinary contribution'. Those individuals who would carry out research in this mode must adopt a different set of research practices and take a different perspective on their careers. But, if they do so, they will be out of synch with the existing reward structure of universities. Some say that the rubric of survival in academic research is changing from 'publish or perish' to 'participate or perish'. How can existing university structures be modified to account for this fact?

Research and Teaching

Universities that wish to participate at the forefront of research will be active in Mode 2. At the very least, they have to become more open and porous *vis-à-vis* the wider community, with 'fewer gates and more revolving doors'. They will have to become much more entrepreneurial in the ways that they utilize their 'intellectual' capital, and this may mean experimenting with a much broader range of contractual employment arrangements. But, to the extent that universities go down this road, they will be helping to establish two parallel structures within universities: one which will carry teaching (Mode 1) and another for research (Mode 2).

In the new, open, more flexible structures that are carrying research, knowledge is codified and transmitted in a different way. Information about the state of the art on a particular question resides less in conventional paper publications — whether in paper or electronic form — than in the collective memory of the problem-solving teams. But, as we have seen, these teams are transient groupings. They form and dissolve according to the imperative of problem-solving interest and the memory of what has been accomplished moves with the relevant experts. It is doubtful if traditional modes of publication will be sufficient to grasp the knowledge and information that is produced in this way. How can knowledge produced in this way be translated into curricula? If it is not codified in books and/or papers, how will it be transmitted?

In brief, how will these structures which support teaching be related to one another? If they are to be related, what would the organization of such universities look like? If research grows and develops in the manner suggested — outside disciplinary structures, more in the context of application — how will the results of research be absorbed by the wider academic community and, through them, make their way into the development of new curricula?

Institutional Management: Cores and Peripheries

Universities in which technology interchange has become a core value, that have 'multiplied up' the number of partnerships and alliances that they are involved in, and which share their staff and other resources with problem-solving teams distributed around the world, need to be organized differently. The existence of Mode 2 must induce changes in current organizational structures, and this is perhaps nowhere more evident than in the perspective that universities will have to take on their intellectual capital.

Heretofore, universities have been seen as 'factories' in which a variety of intellectual capital is employed. Faculty have been specialists, working according to the research practices which we have identified with Mode 1. The unit of organization has been the department and graduate students have been the apprentices. Following the dictates of Mode 1, universities have elaborated the departmental structure and have recruited the best staff they could afford. Universities have often seen themselves as 'owning' this intellectual resource and have used it to establish their reputations *vis a vis* one another. Permanent faculty working on specialist topics according to the criteria of 'good science' set down by Mode 1 is the arrangement that dominates the university scene, despite the fragmentation that it encourages and the financial resources it requires.

In Mode 2, as we have seen, different rules operate. In the context of application, the research agenda is formed and funds attracted in a different way. Researchers work in teams on problems that are set in a very complex social process and are relatively transient. And they move about according to the dictates of problem interest. Participation in these problem contexts is necessary to keep up with what is going on. As a consequence, some of the best academics are tunnelling out of their institutions to join problem configurations of various kinds. To some this is seen as a weakening of loyalty both to their institution and to their discipline. If they intend to operate at the leading edge of research, universities need to change their view of intellectual capital. They need to ensure that they are able to participate in the appropriate problem-solving contexts. Equally, so diverse and volatile are these that no university can afford to keep 'in-house' all the human resources they would need to guarantee a presence everywhere. Universities need to learn to exploit all the advantages to be had by sharing resources. Here, lies a fundamental challenge of the socially-distributed knowledge production system!

A model exploiting the economies of shared resources would seem to demand a relatively small core of permanent full-time faculty, together with a much larger periphery of other 'experts' that are associated with the university in various ways. To achieve this, universities will need to experiment with a much wider range of employment contracts, and accept the fact that they will not be able to own outright all the human resources that they need. To an extent this puts the universities in a Catch 22 situation. On the one hand, the demands on universities in terms of both teaching and research is not only growing but it is also diversifying and will continue to do so. On the other hand, the costs of holding in-house all the resources it needs to accommodate this expansion is not only too expensive but also not flexible enough to meet changing demand. Vice-Chancellors in the future will be distinguished by their ability to utilize their own intellectual capital in conjunction with intellectual capital held by others, in a way that maximizes their institutions' goals. It will not presume that every member of staff needs to be a full-time employee. How will these 'others' fare in the university setting? How will their contributions be recognized? Will they be promoted and according to what criteria? How much will they cost? How will they relate to graduate students? Will they have to do any teaching? These are some of the questions that need to be asked, but it seems clear to me that they cannot be answered without changing the nature of universities substantially.

The argument is that there are now two coexisting modes of knowledge production — Mode 1 and Mode 2. For the future, the key question facing each university has less to do with deciding whether to be a research or a teaching institution, than deciding between which modes of research — and teaching — to adopt. However, to the extent that universities choose to move in the direction of Mode 2, they set themselves the difficult internal problem of keeping research and teaching in some sort of relationship — if, that is, it is still thought worthwhile arguing that a close association of teaching and research ought to be a hallmark of a university.

Technology Transfer

Research partnerships are increasing, and they are important for universities as institutions as well as for academics professionally. This is well illustrated by current developments in the field of technology transfer. Of late, many universities have become interested in technology transfer and in commercializing the results of their research. Many have invested significant sums in setting up science parks, technology transfer centres and venture capital funds to assist academics in commercializing their work. But, we would suggest, the model is not so much wrong as out of tune with the research practices of Mode 2. The model of technology transfer which is operative at the moment is based on the image of the innovative process as a 'relay race'. In this view, some of the discoveries made by scientists within university departments are deemed to be capable of commercialization, were it not for the gap between the university and the marketplace. In other words, the ideas are there, but for some reason the baton is not being successfully passed between universities and industry in the race to commercialization. The solution to this dilemma has been to create a range of technology transfer organizations to bridge this gap — to reduce the probability that the baton will be dropped and the race lost.

These organizations are meant to mediate between the world of academe and the world of business. But, in Mode 2, research is carried out in the context of application in which there is an ongoing dialogue between interested parties — including producers and users of knowledge — from the beginning. In Mode 2, universities that want play a role in the commercialization of research need to be involved in the discussion from the beginning. It is certainly not a game that can be played by limiting one's role to the discovery end of the process. In the next lecture, we will examine the evolving relationship between universities and industry, as universities embrace the next phase of the research revolution in which they seek to play a more active role in economic development. We will see, then, that the 'relay race' model of technology transfer needs to be radically modified, if not abandoned altogether.

Lecture 2

THE RESEARCH REVOLUTION — PHASE 2: UNIVERSITIES IN ECONOMIC DEVELOPMENT

Summary

We turn now to the second phase of the research revolution: the embracing by the universities of a central role in economic development. We introduce the notion of Mode 2 society and argue that this type of society is coevolving, in the sense that it shares certain characteristics with Mode 2 knowledge production. The primary reason for introducing the notion that society and science are linked in a coevolutionary process is to provide some theoretical support for the much-observed phenomenon that the organization and practice of research in industrial and university environments are becoming more alike. The notions of static and dynamic competition are introduced to help explain the implications for universities of adding to their function of providing trained manpower and some consultancy for industry, a new function which involves them in the joint production of knowledge through such new arrangements, such as strategic research alliances. The shift in the universities' core values implied by their becoming involved with industry in the joint production of knowledge are then outlined. We conclude, however, that such involvement, while it can be accommodated within the research practices prescribed by Mode 1, is only a half-way house to the establishment of a genuine Mode 2 university.

INTRODUCTION

The next phase of the research revolution is one in which universities strive to play a more central role in economic development. This aspect of the research revolution, sometimes called the second academic revolution, is a complex affair, involving many shifts in perspectives, identities and organizational structures in contemporary universities. To assist in understanding what is going on, we will introduce the notion of Mode 2 society which was hinted at in the last lecture, when discussing some of the implications of Mode 2 knowledge production. It was observed then that it is one of the imperatives of Mode 2 that exploitation of knowledge requires participation in its generation. In socially-distributed knowledge production the organization of that participation becomes a crucial factor. The goals of participation are no longer simply to secure some national advantage, commercial or otherwise. Indeed, the very notion of what constitutes an economic benefit, and for whom, is at the root of many debates not only in environmental science but in biotechnology and the medical sciences as well. For example, the current push towards 'clean' technologies is about more than just economic benefit. It is also about stabilizing collapsing ecological systems, the health and wellbeing of populations, as well as commercial gain. This is to say that although Mode 2 has been exemplified here only in relation to knowledge production, it has coevolutionary effects in other areas, for example in economics, the prevailing division of labour, and our sense of community.

In mentioning 'coevolutionary effects', attention is drawn to the emergence of a new relationship between science and society. It is no longer one in which science simply impacts on society, but rather one in which science and society mutually influence one another. For that to be a possibility, a society different from the one in which the disciplinary structure of science came to be established would need to exist. Indeed, that is precisely what is happening. Alongside Mode 2 knowledge production a different type of society — Mode 2 society — is emerging. Both Mode 2 society and Mode 2 knowledge production have at least three features in common: they exhibit a greater degree of complexity, are characterized by a pervasive uncertainty, and manifest an increase in experimental behaviour relative to established ways of doing things. All these are plainly evident in the domain of research, as has already been indicated, but they can be found in other social domains as well. We have already seen how the categories which define 'good science' are changing and how, compared with Mode 1 science, Mode

2 knowledge production is more complex; boundaries are fuzzier, research focused around many more problem areas; while greater uncertainty is manifest, in behavioural terms, by greater experimentation in new collaborative relationships with a greater range of partners. In like manner, we can observe similar complexity in society, in the breakdown of the traditional institutional categorizations within which economic and political life are organized, in particular those of the state and the market. One can describe these changes in terms of transgressivity: of the invasion of one set of institutions into the terrain of another. But, it must be remembered, transgressivity is a two-way process. Institutions are both invading and being invaded, and these actions are not only leading to the breakdown in traditional categorizations but also accounting for the accompanying complexity and uncertainty that are manifest today in relations between universities and industry, as each tries to come to terms with its role in the process of economic development.

To grasp what is going on, we shall need to delve, briefly, into economics, specifically the economics of knowledge production. We shall explore the dynamics of competition to illustrate how, through the twin processes of competition and collaboration, Mode 2 society and Mode 2 knowledge production become linked in a coevolutionary process in the domain of economic development. Next, we will examine the effects of this development on the nature of technology transfer, and suggest that a different approach to it is necessary if universities intend to play a key role in economic development. In the final section, we return to the theme of the second academic revolution and point out that, at best, it describes a halfway house in the long cycle of the research revolution. This will set the stage for a discussion of the third phase of the research revolution in which universities move not only into the market but also beyond it.

THE SECOND ACADEMIC REVOLUTION

An academic revolution can be defined as a change sufficiently great to require a shift in the purpose or mission of the university. The second academic revolution has been used by some scholars to denote the move by universities beyond the generation of knowledge through research, its preservation through scholarship and its dissemination through teaching, to full-fledged participation in economic development, whether regionally, nationally or internationally[1]. This phase of the research revolution is being driven, in part, by changes within the governments of many nations, as they move away from research which reflected a preoccupation with the military objectives of the Cold War towards research more closely related to a range of socio-economic objectives, such as increasing competitiveness of the economy or enhancing the quality of life. The establishment of research in universities was a product of post-war conditions and was the outcome of a debate about where the *locus* of national research capability should be. Should it be in universities, in government laboratories, or perhaps left to industry? In the end, the matter was resolved, in most countries, against industry and in favour of a mixture of universities and government laboratories. As a consequence, funding from the public purse became accepted as a legitimate way to support basic research in universities, while applied research remained the responsibility of either government or industry. The recent shift to concern with competitiveness has profound implications for what research is carried out and for the way it is funded. In particular, the decline in government funding for basic research related to military objectives following the end of the Cold War has not been replaced. The 'peace dividend' that many scientists hoped for has not materialized and universities have been forced to meet the decline in funding from traditional sources in other ways. Currently, universities are adjusting to the new political, social and economic priorities, in part by gearing themselves to become major players in economic development at regional, national and international levels.

In addition to carrying out basic research and providing scientific and technological information through consultancy, univer-

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1. H. Etzkowitz, A Webster and P. Healy, *Capitalizing knowledge* (pp.47–72, State University of New York Press, New York, 1998)

sities have traditionally been responsible for the supply of highly-qualified manpower. This has been so for a long time, but it developed strongly in the post-war period. Training the next generation of researchers, whether for universities or industry, formed part of the social contract with government during that period. In a sense, then, universities have always contributed to economic development. Average levels of scientific and technical education in a society are recognized to be key contributing factors to economic growth. So, what is new in this phase of the research revolution? The novelty lies in the ways in which universities are trying to become major economic players. Now, universities are aiming to 'capitalize' their research outputs. In doing so, they are joining industry in the process of technological innovation, another, and many argue, now the primary source of economic growth and international competitiveness. Universities are moving down this road less from the desire to be 'good citizens' than from the need to generate additional income which formerly they might have expected to receive from government.

