GENE MAPPING AND POLICY-MAKING: AUSTRALIA AND THE HUMAN GENOME PROJECT*

Brian Balmer

This paper examines various unsuccessful attempts by Australian geneticists to become involved in the international Human Genome Project. Several attempts were made by various scientists to gain support for organized gene mapping through the National Health and Medical Research Council, the Department of Industry, Technology and Commerce and the Cooperative Research Centres funding scheme. Different expectations of the role of science in each case played a crucial role in shaping policies and their eventual outcome.

Keywords: Human Genome Poject, Australia, genetics, biomedical research, policy process, peer review.

INTRODUCTION

Policies are theories about the world, argues Majone.[1] They are theories about what the world ought to be like, based on what we perceive the world to already be like. Even the absence of active policy deliberation embodies a range of assumptions and constitutes a policy of sorts, as Strickland has put it:

> National policies need not, of course. always involve focused activity of the kind typified by the Manhattan Project or the space program. Policy can take the form of inactivity; it may, for example, involve nothing more than a conscious, collective attitude of 'benign neglect' on the part of government towards an issue.[2]

During the late 1980s and early 1990s attempts were made by a number of biologists to set up, or participate in, schemes which would have given priority to gene mapping in Australia as part of the international Human Genome Project (HGP). None were successful. The processes that resulted in this 'benign neglect' of genome mapping in Australia form the main theme of this paper. The study is based on interviews carried out between March and June 1992 with 24 policy-makers and scientists involved in gene mapping. Its aim is not to attempt an answer to the normative question of whether or not they should have been involved in the Project, but rather to discuss the fate of their efforts to become involved and the factors which influenced the final outcome.

The paper provides empirical evidence that policy can usefully be construed as

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both 'benign neglect' and the embodiment of 'theories about the world'. It furthermore demonstrates the shaping of research policy by a complex array of political, institutional and scientific concerns, rather than solely by the traditionally conceived criterion of 'scientific merit'; the latter being frequently taken as a readily available and unproblematic tool for evaluating policy options.[3]

THE HUMAN GENOME PROJECT(S)

The aim of the Human Genome Project, quite simply, is to draw up a catalogue of our entire genetic make-up – the genome. The maps, like geographical maps, can be of varying type and resolution, from large-scale *linkage* maps of genes in relation to other genes based on frequency of co-inheritance, through various types of *physical* maps that locate 'landmarks' in the DNA and eventually to the highest resolution, the sequence of chemical base-pairs which make up the DNA molecule.[4] Proponents of the project claim that this will provide a valuable resource for science and medicine whilst opponents have challenged the wisdom of the project in terms of the cost, strategy, ethics and ultimate utility of the results.[5] Plans for a US project crystallised throughout the mid- to late 1980s and the US 'Human Genome Initiative' was officially launched at the start of the 1991 financial year with a target of completion in 15 years.[6]

Throughout the late 1980s a number of other mapping projects in different countries had begun to take shape. In early 1991 a world-wide survey of genome mapping activities listed 8 countries with established national genome projects (Denmark, France, Germany, Italy, UK, Japan, USSR and USA) and a further 7 which had made moves to instigate national programmes (Australia, Netherlands, Canada, Chile, Sweden, Korea and New Zealand).[7] In addition, international programmes had been instigated or proposed by the EC, UNESCO, Latin-America and the Nordic countries. World-wide co-ordination, but not research funding, of the initiative was being undertaken by the Human Genome Organization (HUGO) so that the international project could best be conceived of as a loose confederacy of programmes.

AUSTRALIAN GENETICS

The UK survey, published in January 1991, had pointed out Australia's strong base of research into human genetic diseases; highlighted a proposal to establish a cooperative research centre (CRC) for Mammalian Genome Research; and noted national research efforts in mapping of non-human species.[8] The report also mentioned that the Department of Industry, Technology and Commerce (DITAC), as well as the National Health and Medical Research Council (NH&MRC), were taking note of gene mapping through the establishment of various advisory committees. Later in 1991 the NH&MRC committed $AUD50,000 to HUGO.[9] This commitment was followed up a year later when the Council provided $AUD20,000 for an International Genome Sciences meeting in Adelaide. Arguments in favour of an Australian project have also appeared in the policy literature.[10] On all the above grounds, the prospects for some sort of co-ordinated national genome effort seemed favourable.