Economic development is about innovation, particularly technological innovation. In the past, universities have participated in the innovation process through consultancy or by patenting their intellectual property and selling it to industry via licensing agreements. In both cases, they would hope to generate an income stream, through fees in the first case and via royalties in the second. More recently, however, universities have been restructuring their research capabilities internally so as to be more relevant and accessible to industry; and some have begun to take equity in newly-established 'spin-off' firms, based upon their own scientific and technological capabilities. In creating new enterprises alongside consultancy and the commercialization of their intellectual property, and in adjusting their research capabilities to make them more accessible to industry, universities are putting in place nothing less than a comprehensive approach to economic development. In licensing their inventions, they contribute to the expansion of the stock of technologies on which firms can draw; by adjusting their research agenda, they expand the effective research capacity of national firms; and through equity participation in the market they contribute directly to economic development by expanding employment and increasing the flow of technological innovations in the economy. In each case, of course, there is the prospect of generating an income stream which can be used by the university to further enhance its capabilities. As one Vice-Chancellor explained recently, 'The reason we are getting into the commercialization business is that we need the additional income to meet our academic objectives.'

Moving, thus, into economic development, the universities and industry are jointly contributing not only to the expansion of Mode 2 knowledge production but also to the unfolding of a deeper social process in which institutional boundaries become more permeable, making it harder to distinguish between the 'science' of the universities and the 'research' of industry. This process, in which one institution's norms and modes of behaviour goals are modified through interaction with another, and *vice versa,* is one of the conditions leading to the emergence of a Mode 2 society.

THE EMERGENCE OF MODE 2 SOCIETY

Changes in the constitution of science and in research practice – Mode 2 – were identified in the first lecture and attributed there to the growing contextualization and socialization of knowledge. One of the characteristics of Mode 2 science was that knowledge was being generated 'in the context of application', and the argument contained frequent references to the 'social'. The implication was that science could no longer be regarded as an autonomous space clearly demarcated from others in society, particularly from the economy. This much, at least, is not new. Many now argue that science and society cannot be separated, that their respective domains have been transgressed and that, as a consequence, the relationship between them has changed. In traditional society, science was 'external'; society was — or could be — hostile to scientific values and methods and, in turn, scientists saw their task as the benign reconstitution of society according to 'modern' principles which they were largely responsible for determining. In contemporary society, by contrast, science is 'internal'; as a result, science and research are no longer authoritative projects conducing to stability but instead, by creating new knowledge, they add fresh elements of uncertainty and instability. The relationship between science and society is no longer antagonistic but is being transformed into a collusive, or perhaps collaborative, one.

So much is common and uncontroversial ground. But, even in this more 'open' description, much of the attention remains focused on science rather than on society. The latter impinges on the argument only when it touches the former — for example, when controversies about nuclear power, environmental pollution, or genetically-modified food draw in a wider range of actors whose presence and significance cannot be ignored. The perspective is still mainly that of the scientific community — its composition may be more heterogeneous, its values more contested, its methods more diverse and its boundaries more ragged, of course — but it is still distinguishable from other domains such as culture, economy and society. In other words, the relationship is viewed principally from one, still dominant, perspective. Indeed, it is possible to read into this more 'open' description of science a restatement of traditional accounts of the transformation of society by science. Science's success has made the world more complicated and scientists must wrestle with the consequences of this complication. But science is still in charge[2].

It is less common to view this changed relationship from the perspective of society, in part, because the transformation of society is still regarded as predominantly shaped by scientific and technical change. But, for example, the fact that there are now more urgent socio-scientific controversies arises because society as a whole has been permeated by science, and in the process, the culture of science has been transformed into something different — perhaps into a culture of research which is more populist, pluralistic and open. Put another way, as a result of its successes, science has been invaded by a society wanting solutions to more and more

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[2] B. Latour, 'From the world of science to the world of research?' *Science* 280 (10 April 1998).

problems and, in the process, the 'social' has been gradually absorbed into the 'scientific'. In brief and perhaps oversimplified terms, it seems that Mode 2 science has developed in the context of a Mode 2 society, and that Mode 2 society, like Mode 2 science, while continuous with Mode 1 society, has strongly deviant characteristics. Notably, Mode 2 society has resisted categorization into discrete domains such as politics, the market, culture — and, of course, science — just as Mode 2 science has resisted being categorized as either pure, applied, or strategic research. As a consequence, it is increasingly difficult to distinguish between Mode 2 science and Mode 2 society. If categorization has become more difficult, and if, as a consequence, the line between science and society has become harder to draw, one is simply saying that society has become more complex. In sum, scholars as well as commentators have already noted that in many domains – including the state, the market, culture and science – traditional categorizations increasingly lack clear boundaries and perhaps make less and less sense. Transgressivity is now a major theme in much writing on contemporary social change. If the traditional categories by means of which we organize the understanding of our world are becoming more 'fuzzy', then it seems reasonable to speak of the emergence of a Mode 2 society.

THE COEVOLUTION OF SCIENCE AND SOCIETY

There is a further step necessary to complete the argument. It is that these developments in society and in science are not coincidental but are linked together, perhaps in something resembling a process of coevolution. Of course, science and technology are deeply implicated in these coevolutionary processes, but, viewed from the wider societal perspective, they are far from being the driving forces.

Science and technology are *implicated,* above all, in an instrumental-utilitarian sense. They are seen as capable of creating new knowledge and encouraging the development of new products, which in turn give rise to an apparently unending source of new wishes and desires which can only be satisfied by 'more' science and technology. In this sense, science and technology are dominant. However, the mechanisms that determine access to these inexorable processes of interminable wish-fulfilment, oversee and regulate their diffusion, and, above all, shape the desires in the first place, are social in origin. So, too, are the forms this wish-fulfilment will take. In this sense, science and technology occupy a subordinate role.

The changing balance between the state and the market, which so many scholars have tried to describe and explain, is also relevant. On the one hand, the state has apparently retreated, reluctantly yielding the roles as protector and patron it had assumed in the era of the welfare state; on the other hand, it may have taken on powerful new symbolic roles (or reverted to older nationalist identifications which, in the post-war age of linearity, regularity and rationality, appeared to have become anachronistic). More recently, the process of globalization has merely stretched the boundaries that already had become highly permeable. Nation-states have remained locked into a system of semi-fictional national sovereignty, while the international arena is only sparsely furnished with international institutions that work reasonably efficiently. Global capitalism, of course, is subject to no such constraints. Since the collapse of communism, in particular, the way appeared to have been cleared of political obstacles and social inhibitions which formerly restricted the application of crude economic rationality. It began its reign, apparently unfettered by other kinds of rationalities.

Today, however, for reasons that have already been explained, it is not the triumph of one form of rationality (the market) over other forms (such as the social reform imperatives of the welfare state) that needs to be emphasized, but the erosion of the boundaries between different forms of rationality. The highly specialized and differentiated system of modern society of a more or less tightly segregated set of different subsystems — each invested with a specific rationality, each utilizing a specific 'code' as the basis of the crucial distinctions that determine performance — is now dissolving. Under present conditions, the traditional functional differentiations have ceased to provide the (political) stability and (economic) growth which they once appeared to guarantee. Instead, they are more likely to be regarded as obstacles to further innovation. Viewed in the most favourable light, the existing functional differentiations of society are still perceived to be risks that must be carefully managed if innovation is not to be inhibited. Think of how many books on the performance of firms treat innovation as if it were a natural process, inhibited only by established ways of doing things.

The rapid development of new information and communication technologies has created the technical conditions for these far-reaching social changes. Most obviously, it has provided the means by which global capitalism has been able to transcend particularities of all kinds — national, cultural, social, and even individual. But it has also had more radical effects that tend to dissolve existing forms of systemic differentiation. These new technologies are themselves technically transgressive, as demarcations between mass media, voice and data transmission are eroded. But in a more fundamental sense, these technologies have helped to undermine national and institutional boundaries; they have undermined established social hierarchies, moulding these hierarchies into lean organizational shapes and flat, geographically dispersed, structures. Inevitably, individual careers and life courses, the meaning and place of work, and the occupational structure have been profoundly affected.

But neither information and communication technology in particular, nor science generally, are at the heart of these social transformations – even if the pushes, pulls and feedback loops are reinforced through scientific and technological developments. Social change is no more driven by scientific change than science is submissively shaped by society. This is why we prefer to use the concept of coevolution. The observed changes in society and changes within science and technology clearly share a number of parameters that suggest similarities in the operation of underlying forces. If coevolutionary processes are at work in what we describe as Mode 2 knowledge production and a Mode 2 society, they manifest themselves in characteristic bundles in which new sets of perceptions, attitudes, epistemological assumptions, outlooks and rationalities coalesce with altered social practices and institutional constraints. None of these can be said to be prior to the other, nor do they simply reflect simple-minded cause and effect relationships. Rather, these clusters or bundles are made up of elements which are typically linked in a self-organizing mode. Yet, they share a number of parameters. They all involve some element of increased risk, some reversal of conventional notions of time and space, and the increased presence of reflexivity.

The coevolution of Mode 2 science and Mode 2 society, though a multifaceted phenomenon, can be seen, clearly exemplified, in the changing relationships between academia and industry. Here, the boundaries between two, heretofore rather clearly demarcated, institutions have been transgressed to the degree that many commentators have noted the adoption by each of the other's organizational forms and research methods. Laboratories, whether in universities or in industry, look increasingly alike and exhibit forms of behaviour that would previously have been identified only with one type of institution or the other. If research is trangressive, that is, if it has a tendency to dissolve boundaries and render institutions more open and permeable, then this is nowhere more evident than in the emerging relationships between universities and industry. Coevolution is present here and its dynamics are, in part, driven by the nature of competition, but it is a rather different notion of competition than the one conventionally used.

DYNAMIC COMPETITION AND KNOWLEDGE PRODUCTION

In conventional economics, competition describes the process in which the markets maintain equilibrium. Equilibrium describes that set of costs and prices that lead to a balance of supply and demand across all commodities. Because equilibrium is itself a static concept, there is more interest in establishing the conditions that preserve equilibrium, than in describing the path in time along which the economy moves to achieve equilibrium, or to move from one equilibrium state to another. Relationships between supply and demand are such that any minor deviations from the equilibrium position that might occur are restored through price adjustments. In this model, the economy oscillates back and forth around an ideal equilibrium position. In this type of economics there is meant to be a rational allocation of resources, but these resources already exist — they do not need to be created. In other words, in equilibrium economics there is little place for history and the models being used certainly do not show how economic activity generates new knowledge or technology.

The role that competition plays in the generation of knowledge is not much discussed, and even less understood. The reason is that the historically dominant doctrines of economic theory have developed a notion of competition which does not recognize that in a market economy competition is essentially a discovery process, and that its nature changes according to historical circumstances. In the resource allocation framework of conventional economics, competition is considered to be static. By contrast, in the everyday business world, competition is *experienced* as a force in a process of continuous change, a process in which knowledge is generated not only about the market itself, but also about the physical world and technologies to shape it. Equally, it is a world in which later decisions and investments are constrained by prior ones, and to reverse them is either not possible or carries high economic and social costs. In other words, in economics, as in other social processes, history matters. In this view, competition is dynamic. As Hayek has noted long ago, "if the state of affairs assumed by the theory of perfect competition ever existed, it would not only deprive of their scope all the activities which the verb 'to compete' describes, but would make them virtually impossible".

In industry or business, in contrast with much economic theorizing, competition implies rivalry, and rivalry means firms behaving differently from one another in ways which convey competitive advantage and alter the prevailing balance between rival producers. The traditional concept of competition seems to rule out the possibility that rivalrous behaviour can have beneficial effects for individual firms. Actions taken by firms to enhance their competitiveness, such as price reductions, improvements in product quality and advertising campaigns, are seen as imperfections which diminish competition, introduce elements of monopoly and reduce efficiency. This paradox, that competitive behaviour is judged to have anti-competitive effects, is at the root of the difficulty of trying to make sense of competition. The simple point is that the competitive process cannot be understood in terms of equilibrium, but only in terms of a process of change driven by different types of behaviour. It is because firms strive to be different that markets can, with some accuracy, be described as competitive.

But how does differential behaviour operate? In any dynamically-competitive environment, firms increasingly need to generate knowledge if they are to remain competitive. And they do this in ways very similar to those we have described as Mode 2. In particular, firms work continually in a context of application and the competitive situation compels them to try to exploit their knowledge bases in particular directions, prompted by what their competitors are doing and by their perceptions of changes in user needs.

Usually, to do this, a firm has to identify or choose a particular *design configuration*. Now, a design configuration is an interesting object. Fundamentally, it is a particular arrangement of human and physical resources — that is, raw materials, technologies, ways of organizing things — together with the knowledge and skill (dominant competences) to develop them. It is a framework within which each firm hopes to establish a market position. Initially, it is pure potential, but over time, and gradually, it becomes a platform not just for a single product but a whole range of products. Robust design configurations have the ability to develop in many different directions, bringing to consumers a steady flow of product improvements. The VHS video recorder is a robust design configuration, the Betamax system is not, or at least not yet. The Phillips cassette tape is a robust design configuration, seven track, reel-to-reel, tapes were less so. To an extent the Boeing 700 series of aircraft represents a design configuration that is in competition with the 'fly-by-wire' one chosen by a European consortium for its Airbus series.

Of course, a firm's future success depends on the wisdom of its choice of design configuration, but it is also crucially dependent on the ability of its dominant competence to exploit its potential in response to the demand of its selection environment. The role of human resources constitutes the basis of Hayek's insight about competition being a discovery process. Just as nature poses questions for science, so the market is continually putting questions to the firm. Innovations are the answers. In this process, the design configuration functions in the context of application in a way similar to the way paradigms do in the sciences. Design configurations, as with paradigms, are devices which guide inquiry. They are worked out in an exploratory fashion by each firm in real time. The point is that in the process new knowledge is generated.

For the firm, there is a great deal more involved in developing a design configuration than rationally allocating resources. In dynamic competition, a firm's resources are generated, that is, its human and technical knowledge base develops in response to questions posed by the market or, more generally, its selection environment. The ability of each firm to enter a new market, or to respond to signals from existing ones, is always constrained, though not wholly determined, by both the initial choice of a design configuration and the creativity of its workforce. In dynamic competition, technological innovation is a matter of both resources and resourcefulness.

The accumulation of capital, insofar as it involves the creation of technological knowledge, takes place inside the firm, but the rate of that accumulation is related to the extent to which the firm can access knowledge generated by a host of others. It is the need to increase the rate of accumulation that induces firms to seek collaborative relationships, to form consortia, to join international programmes and to try, by dint of their already recognized competence in particular areas, to be invited to become members of networks of various kinds. Such is the nature of Mode 2 that, in these collaborative arrangements, they interact with scientists and technologists from a wide range of institutions who are also interested in, and working on, similar or related problems. The pattern of accumulation of knowledge may be firm-specific, but this should not obscure the fact that accumulation cannot be separated from the larger, possibly global, environment in which knowledge is being produced, even if it is being produced by competitors.

A firm's knowledge base is connected in many different ways to the communities of scientists and technologists who provide a distributed resource upon which it can draw. In particular, the micro-structures of the scientific and technological communities — as organized in universities, for example — have a formative influence on the ways in which a firm can establish its knowledge base. At the very least, this influence is exerted through the trained individuals that universities supply and the technical orientation they are given; that is, their predisposition to use certain technologies, to formulate problems, and to seek solutions in prescribed ways. Because the scientists and technologists that graduate from universities are always specialized, the range of possibilities that is open to any firm is always limited. Similarly, firms are now required to work in increasingly complex selection environments. Design configurations must take into account from the beginning a much wider range of factors before making a choice. To be considered at the earliest stages are a host of regulatory, environmental, ethical and other social considerations. Firms which do not allow these factors a place in the context of application stand in danger of investing in the development of design configurations which, though technically sound, do not meet the standards of the selection environment. This is an example of the transgression of the market by other social factors, which we described earlier, and is perhaps why some economists now prefer to talk about selection environments rather than markets. These days, innovations have to be socio-technical responses to the demands of the selection environment, rather than technical responses to the market, narrowly conceived.

THE COMMERCIALIZATION OF RESEARCH

Design configurations enable the production of a range of products and determine their appropriateness for different market segments. Through the articulation of a particular design configuration substantial economies of scale are achieved on the production side, as well as a stream of technical improvements on the product side. Such design configurations as Boeing's 700 series, Phillips' tape cassette, IBM's PC, or Microsoft's Windows, have been structurally stable for a considerable time, though they have exhibited a more or less continual improvement in technical performance. Once chosen, however, a given configuration locks the firm into a set of choices, both human and physical. Although 'lock-in' may be profitable, it can also prevent firms from moving to new design configurations, and in so doing present firms with the risk of being overtaken by technologies in which they have no competence. Only if a firm is sufficiently strong to impose its design configuration on the market can this danger be warded off. For example, IBM which was originally locked into other design configurations — main frame computers — had to establish an independent team to make PCs. In effect, in trying to establish a new design configuration from within, it had to set up a structure to compete with itself.

Design configurations play a fundamental role in the competitive process in that they form distinct nuclei around which competition is organized. They are the mini-paradigms which guide the search for knowledge. And, just as leading scientists try to make their agenda dominant, so each firm tries to position itself in the market by establishing its design configuration as dominant, hoping, thereby, to force competitors into the position of either imitating them or bearing the cost of finding another set of technologies to challenge it. Whether the design configuration for recording music is the long-playing record (LP), the tape cassette, the compact disc, or now the minidisc, it matters more to the industry than the price of these products. For that reason, it is often the case that the only way forward for a new entrant in an industry is to find a design configuration which draws upon technologies which its competitors do not have. This search for 'difference' is one source of the rivalrous behaviour on which dynamic competition depends.

In trying to establish their design configuration in the market, firms engage in rivalrous behaviour, by trying to behave differently from their competitors, and by trying to find solutions — ways of interacting with their environment — that differ from what others have thought of or which they would find it hard to copy. To do this, firms must become more directly involved in knowledge production which, given the complexity of design configurations, often implies participation in a broader collaborative effort. Only seldom are firms in a position to be able to hold in-house all the intellectual resources that they need to develop the full potential of their chosen design configuration. They need, potentially at least, to be able to draw upon knowledge that is held by others. While many firms now recognize the need to collaborate in generating knowledge, they also realize that they need to maintain a balance between collaboration and competition. This they do by entering into many different collaborative arrangements, and by trying to structure these arrangements so as to be able to move, from a collaborative mode to a competitive one, their perceptions of the market dictate.

TWO LEVELS OF COMPETITION

Using collaboration to promote competition may seem paradoxical, but it is only so if one overlooks the fact that competition is always taking place at two levels.

Static Competition

The first level of competition is among products for market share using some particular set of technologies. Every firm employs a particular process technology to make products or provide services in order to increase its market share. Its overall competitive position is measured by its distance from the average performance of the competing group. Above average businesses expand their market share; below average businesses stand to lose their market share, if they do not change their ways. How rapidly relative position can change depends on the properties of the market and the propensity of its competitors to expand. Firms with a static technology cannot hold their market positions and, unless their market is protected in some way, they will not survive for long. This is the situation in a regime of static competition which is discussed in the standard texts on industrial economics.

Dynamic Competition

The second level of competition is created by the constant pressure to innovate in order to develop the existing technological set or replace it altogether. At this level, competition is in terms of a particular design configuration and the ability of a firm to develop its potential. It is, therefore, about creativity and resourcefulness. Were this not so, large firms would always dominate the innovation process. By improving its technology, a firm is seeking to change its relative position in the competitive hierarchy. But to maintain market share, it must also keep pace with improvements in average practice, and, since average practice is always improving, competition at the second level is like a race in which the finishing line is always receding. It is because the finishing line is always receding that firms know that they need to draw upon knowledge and skills that are distributed more widely. The trend towards strategic alliances is a natural outcome of the need to access these human resources either to identify or develop a design configuration. Resourcefulness consists in the ability to configure resources held by others in a way which allows firms to achieve their objectives. Firms know that the source of any added value lies in the precise constitution of the collaborative groups and in the skills of its members. It must never be forgotten that not all collaborative groups are equally resourceful.

It is competition on the second level that is founded upon collaboration. And, on this level, markets are selecting particular collaborative groups while discarding others. Accordingly, competitive advantage for the individual firm depends upon the group it is in, and this would change if the firm moved to a different group. In forming partnerships and alliances, firms are in fact making key strategic choices. They are making judgements about the knowledge and skills which will be most important to their long-term performance. We have already observed that the choice of a design configuration is amongst the most important that any firm ever makes. But now we see that, increasingly, the choice is of partners. The growth of technology alliances and precompetitive research reflects the fact that each design configuration requires a range of resources whose precise character will be unique. Collaborative R&D is an example not of market-rigging and anti-competitive behaviour, but of rivalrous behaviour of the dynamics of group selection. The problem is not one of replacing competition with collaboration, but of managing the transition from one level to another and back again.

Dynamic Competition and the Universities

Understanding the nature of dynamic competition is central to understanding what participation in economic development is going to mean for universities in the 21st century. In particular, because the growth of the knowledge industries now constitutes the economic basis of international competitiveness, it has been necessary to expand the notion of competition, and to drive home the point that dynamic competition takes place at two levels. It is at the second level — at the level of developing new design configurations — that firms first find it necessary to join teams, that is, to collaborate in the generation of knowledge; it being understood that at a later time their participation may have to shift from a collaborative mode to a competitive one. Also, it is at the level of the design configuration that many challenging intellectual problems have to be addressed, and because significant advances in knowledge may take place, some of the best scientists aspire to be part of these teams. This is one example of the transgressivity of research — one source of the blurring of scientific identities and increasing permeability of institutions that has already been explored. The shift in *locus* of innovation — to the generation of specialized knowledge in the search for a winning design configuration — is having the effect of drawing universities, as knowledge producers, deeply into the competitive process at the second level. Thus, while massification has modified universities so that they can reach out to a broader range of students, international competitiveness is having the effect of drawing the universities, and others, into a new context of application.

The nature of dynamic competition is such that it is going to alter the basic relationship between universities and industry. When one is working within the framework of static competition, one is closer to Mode 1 conditions. There, the function of the university may be simply to bring its knowledge to the aid of industry, primarily through consultancy. Consultancy does not usually involve the university as an institution directly. It was something that some university professors could undertake, provided it did not amount to more than, say, one day per week, over any particular year. Such consultancy was intended to solve particular industrial problems, but usually well within a particular design configuration. But the same conditions do not apply when firms are operating in a regime of dynamic competition. In that regime, the firm is trying to identify a winning design configuration or to develop it more creatively than its competitors. In this context, each firm tries to behave differently from its rivals. And it does this by drawing on many other sources of knowledge, including universities, primarily by forming teams. But not all teams are equally resourceful, and it is the differential creativity of these teams that determines which design configurations will emerge. That is why it is so important for firms to choose their collaborative partners with care, and there is plenty of evidence to suggest that, as far as industry is concerned, universities are still the preferred choice.

The point of this extended excursus in economics is that, today, the commercialization of research is organized less around the translation of discoveries into new product lines than in searching for design configurations with the potential to be developed in a variety of ways. Translating discoveries into product lines describes Mode 1 behaviour and, perhaps not surprisingly, it is the one most frequently adopted by universities when they try to capitalize their knowledge. By contrast, searching for new design configurations has many of the characteristics of Mode 2 knowledge production which we have already described. It is a search that holds out much promise for identifying intellectually challenging problems, and many of the best academics want to work on them. But, it is not a model that the universities can readily adopt, given the way they are currently organized.

If universities intend to play a role in configuration choice and development, they need to become more open and porous as institutions, and be prepared to interact more intimately with industry. They need to find ways to become team players and accept that, whatever groups they join, they will be involved in a process in which both competition and collaboration are involved and, therefore, the composition of a team is likely to change over time. Equally, if universities are to become active in capitalizing their own intellectual capital by establishing their own firms, they too will need to identify and develop winning design configurations. And, just as industry needs the resources of universities to do this, universities too need resources held in the socially-distributed knowledge system if their companies are to compete successfully in markets characterized by dynamic competition. This is the theoretical and practical basis for the revolution in the nature of technology transfer which is currently taking place in universities, and which is moving some universities to play a key role in economic development.

THE CHANGING NATURE OF TECHNOLOGY TRANSFER

As innovation becomes more knowledge-intensive, companies are in need of more and more knowledge in order to compete. Increasingly, they will need access to knowledge generated elsewhere. One avenue is to join with other firms in the generation of knowledge, for example, in precompetitive research projects of the sort favoured by national governments, the European Union or the World Bank. But while such collaborations are possible, they are still rather infrequent. For many reasons, the universities are still the preferred option. However, to tap into university-based knowledge requires that a number of prerequisites be met. From empirical research, we know that geographical proximity is important; it facilitates the kind of information exchanges and informal contact that is necessary before any — closer — co-operation can be initiated. Successful long-term collaboration often involves a rather lengthy prehistory of interaction in which the partners are 'getting to know' each other. Other successful arrangements point to the importance of establishing some kind of intermediary agent or structure with which to stimulate or recreate the closeness achieved, alternatively and over a longer time, by informal contacts or geographical proximity. Where this is done on a long-term and more systematic basis, collaboration tends to have a greater chance of succeeding. In the end, collaboration must be built upon a foundation of trust, involving building informal contacts and mutual accommodation. If the institutional context prevents these arising, no amount of rhetoric is likely to overcome any existing barriers. The need for mutual accommodation is nowhere more clearly visible than in the field of technology transfer.

Technology transfer is now a vast field of activity, but our understanding of its role and function, too, is undergoing a radical transformation, partly to bring it into line not only with the needs of knowledge-based businesses but also with those of the knowledge industry. The transformation of the function of technology transfer can be dated from the late 1970s and early 1980s. These years have been identified as a watershed in the history of technology transfer in the universities, both in the United States and in Western Europe. Before that, the movement of knowledge from universities to industry occurred largely through traditional processes: graduates who went to work for industry; the publication of results of university research in professional journals; and consulting by university staff. Beginning about 1977, by common consent, there was a sharp increase in the number and activity of new transfer mechanisms, including:

1. Setting up or reorganizing university patent offices.

2. New experimental approaches to obtaining value from intellectual property, such as equity ownership.

3. Enhanced development of liaison programmes or a fresh drive for new membership.

4. Rapid growth in industrial sponsorship, both in absolute value and as a percentage of total research funding.

5. Increasing involvement of universities in regional development plans.

For example, in the USA, there was, during the 1970s, a change from relatively passive knowledge-transfer process to one in which the universities added a new active engagement in the commercialization of research and the processes of economic development. A similar conclusion could be applied to most of the countries of the Organization for Economic Co-operation and Development (OECD).

Be that as it may, technology transfer is at a watershed, and it is not only an increase in the volume of activity that is occurring but also a readjustment of the notion of technology transfer to accommodate the emerging knowledge industries. Consider, for example, the reflections of a recent report from the University of California. Firstly, in line with the argument developed so far, the committee observed that:

> the distinction between basic and applied research has become blurred, both because of the shortening of the lead times between discovery or invention and application, and because of increased recognition that breakthroughs in our fundamental understanding of nature are often stimulated by the struggle to find solutions to practical problems...[and secondly that the] process of *knowledge transfer*, a traditional function of the university, is considerably different from the process of technology transfer. Unlike knowledge transfer, in which knowledge is passed from the university to the receiver easily and usually with almost no follow-up, technology transfer requires considerable effort at all stages of the process. The analogy of a relay race, in which the baton is passed cleanly and quickly from one runner to the other (the linear model in another guise?), fits most knowledge-transfer situations but does not apply to technology transfer. Technology transfer is more like a basketball (or soccer) game, in which the university is only one player. This player may bring the ball over the half court (centre field) line, but it must then enlist the aid of team-mates in order to score. The "ball" is passed back and forth constantly among the players who may include business people, venture capitalists, patent attorneys, production engineers, and many others in addition to university faculty.... Given the need for a more precise term, the working group decided to use the concept of *technology interchange* rather than technology transfer. Tech-

nology interchange not only is more descriptive of the underlying process but also begins to erode public and university misconceptions about the relative contributions of the parties to that process. The groups and individuals involved in the design, development, production, and commercialization of new technologies are so highly interdependent that assignment of relative weights to their contributions is impossible. Continuous interchange is the key factor in contemporary technology transfer.[3]

In other words, the older view in which a linear process connects discoveries and inventions to the production process, is being displaced in favour of a more continuous, interactive one. But the key point is that while, in the linear view, the university was distanced from the commercial process, and could still preserve its 'academic' values, in the present view of technology interchange, it must become involved at both individual and institutional levels. If one plays 'the game', one must expect the players to adapt to the rules, and this usually means adapting behaviour. What would such an adaptation require of the university and its faculty? What would happen if technology interchange were to move from the periphery to the centre of the universities' value system?

In this circumstance, one might expect to find the following:

1. Every major research university will eventually articulate, in formal policy and mission statements, its commitment to technology-transfer efforts and reflect this commitment expressly in its organizational structures and its resource allocations. No university will be able to ignore this.

2. At the same time, universities that will be expected to increase their efforts at technology transfer, including commercialization of research and increased efforts at economic development only indirectly associated with teaching and research, will also come under increasing attacks. They will be told by both faculty and others that they are being too commercial, not sufficiently protective of their reputation for objectivity,

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3. University of California, private communication, 1992

and that they are violating the traditional tacit agreement with the rest of society that they ought not to be commercially oriented.

3. Institutional policy and practice will increasingly allow those university faculty members who wish to become involved in activities associated with commercialization of their research to do so. This will be accomplished without serious damage to the collegial atmosphere or with the notion that faculty owe their primary allegiance to the university. As universities recognize their obligation to serve society through technology-transfer activities, institutional purpose and individual interest in this request will converge.

4. Organized units within the universities staffed by professionals and dedicated to specific tasks related to technology transfer will continue to be formed and increase their activity. Technology transfer (or some other name or expression for the same concept) will become the structuring principle under which these activities will be co-ordinated and overseen. One major thrust of this new organization will be co-ordination of relations with industry. The seemingly disparate activities of corporate donor relations, corporate research partnerships, corporate/university economic development initiatives, student employment opportunities, continuing education, and technology licensing, will come to be viewed as part of a pattern of important and unitary interactions with corporations which need to be fostered and maintained over the long term.

5. Every major *research* university will eventually become a *financial* partner in start-up companies set up to exploit the universities' intellectual property. This financial involvement will extend beyond passive ownership of equity in these new companies to some form of active participation in the generation of venture capital. In most cases this involvement will be formally separated from the university through the use of buffer organizations.

6. The total and relative financial contributions of industry to the university will steadily increase. These contributions include gifts, research funding, payments of licensing fees and other direct payments for the use of university property, and membership dues and other special payments for access to the university. In addition, the government will increasingly recognise and reward universities for their efforts to interact with industry.

7. Continuing education, both as an activity instrumental in the technology-transfer process, and as an organizational form within the university capable of facilitating technology-transfer efforts, or useful as a model for other efforts, will become more important and visible. Depending upon a given university's academic culture, continuing education units will be empowered to undertake significant additional functions, or not. In some situations the development of technology transfer may even contribute to the decentralization of continuing education.

8. Policies governing university and faculty interactions with commercial concerns will become more process-oriented and less proscriptive. This will result in the formulation of special review committees designed both to protect university values and to foster appropriate university commercial involvements.

The summary drawn from the work of Matkin captures well the term of the next phase of an evolutionary process in relation to the role of universities in economic development[4]. Depending upon the university, it gives an idea of the distance which it will have to travel if it wishes to be a player in the game. It supports the view that the process of commercialization of research is more accurately described as technology interchange, a process of continual interaction between professors and a range of other actors who are

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4. G. W. Matkin, *Technology transfer and the university* (Macmillan, New York, 1990).

involved in the commercialization process. In the preceding paragraph, we have tried to indicate how the adoption of technology interchange will modify the university, and we conclude this section with the sombre observation that, if the universities do not develop along the lines suggested above, they will be bypassed by other organizations that will. The firms, particularly those in the advanced industrial economies, need the output of the knowledge industry, and the universities should be an integral part of it. To say the least, they will not be able to participate to the full unless they change.

CONCLUSIONS

In this lecture, we have laid out some of the features of the second phase of the research revolution, a development which began in earnest in the 1970s when universities moved progressively from research consultancy, through the licensing of intellectual property and technology-transfer activities, to taking equity, with others, in the capitalization of the knowledge generated through research. In becoming involved in the capitalization of knowledge, universities are, to a certain extent, staking their future on the income that might be generated from playing a more direct role in economic development, a role that takes them beyond the provision of qualified manpower, on the one hand, or the provision of fundamental knowledge, on the other. In making this move, universities have adopted forms of organization and research practices which resemble those which pertain in industrial laboratories, just as industry have adopted some of forms of research and patterns of research behaviour which have been found successful in universities.

Both types of organization have become more alike as they have become more permeable and as their goals begin to converge. This is perhaps one of the best examples one could find of the idea that research is transgressive. Research seems to cross all boundaries — cognitive, organizational and institutional. It blurs the boundaries between disciplines, it creates new, often flatter, organizational structures and it makes institutions more permeable. Indeed, research has many of the characteristics that we have ascribed to Mode 2 knowledge production. But this development is taking place within a larger process of an emergent Mode 2 society. The examples given above, though drawn from the market, indicate how traditional institutions and modes of behaviour are being adapted by both universities and industry, so that the line between the science of the universities and the research of industry, particularly in the search for winning design configurations, loses much of its significance. In this, many universities have not been passive. Many have moved over the last twenty years from spasmodic consultancy, to patenting their intellectual property and licensing it to industry, to establishing research groups likely to be of interest to industry or society more widely (particularly in the biosciences), to setting up science parks and taking equity participation in companies aimed at exploiting their own intellectual property. This constitutes what has already been labelled a second academic revolution and the process is in full throttle on many university campuses. As is perhaps now evident, the process is promoting the very coevolution of Mode 2 society and Mode 2 science that was outlined in more general terms at the beginning of the lecture.

But it is time to move on. In the third lecture, an attempt will be made to demonstrate that the second academic revolution is in fact only a phase in the research revolution, and not the one which will test the universities most severely in terms of its mission statement, modes of governance, goals and objectives. Transgressivity is a characteristic not only of research but also, more generally, of contemporary social change. The mutual adjustment and accommodation of Mode 2 science to Mode 2 society will have to take place in the universities for the reasons that universities are still important knowledge producers and also the primary sites at which the training of future generations of knowledge workers will take place. At least this is so at the moment. If universities do not participate in this — third — phase of the revolution, they will be marginalized by a society that increasingly knows how to use research to attain its ends. If universities do engage in the third phase and make the necessary adjustments, new types of science and scientists will be necessary and they will take universities not only into the market but also beyond it.

Lecture 3

THE RESEARCH REVOLUTION – PHASE 3: UNIVERSITIES MOVE BEYOND THE MARKET

Summary

In this lecture, the discussion of the characteristics of Mode 2 knowledge production will be resumed. The notion of reliable knowledge is introduced and it is suggested that in the realm of knowledge production, as in so many other areas of society, the former certainties concerning the nature of scientific knowledge — definitions of knowledge, how it should be pursued, the contribution that it makes to society, etc. — have become problematic. The idea that science is, in some way, special and deserves privileged treatment has fallen under suspicion, and the value of the knowledge which it produces is now contested. Nonetheless, the view persists that there is some quality or set of qualities in the way that science works from which it derives its special status. Historically, the defence of this special status has been in terms of its ability to produce reliable knowledge using the twin processes of consensibility and consensuality. The main elements of this argument are presented, from which it is possible to show that there is no reason, in principle, why Mode 2 knowledge cannot be as, or perhaps even more, reliable knowledge than that produced in Mode 1. The main thrust of the argument is that the introduction of the social does not necessarily undermine reliability but, rather, may enhance it. For this reason, it is called socially robust knowledge which may come to replace merely reliable knowledge. Therefore, if, on the one hand, the current organization of disciplinary science and its associated apparent remoteness from society can be seen to be leading to contestation, and if, on the other hand, contextualized knowledge reduces contestation while bringing no intrinsic decrement in reliability, what is to stop scientists from embracing the social and taking part in the production of socially-robust knowledge? So-

cially-robust knowledge is produced when scientists enter what is called the contemporary *agora* — the sites where in the interaction of a range of perspectives problems are identified and research agenda established.

The third phase of the research revolution, then, describes a society in which the universities participate in the *agora*. Just as the universities prospered as centres of pure science in the immediate aftermath of the Second World War, so to prosper in the post-Cold War environment, they need to establish themselves as participants in the production of socially-robust knowledge. To do this, universities must move out of the ivory tower, not into the market, where to some extent they increasingly are already, but beyond it. Socially-robust knowledge is a type of knowledge that is beyond both the disinterested knowledge of the disciplines and the 'useful' knowledge demanded by industry. It is generated not in the market but in the contemporary agora. Involvement in the agora and the participation in the production of socially-robust knowledge require both a radical reorganization of the university and a more or less complete 'rethinking' of science.

INTRODUCTION

The emergence of novel and transgressive socio-economic forms, which characterized Mode 2 society, was described in the previous lecture. It was further argued that these forms which occur both in society and science are linked in a coevolutionary process. Mode 2 science is emerging in the context of this Mode 2 society, although their relationship is not linear but reflexive.

In this lecture, we want to begin by exploring further what is meant by the context of application, and by contextualized science. This will lead to a consideration of a new form of knowledge — socially robust knowledge — and how it is generated. We will then turn to examine the implications for the universities of participating in the production of socially robust knowledge.

SOCIETY 'SPEAKS BACK' TO SCIENCE

In modern times, science has always 'spoken' to society. The argument that will be developed here is that now society 'speaks back' to science. This, in the simplest terms, is what we meant by the term contextualization. Communication between science and society is by now a familiar theme. Science has always 'spoken' to society — in the sense that it has provided a continuous flow of new ways of conceptualizing the physical and social worlds. These new conceptualizations, of course, have often depended on the availability of particular investigative techniques and have been grounded in particular socio-economic environments. So there has always been a reflexive element. This is not new. But, although inevitably rooted in particularities, science has been able to transcend these constraints and produce generalizable outputs — which, of course, can then be translated back into 'local' contexts in the form of socially-desirable and economically-useful goods and services. And its ability to transform the particular into the generalizable and back to the (improved) particular — the 'local' into the universal and back to the (enhanced) 'local' — has always been science's special mission. It has also been the basis of its social power and, consequently, its institutional and professional privileges. To realize its potential for innovation, it has been argued, science has to be allowed to 'speak' to society — and as freely as possible.

Today, society 'speaks back' to science. To some extent, science is 'listening' as a consequence, in part, of the boundaries separating science and society becoming much more porous. Again, this is not entirely new. Indeed, the capacity of scientific and technological research and development to generate innovation depends not only on research but also upon the existence of creative and interactive links between science and society, many of which are mundane but some of which are crucial. These links then create a climate conducive not only to further innovation, but also to wealth creation, improved health (and other quality-of-life indicators), and long-term sustainability in harmony with the natural environment. Whether these links are strongly articulated through national innovation policies, or more weakly through popular and political expectations of science and technology, science and technology are apparently the driving forces behind increased international economic competitiveness and further societal change. The dominant assumption is that scientific and technological knowledge production makes an essential and integral contribution to the functioning of societies now, and will continue to do so in the future. However, this emphasis on the potential of science and technology for innovation is from a societal perspective only half the story — its main focus being their impact on society. But it is equally important to describe and understand the impact of this mutual interpenetration on science itself. This is the other half of the story — and what is meant by the contextualization of science.

If this argument is accepted, the dichotomy between Mode 1 science and Mode 2 knowledge production becomes less sharp. It is common ground that in modern science there are now more actors, that more forces — social, economic, political — act on science, and that there are much greater expectations that science can provide useful answers to an ever-increasing range of societal problems. But from the point of view of the academic scientists themselves, none of this means that context-free science — free from all contextual interference — has ceased to exist. Even if they must take into account the social context when they come to frame their research, Mode 1 science still lives in the functioning of the canons of empirical method, protected by its voluntarily-accepted social norms. No set of socio-economic priorities should be allowed to touch this system. Indeed, it has traditionally been argued that this system can be preserved only if a particular relationship between science and society is maintained. It is a relationship in which society is compared to the flesh of a peach, science to its hard pit. In this view, science is surrounded by a society that remains foreign to the workings of scientific method. Society, for its part, could reject or accept the results of science; it could be hostile or friendly towards its practical consequences. But there was no direct connection between scientific results and the larger context of society. Social influences, in this view, could do no more than slow down or speed up the advancement of an autonomous science. Clearly, in such a model the context is not able to speak back.

The thesis we want to explore now is that a Mode 2 society generates the conditions in which society is able to 'speak back' to science, and that this reverse communication is transforming science. In other words, contextualization is affecting scientific performance, deep down, at its epistemological roots, and altering the conditions of its objectivity or, more modestly, its reliability. It is this transformative aspect of the context that makes Mode 2 a new mode of knowledge production. But, what would be the particular characteristics of contextualized knowledge that allowed such a 'reverse transformation' to occur, but did not, at the same time, undermine either disinterestedness or reliability? The challenge is to demonstrate that contextualization, often a reflection of shifting and unstable configurations of interests and perspectives, actually enhances scientific reliability.

When modern science began to carve out its own social space of relative autonomy and freedom from direct social and political control, including the cognitive authority of the church, it consisted of the esoteric activities of tiny groups of practitioners committed to exploring the natural world, guided by a set of rules and practices which they called the experimental method. The potential application of any insights they gained and of the results they produced to solving practical problems was always a lingering presence; many early modern scientists were expected to contribute to the solution of practical problems — in navigation or artillery — and many early scientific organizations, such as the Royal Society and the academies of arts and sciences established in the 17th and 18th centuries, were originally founded with instrumental motives — for example, to encourage agricultural improvement. However, the applicability of their results was neither their main purpose nor their principal motive for developing experimental scientific techniques.

Yet, not much more than three centuries later, applicability — or, more broadly, instrumentality — has become a dominant theme. While we continue to be in awe of the apparently-inexhaustible capacity of science to produce novelty (and to do so with increasing efficiency and productivity), there are inexorable demands that this novelty must contribute more exactly — and more exactingly — to improving present and future societal arrangements, informing social values and life styles, and helping to develop more sustainable relationships with the natural environment. Of course, it is easy to describe this ongoing process of contextualization in different research fields, by pointing to shifts in research agenda and how research priorities are set, and describing how the policies of research councils and other funding agencies are articulated and directed towards certain objectives (which, in turn, must be compatible, or converge, with how problems are defined in scientific terms). But contextualization has a second and deeper meaning which relates to our conceptions about how science 'really' works, what is distinctive about it, and what, therefore, should not be touched and cannot be altered without running the risk that we will 'kill the goose that lays the golden eggs', in other words, inhibit science's capacity to generate novelty. It is this second meaning of contextualization which needs to be investigated.

The demarcation between science and non-science

Not too long ago, questions about the distinctiveness of science were thought to be easy to answer. Philosophers of science established so-called demarcation criteria to distinguish between science and other domains. They developed a checklist of criteria which could be applied to detailed examples of scientific practice, to the rules and methods inherent (as they saw it) to science's performance. These efforts to establish a clear demarcation between science and non-science failed utterly. They were finally demolished, in part, by Paul Feyerabend's triumphant-anarchistic demonstration that in science 'anything goes', but more importantly by many excellent empirical studies in the history of science which demonstrated that there were no hard-and-fast and invariable criteria to determine what was 'scientific' and what was not. Instead, the picture that emerged from these studies was one of science as essentially a social process. Moreover, it was a picture of far greater diversity of, and even dissonance between, scientific practices and research fields in different historical (and geographical) settings than the dominant account of a unified and context-free science was prepared to acknowledge. However, this is not to say that in research 'anything goes' or that scientific knowledge production cannot be distinguished from the production of other kinds of knowledge. Nor does it justify the assertion that 'science is merely a social construction', which is no more satisfactory than rival accounts of science as absolutely unperturbed by its social context.

But, even if the attempt to define science in terms of near-absolute demarcation criteria is accepted to have failed, it is still possible to distinguish science as a separate subsystem of society in terms of its distinctive normative values, epistemologies, methodologies and social practices. But even here there are difficulties. Previously, we argued that boundaries between the differentiated segments of society have become fluid and porous. It, therefore, becomes more difficult to regard science as a distinctive subsystem of society, clearly demarcated from other subsystems, because all social systems and subsystems are in flux and have become transgressive. Science cannot be an exception to this general rule. As Mode 2 characteristics pervade society and knowledge production becomes more distributed, the question becomes urgent of how far these processes are affecting, and in what way, the core of scientific knowledge production.

Is there, to put it bluntly and simply, a distinct mix of practices, methods and beliefs — a hard epistemological core — underlying scientific knowledge production, which cannot be changed without destroying what makes science work? The existence of such a hard core is deeply held by scientists and appears unassailable, because it is tightly wrapped up in, and protected by, many soft layers. One such layer protecting this hard core is the set of social norms governing collective scientific behaviour that was first articulated by the American sociologist, Robert Merton. Merton suggested that the coherence of the scientific enterprise was maintained by the voluntary acceptance by scientists of the following social norms: universality (scientists must be open with respect to communicating the results of their work); organized scepticism (by means of which scientists put one another's results to the most rigorous tests before accepting them); and disinterestedness (scientists should be motivated only by curiosity). Following these norms was critically dependent on the existence of a creative space somewhere in society in which the production of scientific knowledge as a public good could be pursued. In return for producing basic research, society should maintain this space and allow scientists to pursue their enquiries wherever they might lead. In other words, science should be an autonomous enterprise. These norms encapsulate what is sometimes called the Mertonian ideal of science, and they are so-constructed that any breach of them compromises the quality of the research output. These norms, then, protect the hard core of science from undue external influence and are so-constructed that, if tampered with, it would alter, detrimentally, the production of good science.

At greatest risk, apparently, is the autonomy of science. It has always been vigorously argued that the existence of a social space, however conditional and precarious, where cognitive and intellectual interests can be pursued which are exempt from direct social control and blatant political pressures, is an indispensable precondition of efficient, effective and, above all, high-quality science. But, similar arguments can be made for other classical social norms, for example universality, organized scepticism, and disinterestedness: the so-called Mertonian norms of science. For example, if researchers become too closely involved in running their own biotechnology firms, or too anxious to become entrepreneurs in pursuit of profit, will it be possible to continue to regard the pursuit of disinterested scientific knowledge as a public good? These are not merely, or even particularly, moral questions. When Robert Merton originally identified these norms, he regarded them as essential elements within the ethos of science. In particular, he emphasized their functionality. The norms were necessary to guarantee that science would continue to 'work'.

However, it can be readily demonstrated that many other groups have their set of professional norms — doctors, for example — which are designed to give its practitioners a degree of autonomy and to protect the profession from undue interference. In what way are the social norms of science different? Possibly, what distinguishes scientific communities from these other professional communities is that science seeks to preserve its autonomy, not for science's own sake, but as a space in which creativity and originality can be nurtured for the greater public good. The historical record suggests that it is this characteristic that justifies the distinctiveness of science, although with significant qualifications. Plato had a similar idea: that the good of society could be found by stepping back from the hurly-burly of social life, by contemplating the 'good' — the *agathon*. The creative space, in this instance, was meant to be cultivated and preserved by the philosophers.

But science, because of its commitment to the empirical, is not in the position of the Greek philosophers. Scientific activity, as one of the most sophisticated expressions of human creativity, still depends on the 'materiality' of scientific practices — the material — human, physical, financial and technical — which is required to undertake research. Scientific practice requires elaborate and sophisticated experimental systems consisting of instruments, organisms, hypothetical (because theoretical) entities; and complex laboratory and other organizational arrangements which include people, objects, financing and spaces. By themselves, all this material would not be sufficient without the beliefs, theories, ideas and speculations of scientists themselves, and also without the testing and validation procedures needed to assess 'success' and 'failure' and to establish priorities. Indeed, the coherence of the whole scientific enterprise is produced by the conjunction of this cognitive and normative material — which, of course, is the product of previous processes of knowledge production. Given this close interaction, it is hard to see that a very strong case for autonomy — at least in the sense proposed by Plato — can be made.

When the evidence is weighed, perhaps what is truly distinctive about science is this mixture of the 'materiality' of scientific practice and of these more theoretical, speculative and often formalized beliefs which have shaped scientific 'reality' (which, itself, is constantly being tested, validated and revised). The result is a shared view of a common reality, primarily of the natural, but also of a social world. This belief in a common reality is no longer naively imagined to be an 'image' of an independently existing 'outer reality'. It is only an imperfect and incomplete representation of it. Since this 'reality' is common to all researchers, it makes sense for them to share, compare, revise and combine their diverse 'facts' and 'maps' into a version, or a portfolio of equivalent versions, of this 'reality' on which they can all (potentially) agree. Although science does not have a monopoly of understanding the natural world — other belief systems also claim such understanding, albeit in different variants — it has succeeded in establishing the strongest claim to offering the most comprehensive view of this 'reality'. Everyday or commonsense knowledge versions of this 'reality' continue to circulate; indeed, they are indispensable. But the boundaries between scientific beliefs and commonsense beliefs, although shifting, fluid and even overlapping, continue to exist. Because of its unique combination of practices, procedures and already validated knowledge, science seems always to be more successful than commonsense knowledge in extending, revising and discovering new knowledge about this common 'reality'. But an important qualification must be added. Although few dispute science's superiority in improving our knowledge of the natural world, its superiority with regard to the social world, and our place in the natural world, is more often challenged.

This is where contextualization enters anew. If it is accepted that the processes that have enabled science to arrive at such a monopoly of definitions of the natural world and of a common 'reality' are also social, why is there such resistance to admitting that the result — the common 'reality' — is also open to social shaping, at least under certain constraints which need to be explored? Why is the social world excluded as being part of this 'reality'? Why is the place of social knowledge in the production of scientific knowledge denied, or even suppressed? Is it because it is seen as exposing science to unwelcome external influences?

Part of the answer lies in the history of the institutionalization of science. From the start, science renounced the claims, in the famous passage of the Charter of the Royal Society, 'to meddle with politicks, rhetoric, divinity'. Of course, with the benefit of hindsight, it is possible to see that science, at any rate that branch of science preoccupied with producing a better understanding of the natural world, was right to try to exclude the political and social world with its religious wars, intolerance and violence. In the same early modern world, there was also an insatiable appetite for meaning and certainty at a time when meanings were being continuously reworked and certainty could not be achieved. Later, when science and technology had become firmly locked into the project of modernization, they indirectly contributed to knowledge about the social world. The social sciences, growing up in the shadow of politics and under the tutelage of the nation-state, attempted to emulate, and imitate, the more successful natural sciences. The modernization project itself was inspired by a strong belief that the rationality of science would spread to all other realms of political and social life. The 'success' of the application of scientific and technological knowledge during industrialization and the spread of science-based innovations, helped to maintain social consensus, and social peace, in liberal Western democracies. However, despite their 'success', the natural sciences are still reluctant to admit a more social view into the common 'reality' which they have so brilliantly contrived. There remains a deep-seated fear of becoming contaminated by the social world.

According to some scholars, the history of the development of a concept of 'objectivity' was characterized by the struggles of scientists to control their own fears. Perhaps the greatest of these fears concerns their own imagination and feelings which they came to distrust deeply. Repeated attempts were made, from the late-18th to the mid-19th centuries, to distinguish between those parts of their creative insights and imagination that could be controlled by reason (which came to be recognized as 'objective'), from those darker parts of the same imagination that tended to run out-of-control and, therefore, could only lead to error and deception. Out of scientists' struggle with their own feelings which they regarded as dangerously 'subjective', there emerged a still powerful notion of objectivity in the now much wider spectrum of what is understood by objectivity — notions which are polymorphous, multidimensional and historically contingent. Today, scientists have to confront another, but analogous, fear — their fear of the social world, of imputed interests and ideological distortions, of cultural influences, and of their own subtle and not-so-subtle accommodation to political and economic pressures. If they openly acknowledge these perceived threats, it may be possible to develop another model of knowledge production, in which knowledge becomes socially more robust. There is no irreducible essence of science that would invalidate such a decision. Rather, the actual practice of science, instead of feeling bound by inherent rules which constrain it to a particular path of development, might be set free to explore different contexts, and perhaps to evolve in different directions. The research process would cease to be seen as moving uneasily between the imperatives of inner and outer-directedness, to a more comprehensive, socially-embedded process in which all the contingencies, constraints and opportunities created by contextualization would be made more explicit and, therefore, capable of critical and reflexive debate. It is in this sense that we talk of the contextualization of science, as an enlargement of its scope and enrichment of its potential, not as an instrumentalist alternative.

Earlier, the question was asked whether there was a hard epistemological core underlying scientific knowledge production which could not be changed without destroying what makes science work. It does not appear so. Rather, there seems to be a wide range of conditions, practices, methods and beliefs in which science has flourished. This historical record tells us this much. But, if it is indeed the case that there is no unique hard core but a diversity of research practices, it is hard to see what could be lost by openly admitting the social into the mix. On the contrary, as the next section shows, there might be something to gain.

FROM RELIABLE TO SOCIALLY-ROBUST KNOWLEDGE

The argument so far has passed through three stages. First, that the great conceptual, and organizational, categories of the modern world — state, market, culture, science — have become highly permeable, even transgressive. They are ceasing to be recognizably-distinct domains. As a result, commonsensical distinctions between the 'internal' and the 'external' have become increasingly problematical — a change which has radical implications for demarcations between science and non-science, for notions of professional identity and scientific expertise, and for the relationship between universities and industry.

Second, that the range of external factors that scientists must now take into account is expanding — inexorably and exponentially. This is hardly a novel or a controversial observation. The increasing emphasis on the contribution of science to wealth creation (and social improvement), the growing deference to so-called 'user' perspectives, the great weight now attached to ethical and environmental considerations, are all examples of the intensification of what we have called contextualization. But, in the eyes of many scientists, this contextualization is unwelcome and imposed. It is something that must be lived with — and worked round — because it is only by acknowledging these apparent 'externalities' that the funding-base of science can be secured. In the light of the first stage of our argument, that is clearly not a view we share. In a fuzzy world, contextualization cannot be reduced to an accumulation of 'externalities' — which cannot properly be characterized as such. A real shift is taking place from what can be called weakly-contextualized to strongly-contextualized knowledge production; this is no mere rhetorical shift from a once-dominant Mode 1-like discourse of, say, physics to a Mode 2-like discourse of, say, bioengineering. Again, this assertion is not especially controversial. There is substantial evidence — anecdotal and statistical — to back it up.

Third, that under contemporary conditions the more strongly contextualized a scientific field or research domain is, the more important the knowledge it is likely to produce. This is one reason why some of the best scientists want to work in the context of application. This is a reversal of the traditional pattern of scientific working, which has been to restrict as far as possible the range of external factors, or contexts, which must be taken into account. Many of the most powerful scientific techniques — reductionism, normalization, sampling methods, control groups — are based on this presumption of containment or insulation. The laboratory, or wider research arena, was a sterile space — in a metaphorical as well as physical sense. Good science was constantly at risk of being contaminated, even overwhelmed, by a surfeit of contexts. Our argument is that this has now been turned on its head. Those scientific fields which have continued to restrict the range of external factors which they take into account, to preserve a 'sterile space', and which we have characterized as weakly contextualized, are tending to become less creative and productive. Those which embrace, willingly or otherwise, a diversity of external factors, and which can be described as strongly contextualized, are not only more 'relevant' (this is an inevitable outcome, whether welcomed or resented), but also more dynamic in terms of both the quantity and the quality of the knowledge they produce.

The time has come to proceed to a fourth, and crucial, stage in the argument. Some — perhaps many — scientists may be prepared to accept that more highly contextualized knowledge is not only inevitable (in the sense that, in the absence of contextualization, resources for science would dry up), and 'relevant' (in the sense that political, economic and social agenda are more directly addressed), but even scientifically beneficial (in the limited sense that a wider range of perspectives and techniques may be brought to bear on scientific problems). But, most will be reluctant to admit the idea that the more highly-contextualized knowledge is the more reliable it is likely to be — not necessarily within the framework of disciplinary science which defines reliability almost exclusively in terms of replicability — because it remains valid outside the 'sterile spaces' created by experimental and theoretical science. Such knowledge is properly called 'socially-robust'. To demonstrate this larger reliability of contextualized knowledge, it will be necessary to question some of the epistemological assumptions on which science is thought ultimately to depend.

Science as Reliable Knowledge

Reliability is considered the major epistemic value of science. Without reliability there is no science. The most sophisticated models of the natural world would be useless if they could not be relied upon to be correct (at any rate within the constraints of the available science). As a result, scientists have developed highly-elaborate procedures and methods for testing, cross-checking and validating results and theories in order to produce what approximates to 'good science'. Of course, scientists are not alone in their commitment to reliability. Lawyers, accountants and many other professions are equally concerned that the outcome of their work should be 'correct'. However, there is an important difference. Scientists test their results 'against Nature', not against books of rules such as laws, or against a body of figures and procedures designed to produce a balance sheet. A more fundamental difference is that the search for reliable knowledge is embedded within the basic belief system of science, both conceptually and in terms of its empirical practices; it is not an externally imposed requirement or constraint. Although mistakes and faults may go unnoticed initially, eventually they will be discovered by other scientists in new contexts. This compulsion continuously to check and test one's own and each other's claims and results is deeply ingrained in the training of researchers. It has also been institutionalized in scientific practice; a good example is the pervasive peer-review system. There is a constant fear of contamination — whether by 'natural artefacts' that invade the experimental environment, producing 'dirt' or causing 'noise'; or by the intervention of social, economic or political interests which are also suspected of distorting the reliability — or, more fundamentally, truth value — of scientific results. It is for this reason that the commitment to the autonomy of science and the belief that it must be independent from other social institutions and systems are so strong. In the eyes of many of the institutional leaders of science, any penetration of science by other cultures — whether democratic or commercial — is bound to compromise its autonomy and, therefore, must be resisted.

However, it is clear from the work of many historians of science that the search for absolute, or near-absolute, 'truth' was gradually replaced by the more pragmatic goal of producing 'reliable' knowledge. Science's assertion of intellectual and institutional autonomy has been justified — modestly — by the need to maintain the conditions under which such knowledge can be produced, rather than — arrogantly — by a claim to reveal or recognize 'truth'. Indeed, science's autonomy is rooted in uncertainty and in the need, in the absence of terminal 'truths', to maintain disinterested (and, therefore, uncontaminated) methods by which all theories, results and other claims can be constantly interrogated. So what emerges from the history of science is a gradual process of complex objectification rather than of grand assertions of the discovery of once-for-all methods guaranteeing objectivity. Moreover, the concept of objectivity itself is a many-layered, polymorphous and polyvalent notion. It comprises many strands — moral, methodological, epistemological and pragmatic–instrumental, the cumulative effect of which is to create the conditions of objectivity. But the meanings attached to objectivity do not cohere either in precept or in practice. Sometimes, objectivity is seen as a method of understanding, the stepping back from a subjective point of view; at other times, as an attitude or ethical stance that can be described as neutrality or impersonality. But whatever its many-layered meanings, it is still the best method to obtain certified and reliable knowledge. Without this reliability, science would only be a game of the imagination — a powerless effort leading nowhere.

No one has done more than John Ziman to emphasize this aspect of science. In his view, science produces reliable knowledge because of the particular rules which all scientists must adopt in the process of generating and communicating new knowledge. For him, as for Merton, 'scientific knowledge is the product of a collective human enterprise to which scientists make individual contributions which are purified and extended by mutual criticism and intellectual co-operation'. In its simplest form, the model consists of a number of independent researchers, linked by a common set of processes governing the status of the knowledge produced. According to this model, the goal of science is to extend the sway of rational opinion over the widest possible field. Furthermore, Ziman argues that scientific knowledge can be distinguished from other intellectual artefacts of human society by the fact that its contents are open to consent — that is, each message is neither so obscure nor ambiguous that the recipient is unable to give it whole-hearted assent or to offer well-founded objections. To be comprehensible to others (although the definition, and so the extent, of 'others' is crucial), is necessary if a scientific object, whether theory or set of empirical findings, is to be made available to be added to the stock of knowledge or open to improvement or refutation[1].

Furthermore, according to this model, the goal of science is to achieve the maximum degree of agreement, that is, of consensuality. Ideally, the general body of scientific knowledge should consist of facts and principles that are firmly established and accepted without serious doubt, by an overwhelming majority of competent, well-informed scientists. Thus, it is convenient to distinguish between a clear message with the potentiality for eventually contributing to a consensus, and a consensual statement that has been fully tested and universally agreed. Clear messages are a necessary condition for any scientific communication, whereas only a small proportion of the whole body of science is undeniably consensual at a given moment. It is through the operation of the twin processes of consensibility and consensuality that science is able to produce reliable knowledge.

Conversely, if messages are so obscure that they cannot be understood and thus incapable of being tested and purified by others, then consensus cannot be established. It follows that such messages should not be admitted to the realm of science. Equally, if the social relations of knowledge production and the economic conditions under which it takes place inhibit the free flow of information, this crucial consensus-building process is undermined and, with it, the claims of science to produce reliable knowledge. Such an argument is hardly novel; it has been used for many years, for example, to defend science from being co-opted by, or subordinated to, the values of business and political cultures. Business culture, in particular, because of its focus on short-term performance and its ethos of confidentiality stimulated by the perceived need to protect intellectual property, is frequently criticized for its predisposition to distort the free flow of information. Such distortion restricts consensibility and weakens the fabric of consensuality — the very elements which enable reliable knowledge to be produced.

However, there are two main difficulties (or limitations) within

1. J. Ziman, *Reliable knowledge*, pp. 1–10, Cambridge University Press, Cambridge, 1978.

this model — which, admittedly, has been presented here in an oversimplified form. The first, which is conceded by most scholars, is that although it is science's goal to achieve the maximum degree of consensuality, nevertheless only a small proportion of the whole body of science is undeniably consensual at a given moment. But, if the objective of maximum consensuality can only be achieved sometime in the future (and a future that always recedes), what is its current status, and force? In practice, most scientists, in terms of their day-to-day behaviour, seem content to work within the very limited consensus(es) of their own specialisms. It is within these relatively limited horizons of discipline-bound peer-group consensus that research activity takes place, theories are constructed and evidence collected and analyzed, and scientific reputations established and maintained. Only rarely can an overarching group of 'integrators' be identified which is attempting in a systematic way to extend these specialist consensus(es) to the 'maximum extent'. Nor does it seem to be true that scientific recognition by peers depends on one's findings being absorbed into the existing consensus. Rather, that consensus may not arise until much later when all the implications of a particular theory or set of findings are corroborated. Even Nobel Prize winners who have launched new research trajectories often have to leave the building of the 'maximum range of consensus' to historical processes. The ideal of a widespread consensus seems to lie always in the future, often the remote future. In the short term, the consensus-building process is a much more local affair determined by the peer group of each specialism.

The second difficulty, which follows on from the first, is that the emergence of ever-finer specialisms which science raises leads to a proliferation of ever-narrower consensus(es). But, if, as the model of consensuality and consensibility suggests, the more widespread the consensus the more reliable the knowledge, how can reliable knowledge be generated when most disciplinary experts frankly admit that they know more and more about less and less? Rather, the disintegrative characteristics of modern scientific practice appear to be reducing the prospect of producing reliable knowledge — if , that is, reliability rests on the possibility of achieving widespread consensus. The whole process appears to have been thrown into reverse. Of course, someone trained in the techniques of a particular specialism, in principle, could check research findings in another specialism — but this is hardly so in practice. This cross-disciplinary, cross-specialism checking capacity depends on two conditions being satisfied — first, that generic techniques can be identified and applied (apart from allegiance to common norms of behaviour), and second, that the consensibility of scientific findings in different disciplines and specialisms can realistically be maintained.

Neither condition is easy to satisfy. Instead, scientists rely on the trust they have in each other and in the integrity of the consensibility process. Not only do they trust their colleagues, they also trust that the publication of research-findings which enables them to be checked, and improved or refuted, will inevitably bring to light 'wrong' facts and eliminate unsustainable theories, even within the narrow territory of a particular specialism. But, again, this only happens in the long-term which raises again the first difficulty. So instead of there being a broad consensus, the pattern that emerges is of a set of discrete consensus(es). Although each is the product of the dynamics of research within a specialism, severely limiting the possibility of creating broader consensus, consensuality nevertheless is maintained by the exercise of mutual trust among scientists, based on their belief/agreement that the process of open interrogation of research-findings is broadly similar across specialisms. There is another reason for believing that the emergence of more and more specialisms and subspecialisms does not threaten the long-term production of reliable knowledge. It can be argued that, so long as scientists are free to pursue their own ideas, they will inevitably raise problems that cross fixed disciplinary or subdisciplinary boundaries. As a result, the unconstricted pursuit of knowledge through a vast process of checking and cross-checking will, in the end, still produce a robust fabric of reliable knowledge. The very proliferation of discipline- and specialism-bound consensus(es) will ensure their intermingling, so producing a web of overlapping consensus(es), which arguably approximates to a grander overarching consensus and certainly produces the conditions for consensuality.

These processes of consensibility and consensuality admittedly are slow. They are, however, self-regulating and systematically eliminate errors. It is argued that these processes are most effective if the science system is kept separate from other forms of knowledge production which might transgress the imperatives of consensibility and consensuality. The basis of the argument for separation is that the capacity to create consensus depends on the clarity with which research results are communicated. This, in turn, depends on systems of training and socialization which can only be expressed through the practices and procedures of the particular specialisms into which the modern scientific enterprise is currently subdivided. It is an apparently convincing chain of argument. Consensibility and consensuality are now global phenomena which sustain the belief in the universality of scientific knowledge, although, at any particular time, this universality only comprises an aggregation of the relatively constricted consensus(es) of an ever-increasing number of specialisms.

Nonetheless, the actual operation as opposed to the principled articulation of consensuality reduces the potential for producing reliable knowledge. If, according to this model, the achievement of greatest possible consensus remains the long-term goal, the reliability of the knowledge actually produced (i.e. in the short- and medium-term) must be compromized by the difficulty of creating anything apart from a plethora of constricted, and perhaps incommensurable, consensus(es). And there is a further complication: it is now routine to regard the corpus of scientific knowledge as provisional, reflecting the prevailing pattern of specialist consensus(es) which are subject to rapid change and radical reconfiguration. To the extent that these consensus(es) are provisional, their reliability is reduced — but to what extent and in what ways cannot always be established. It would be wrong to push the argument too far by inferring that the increasing specialization of science is producing increasingly unreliable knowledge; the provisional nature of science from which the volatility (and, arguably, unreliability) of scientific consensus(es) is derived, is a reflection of its dynamism which, in turn, reflects science's more sophisticated understanding of the natural and social worlds — which is itself a form of enhanced reliability. However, there must be some relationship between the breadth of the consensus and the degree of reliability that can be claimed, although discipline-bound research is not inherently more reliable. A limited consensus within a particular specialism involving a single peer group may be very similar to a limited consensus in a cross-disciplinary field involving different peer groups, in terms of the reliability of the knowledge it produces. In both cases, the consensibility criterion applies: research outputs must be sufficiently comprehensible to be tested. But the *locus* of consensuality will be different because the composition of the relevant 'experts' is different. In both cases, a limited consensus is achieved — arguably to the detriment of the reliability of the knowledge produced.

In brief, science produces reliable knowledge because, if the rules which guide research practice are followed, a limited and provisional consensus is produced. But not everyone is equal. It is only important that such a consensus is established among the members of a tight-knit community of other specialists, within a particular peer group. They alone, it is argued, are in a position to judge their peers and to uphold the standards leading to good science. In the context of the development of Mode 2 knowledge production, with its shift from a discipline to a problem focus, a key question therefore arises. In this new environment characterized by more intense interaction within a much wider community of other practitioners and embracing other disciplines, or stretching across the boundaries of academia and industry, or embracing even more heterogeneous 'stakeholders' — is it still possible to produce reliable knowledge? To argue that, in principle, additional criteria have to be considered in addition to traditional scientific excellence — even if it continues to be a predominant element in the quality-control system — is easy enough; the tensions, dilemmas and even contradictions that actually arise in scientific practice are more difficult to dismiss. So it is essential to consider how a shift to Mode 2 knowledge production, to greater emphasis on problem-relevance and on the specific contexts of application in which this relevance arises, affects the formation of consensibility and consensuality.

Consider the case of university-industry relations. Amongst scientists, the argument is that the closer the interaction between academia and industry, the more difficult it becomes to sustain the traditional academic ethos — and, in particular, the commitment to disinterestedness which marks the frontier between academic science and industry. Mode 2 knowledge production, with its emphasis on problem-solving in the context of application, tends to erode the independence of academic researchers and, consequently, weakens their defences against external influences. These influences are not hypothetical. The frontier land between academia and industry is rapidly becoming populated by semi-autonomous research entities that earn their living by undertaking specific projects. These projects are supported by a variety of funding bodies, including private-sector firms and government departments. Some of these bodies make elaborate efforts to foster originality and integrity; after all, it is hardly in their interest to commission second-rate research. But inevitably, there is a general tendency, and often explicit instructions, to favour projects with apparently better prospects of 'wealth creation', or with practical, medical, environmental or social applications. Mode 2 research, however remote from actual application, is characterized by its potential for use, and critics of Mode 2 research are unequivocal in their view that whatever may be the benefits of this way of organizing inquiry, it is clearly an activity where socio-economic power has the final authority.

But, does this applications orientation and engagement with 'extra-scientific' forces fatally undermine Mode 2's capacity to produce reliable knowledge? Certainly, secrecy and short-termism are counterproductive. If sustained over a long period, they would seriously weaken reliability. But how precisely does this broader configuration of researchers — coming from universities and industry, government laboratories or even the semi-autonomous research entities referred to above, who have been orchestrated or 'self organized' to search for solutions to a common problem — undermine consensibility and consensuality? Consensibility, as has already been explained, requires the transmission of clear messages about the research questions to be addressed, the techniques employed and results obtained. It is not clear why research carried out in a problem context should weaken consensibility within the problem-solving group. In fact, if clear communications are not maintained within the research group, less satisfactory solutions to problems are likely to be produced. Consensibility, although it may be more difficult to sustain under Mode 2 conditions, is equally — or perhaps even more — crucial. It can even be argued that, because communication within a Mode 2 research group cannot be taken for granted (which, sometimes mistakenly, might be the case in a tight-knit Mode 1 group), greater emphasis will be placed on the need to transmit messages more clearly.

In a similar way, consensuality would still operate under Mode 2 conditions even if a more diverse set of people with different scientific backgrounds and training, and probably with different attitudes and outlooks regarding the potential of future use, has to be engaged. It is not clear why the importance of consensuality should be less within such a diverse group, despite the (apparently) greater difficulties in communicating and reaching a consensus. Peter Galison has described the emergence of so-called 'trading zones' characterized by ingenious processes of negotiation between the different parties. For example, they devise 'pidgin' languages which bridge disciplinary gaps, and allow everyone to understand and be understood by the others. The members of such groups have very clear and nuanced strategies of mutual exchange at work because, in their pursuit of a common objective, they depend on the knowledge, skills and know-how of others which they would be unable to obtain otherwise[2]. But there is no suggestion that consensuality, like consensibility, cannot be practised in such a context.

Even if there are no principled reasons why consensuality and consensibility cannot be maintained under Mode 2 conditions, clearly it would be misleading to suggest that nothing has changed. Something must be different, even if the outcome can still be called reliable knowledge. The question must be asked: does Mode 2 produce a different kind of reliability and, if so, in what sense? Reliable

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2. P. Galison, *Image and logic* (University of Chicago Press, Chicago, 1997).

knowledge, as traditionally defined, presumes that consensibility and consensuality operate mainly within a disciplinary context, even if disciplines are constantly forming and reforming. The relevant community is easily recognizable, their knowledge is specialized and peers are known to each other. The reliability of such knowledge is rooted in its relevance to these disciplinary or subdisciplinary structures — it is inner-directed. In contrast, reliable knowledge produced by a wider network of collaborators working under Mode 2 conditions is reliable in terms of a wider consensuality — it is outer-directed. It is reliable in terms of the problem relevance of the context in which it arose and which continues to influence it. Of course, these two kinds of reliability are not separated from each other in watertight epistemological or practical compartments. There are visible and invisible, formal and informal, cross-currents and systems of exchange between them. To occupy one, the many 'trading zones' in which inter- (or trans- or even intra-) disciplinary knowledge is created does not require the abandonment of one's disciplinary 'home', or the loss of one's primary identification as an academic or industrial scientist. In some respects, it may even strengthen disciplinary and professional identities. In other respects, subtle accommodation processes may be at work, creating multiple and modified identities which are different. The experience of life in a 'trading zone' may be not unlike that of the emigrant. Although some trading-zoners will return to their old disciplinary 'countries' — and maybe return again, perhaps frequently — old loyalties are fiercely maintained while new identities are created, producing new hybrid researchers.

Reliable knowledge, therefore, has always been reliable within bounds. In its conventional (and constricted) and refined (or 'pure') sense, these bounds embrace a relatively small number of peers. They police the bounds of reliable knowledge, ideally through disciplinary cohesion, in order to limit as far as possible the contamination likely to be produced if the surrounding social context is allowed to enter the realm of knowledge. The ethos of academic science, and its social practices, were designed to achieve this containment. But it is difficult to see how this containment strategy can remain valid — except in the exceptional context of the need to preserve scientific 'enclaves' — when science becomes contextualized. In this new environment, the boundaries within which reliable knowledge is contained have been dramatically extended, even abolished. Reliable knowledge, as validated in its disciplinary context, is no longer self-sufficient. Instead, it is endlessly challenged, and often fiercely contested, by a much larger potential community, which insists that its claims to be heard are as valid as those of more circumscribed scientific communities, and demands that its preferences too are taken into account. Of course, reliable knowledge in terms of its disciplinary relevance and validity, like objective knowledge, is not simply to be discarded or ignored; they both continue to provide the foundations on which our knowledge of the natural world depends. But neither is any longer sufficient in itself.

Where does this argument lead? Contextualized science produces socially-robust knowledge, that is, knowledge which is valid outside the sterile spaces of the laboratory. Further, there is no inherent reason why such knowledge should not be as reliable as that produced in Mode 1. Indeed, it may be more reliable because of the need, in the context of application, to ensure that consensibilty and consensuality be transparent.

THE EMERGENCE OF A CONTEMPORARY *AGORA*

In our description of Mode 2 society, we emphasized the sprawling, fragmented, unruly and transgressive evolution of societal changes. These changes are framed within what has become by now the standard political model, even if still confined to one part of the world — Western liberal democracies. Therefore, before proceeding with the argument, it might be useful briefly to re-examine the relationship between science and democracy and the significance of the emergence of a special public space — which we will call the modern *agora* — for the wider relationship between science and society. It is important to emphasize, *contra* Merton, that science does not necessarily depend on democracy. In its beginning, modern science owed nothing to democracy. Its sources were in aristocratic patronage in the Italian city states in the 16th and 17th centuries, and in the tolerance and curiosity shown by enlightened monarchs in the 17th and 18th centuries. Although relative religious freedom encouraged the development of science and, later, the growth of a powerful bourgeoisie was an important source of support, science flourished before democracy.

However, in early modernity, science, like other social institutions, benefited greatly from the emergence of a public space, neither directly controlled by the political ruler and/or organized religion, nor relegated to the private sphere. The effective functioning of science depended upon its espousing the principle of meritocracy, but not of democracy. Even today, although public demands for some form of democratic participation in shaping science are powerfully articulated, there remains an inherent contradiction between science and democracy. Democracy works by seeking to resolve conflicts through compromise and negotiation between divergent and conflicting interests — either by direct voting or indirectly by defusing them through other arrangements; science works by very different rules in which majority voting and contingent compromise have no part.

The public space that emerged in early modernity has developed into what we now call the contemporary *agora* where political and market exchanges of all kinds take place. The enlargement of this public space encouraged the growth of a 'public' science. As a result of the rise of the nation-state which emphasized cultural homogeneity, science with its universalistic aspirations became an important vehicle not only for national aggrandisement and prestige, but also for the development of an educational system based on an enlightened and scientific world-view. Later, this same public space became the privileged arena in which science was able to build its alliances with the state and industry. At the same time, because of the expansion of Europe and the emergence of Western hegemony, science became the standard-bearer of enlightenment, modernization and rationality which spread around the globe. More recently, the market has come to dominate the *agora*. This development of a globalizing economy has made science an even more attractive partner. However, this public space is not only expanding 'externally', in economic and geographical terms, as a result of market globalization and the spread of new information and communication technologies; it is also expanding 'internally' by absorbing segments from what was previously either the private sphere or under the jurisdiction of religion (which itself has become privatized — at least in the West). So, for science there has been a substantial increase in the density of regulations — for example, ethical guidelines or intellectual property rights — which indirectly but powerfully demonstrate its domination of the *agora*.

The dominant place of science in the *agora* and its multiplying interlinkages with the social world are the result of contextualization of science — which is itself the result of science's increasing engagement with different and diverse social objectives; of the multiplication of sites where knowledge is produced and used; and of science's many other links to changes in the construction of social 'reality'. Because contextualization is a reflexive process, it is difficult — and perhaps unnecessary — to try to determine whether (and, if so, to what extent) science has opportunistically adapted to new demands, or whether, and to what extent, science has been instrumentalized by the forces of the economy. A more important question is how permeable scientific activities have become as a result of this reflexive contextualization, or how resistant the hard epistemological core of science remains. Japan may offer an illuminating example. When in the last quarter of the 19th century Japan opened itself to westernization, it took over many of the practices, methods, and concepts of science as it was understood in the West. However, Japan did not adopt the metaphysical assumptions on which science is based in the West. In other words, an instrumental–utilitarian transfer is possible, apparently without great loss[3].

What science and scientists are now faced with is an *agora* with multiple publics and institutions, like the media, who vigorously lead their own lives and conduct their own negotiations in the *agora*. They are faced with a complex bureaucratic and admin-

3. S. Fuller, *Science: concepts in social sciences* (pp.132–34, Open University Press, Buckingham, 1997).

istrative web of funding-agencies which make up their own policy goals, guidelines, assessment procedures and allocation mechanisms, in a science policy landscape that seeks to accommodate an increase in private financing, while becoming much more discriminating and demanding in public funding. Researchers have had to develop a new range of skills in communicating with their potential funders, in writing grant proposals, and in plausibly promising outcomes which they cannot specify in advance. They face an industry-business landscape which itself is undergoing major restructuring. The former state industries, which had been the most reliable and familiar partners, are themselves under attack for lagging behind in innovation and for lack of efficiency. The much-vaunted small and medium-sized enterprises lack sufficient human, infrastructural and financial resources to be attractive partners for university research, but that too is changing rapidly. Moreover, there are big differences between research fields, with biomedical sciences leading in the privatization of research, while other fields are still struggling to find their niche in an altered science policy (and funding) landscape.

Undoubtedly, the greatest challenge for science and scientists in the contemporary *agora* does not come directly from markets and their extending demands, nor from a restructured industry which seeks to decrease its traditional in-house research. Nor does it come from the state's shifting funding patterns and the resulting changes in the entanglement of different science policy alliances and their criteria. While making new demands on the ingenuity of researchers, they will be able to accommodate these changes, especially since the overall funding level for research is not falling. The main challenge in the *agora* comes at a deeper level. It arises from contextualization itself, which has so greatly enhanced the success of science, opening up new research fronts, expanding research horizons, and establishing new and apparently-flourishing research fields. But, contextualization comes with a price attached: the context talks back. This is what science and scientists hitherto have not been accustomed to, and it may not be surprising that they see it as, first and foremost, a threat to their cognitive and social authority. Mounting their defences, it is all too easy to blame it on the rise of anti-science sentiments, on the subversive influence of social scientists and other 'relativists', or simply on the irrationalism which has survived under the aegis of rationality and scientification. Probably, no amount of empirical evidence to the contrary — like the consistent findings of public opinion polls or survey data, which show that the overall trust in science is no worse than the decrease in legitimacy of other public institutions, or that science is still highly regarded in its overall problem-solving capacity — can convince the scientific sceptics in the *agora.* But to try to salvage an outdated image of science, one that no longer does justice to the new realities of the agora and the demands articulated there towards science, is likely to be a self-defeating strategy.

By taking a 'context which talks back' seriously, scientists can discover the extent to which the contextualization of their research activities has worked. They may entertain the extent to which the hypothesis whether, and if so in what ways, the subjective experience of people has been affected, or what other, more long-term or large-scale societal changes are likely to be brought about by their research activities. While most researchers, through the peer-reviewed publication system, have a pretty good idea about the impact that their work has had on their immediate colleagues, and many are also keen to know and see whether their research extends to other specialties and disciplines, few scientists have any real incentives to ponder about its effects on the social context. While those researchers who are closely collaborating with industry have learned perfectly well how industrial management reacts and acts, and can interpret or even anticipate industry's attitudes and decisions to their research and its future, no such intimate learning experiences exist with regard to the wider public. And, yet, this is also what the *agora* is all about.

The *agora* in its contemporary form, therefore, embraces more than the commercial market and more than politics. As a public space, it offers space for exchanges of all kinds, for the articulation of wishes, desires and preferences as much as for demands. It is also a space in which certain forms of contestation are legitimate, at least within the bounds and rules of Western liberal democracies. While the *agora* should also be thought of as a structured space, it would be wrong to attempt to subdivide it again into sectors like markets, politics or the media. As befits a Mode 2 society, these forms of differentiation are partly breaking down, replaced by fluid and dynamic interlinkages that spread throughout it. As a public space, it has structured itself through the interaction of the agents who are actively engaged in it. This is what is meant by a process of structuration. While some actors are more visible, more easy to identify and recognize and certainly more powerful than others, it is also a space in which different perspectives are brought together, ultimately creating different visions, values and options. In this sense, context also contains contingency, but there is no contingency in this public arena that operates without some kinds of constraints. The procedures of democratic debate, contestation, forms of protest and of negotiation, constitute one set of constraints. The economic constraints under which markets operate, especially on the global level, are another set. Governmental policies, laws and regulations, far from being completely subservient to business and market interests, can also be regarded as constraints. The media and their influence on public opinion operate as constraints again, but of a different kind. But such distinctions merely reflect our inability to conceive of interlocking contingencies and constraints that arise in different parts of the *agora*, with heterogeneous, but partly overlapping actors, and what outcomes they are likely to produce. The grounds of the *agora* keep shifting continuously, as do the interconnections.

CONCLUSIONS

Thus far, we have described some of the features of a Mode 2 society and have suggested that there exists a process of coevolution between Mode 2 society and its dominant mode of knowledge production — Mode 2 science. We have illustrated this coevolutionary process in the case of the changing relationships between universities and industry. More generally, however, society and its mode of knowledge production are evolving together. The two are connected by contextualzation, the process whereby social anticipations, perspectives and beliefs are brought into the research process and affect the agenda — that is, what it is thought worthwhile doing, how, and by whom. Most recently, such social anticipations and perspectives have been mediated largely through national research programmes. This form of mediation produces only weakly contextualized knowledge because it still requires a response from the research community to the objectives as formulated if resources are to be liberated and, in the absence of dialogue over aims and objectives, may leave the intellectual structure of inquiry unchanged. Such responses require a great deal of interpretation by researchers before their work, structured by the canons of disciplinary relevance, can be adapted to programmes set by other criteria. Yet, even here, some contextualization, however 'weak', must be taking place.

Yet, government research programmes do not capture the process of coevolution which we have adumbrated. There is little in the way of mutual articulation of a research agenda in a problem context. For the most part, the dialogue takes place between the major institutional blocs — the state, industry, science — and is carried out by their representatives: MPs and civil servants, industrial R&D managers, and senior university scientists working with research council committees, etc., on the demand/social side, and universities, research councils, and other public R&D institutions on the supply/knowledge side. There is little in the way of mutual development of a research agenda or co-operation in the joint production of knowledge. Mode 2 knowledge production is not about establishing programmes that bring together a range of disciplines to bear on a problem; it is about developing a research agenda relevant to a problem context, using whatever configuration of expertise seems relevant to those involved in the process where the agenda is developed and executed by the actors themselves. Contextualization describes how science and society interact in this latter process. The sites where this process takes place have been characterized as a contemporary *agora*.

A key characteristic of Mode 2 society is the way it is able to generate 'transaction spaces' in which different perspectives and interest can become aligned in the genesis of a research project. The cognitive landscape of Mode 2 science is filled with such transaction spaces, which in a Mode 2 society can replace the more formal, institution-based peer-review groups in terms of deciding what research will be done and by whom. A transaction space is more than a peer-review group; it is also a vehicle for prosecuting the joint production of knowledge. It is not about vetting other people's proposals, it is about developing a research and implementation strategy — including funding possibilities — of its own. In a Mode 2 society, transaction spaces replace, to some extent, the cross-institutional committees where bargaining of various sorts used to take place by representatives with the power to release institutional funds.

Because of the way in which Mode 2 society and Mode 2 knowledge production operate, the outcome is socially-robust knowledge. It is the form of knowledge appropriate to a Mode 2 society in that it addresses a concrete problem using the appropriate configuration of intellectual and other resources. Because it has involved a participative process, it is less likely to be contested. We could, therefore, go on to say that, whereas Mode 1 knowledge production emerged as the primary form during an institutional regime characterized by strong institutional boundaries and managerialism within, Mode 2 knowledge production emerges in the context of the more fluid institutional structures that we have identified with our Mode 2 society.

The transition from Mode 1 knowledge production to Mode 2 knowledge production requires that universities and university science move from the relative isolation of the ivory tower into the complex world of the *agora*: a new type of public space in which many issues are settled — political, economic, social. Of course, many businesses are active in the agora, but it would be inaccurate to regard the *agora* simply as a marketplace, as is sometimes done. It is the public place — filled with different anticipations, perspectives, and interests — where issues are discussed, priorities settled, and programmes executed. It is into this arena that the scientists of the universities must venture, if universities are to play their part in the production of socially-robust knowledge. In entering the *agora,* science will, in fact, be moving beyond the market.

It is because it is necessary to communicate the significance of what is taking place on the many interfaces between science and society, that a rethinking of science has now become necessary. In an older configuration, the relevant elements were basic research, disciplinary contributions, reliable knowledge, and a cultivated distance from immediate involvement in society's problems. This image is a dead duck and will be strongly contested in any Mode 2 society. By contrast, in the new configuration, the relevant elements are research in the context of application, transdisciplinary contributions, socially-robust knowledge, and multiple lines of participation by a wide range of experts in the *agora.*

And so, we come to the next phase of the research revolution: the third academic revolution. It is that aspect of the research revolution in which the universities strive to work out new ways — mission statements, modes of governance, career structures, funding possibilities, etc. — to allow them to participate fully in developing a new mode of knowledge production for a new type of society. Participation in the new mode holds out perhaps the only prospect the universities have to re-establish themselves as key players in their social context — a development that could be threatened by a stubborn commitment to maintaining the disciplinary structure of science. Universities need to change and, indeed, they are changing. As was demonstrated in the second lecture, they have already a transforming role in economic development. To date, universities have accomplished a great deal in commercializing the results of their research. At the very least, they have shown that they can move their knowledge — their science — into the market. The deeper challenge, however, is for them to become the vehicles for taking their science beyond the market, and in so doing, redefining what it means to do academic science. To succeed, they must take a leadership position in the contextualization process. But, as we have seen, to do this they must take stock of what kind of knowledge is required, and how they intend to contribute towards helping to produce it. Universities must enter the *agora* with the same vigour with which they once embraced government, and put their resources — intellectual and financial — to the task of generating the structures that will support new kinds of science and new kinds of scientists.

To conclude, it is important to highlight just how far we must move in rethinking science, and how little it is possible to do so by simply tinkering with the arrangements between the state, the market and the universities. So far at least, the emergence of contextualized knowledge in the *agora* seems to be a largely self-organising affair. Though governments continue to be involved in the *agora*, research does emerge from the bureaucratic planning processes that are, by now, so familiar. Because it is largely self-organizing, universities need to decide for themselves what they are to make of themselves. There is no blueprint to follow. Burton Clark, the distinguished American sociologist, has referred to this imperative in terms of the emergence of the entrepreneurial university. But, it is not the familiar individual entrepreneurship so prevalent in the management literature that he is advocating, but the collective entrepreneurship of the *collegium*. There is no pre-existing blueprint readily available, and, in its absence, collective entrepreneurship would seem to be a necessary basis for developing survival strategies.

The situation facing science in general and the universities in particular has been very well described by the philosopher Otto Neurath. Neurath repeatedly used the metaphor of scientists having to rebuild their ship while on high seas. This metaphor has generally been interpreted as referring only to the cognitive content of science. The new planks needed to replace the old and decaying wood were to be taken from other parts of the ship, while ingenious *bricolage* and engineering helped to keep it not only afloat but also ploughing through the waves. However, in the light of Neurath's lifelong passionate interest in how science could reach out to a wider public, he would probably have accepted a much wider interpretation of his metaphor. This metaphor — of scientists rebuilding the ship of knowledge while it forges ahead — can also be used to describe the more heterogeneous (and also more ambiguous) constitution of reliable knowledge now needed to keep the ship of science afloat amid the turbulent waters of contemporary society. To suggest that reliable knowledge must engage the social world more openly and directly, is not to seek to diminish but to enhance the status and validity of science, by arguing that reliable knowledge — to remain reliable — also has to be socially-robust knowledge.