Apart from these specific moves towards establishing a genome project, general statistics indicate that Australia is active in biomedical research, including genetics. In the broad field of medical research, Australian scientists receive 16 per cent of the national expenditure on research and produce between 46-50 per cent of Australian scientific publications, 2 per cent of world biomedical publications.[11] Moving to a more particular level, the Australian Science and Technology Council (ASTEC) records that for 1984, Australian publications in the subfield entitled "genetics and heredity" accounted for 10.99 per cent of all publications in that subfield.[12]

A bibliometric survey of publications involving gene mapping, updated for this study, gives some indication of activity in this specific area.[13] The study showed Australia performing reasonably well in terms of numbers of publications (Table 1). The Australian share is small in comparison with the leaders, the US and the UK. Australia, however, ranked eighth in the world for 1992, ninth for 1991 and 1990, and seventh for the preceding two years. The scores also compare favourably with three other "medium performing countries" used by ASTEC for comparative purposes in their aforementioned report: Canada, Sweden and the Netherlands. All of these countries were identified as having made plans for organized genome projects in the 1991 survey.[14]

TABLE 1
HUMAN GENE MAPPING
(% Share of publications)

	Year				
Country	1988	1989	1990	1991	1992
US	52.1	46.2	46.8	44.3	43.7
UK	11.7	11.8	12.4	11.0	11.8
Australia	3.1	3.5	2.3	2.7	3.4
Canada	4.2	4.9	4.8	4.8	3.7
Netherlands	2.4	2.7	2.9	3.5	2.6
Sweden	1.8	1.9	1.5	2.0	2.0

All of these bibliometric indicators point to active gene mapping research drawing from an equally active biomedical community. At a broader level, the strong agricultural sector in the country would suggest that a project with a strong comparative mapping component might also have been a feasible proposal. So, although the expertise and research activity appear to have been present in Australia, by early 1992 the country had not initiated a genome project of any description. The CRC proposal had failed to mobilize funds, DITAC appeared to be backing off from the area and interviewees were consistently saying that the NH&MRC had no formally articulated policy towards gene mapping.

Although this situation by no means suggests that there must (or even should) be some type of a human genome project in Australia, it does mean that one cannot account for there being no formal project solely in terms of any lack of activity in the field. This case study does not attempt to evaluate what *ought* to have happened, but to explain what *did* happen. No one went running for the statistics in order to construct a detailed case for or against the project. In this respect it is enough to note that the point of departure for the study was an active gene mapping community who tried but failed to set up some sort of organized project. An account of the characteristics of this community forms the next section of this discussion.

PROFESSIONAL STRATEGIES AND GENE MAPPING STRATEGIES

The gene mappers interviewed were all employed within one or other of the various publicly funded research institutions of Australia, in this instance universities, CSIRO institutes or hospital-based research laboratories. Although a putative Australian project, like the various international genome projects, would have as its aim the mapping and sequencing of the entire human genome, an important strategic split - identified in interviews - runs through the gene mapping community.[15]

One type of mapping project involves "mapping for mapping's sake", constructing maps of whole regions of the genome regardless of what is expected to be there. Scientists in interviews referred to it in terms of a project with the biology removed from it, an information gathering exercise to facilitate biology, and described it, in both laudatory and derogatory ways, as "stamp collecting" or "fishing". This way of mapping presents the most direct means of generating a complete map and has been supported in the policies of the genome projects in the US and the UK.[16] The second style of gene mapping is conceptually located within the problems posed by medical or biological disciplines. Investigators will be working on a particular disease, for example, where locating the gene as the causal agent is only one facet of studying that disease.

It is important to note that these different strategies are not 'either-or' for scientists and the first can be construed as a long-term version of the other. A number of laboratories around the world undertake both sorts of project although it is far less likely that any group would be solely mapping 'for its own sake'. None of the Australian scientists working on human genetics with whom I spoke were working exclusively in this mode. The reason is bound up with the structure of the scientific profession. Put succinctly by one interviewee:

> No group would try to make a name for itself as a human genome mapping group - so mapping becomes part of a project which is hypothesis driven, always in relation to a particular disease.[17]

The amount of effort involved was also bound up with the risky nature of the activity in terms of getting results:

> . . .you might get lucky and do it in three weeks or you might just do it all in ten years time mucking about and not having got anywhere... I mean that's the way genes are mapped, it's the only way that genes will be mapped in many cases and you get on and do it.[18]

A further three scientists linked this riskiness with publication by talking about the difficulties of getting negative results published, i.e. papers which say 'we have looked at *n* per cent of the genome and know that the gene for *x* is not in there'. One described the difficulty of publishing along the way, which was possible in other fields but not gene mapping - again partly because of the difficulty of publishing negative results: "...if you don't find the gene you have nothing to tell people about, well not quite, but it's pretty much an all or none effort". Another scientist pointed out how little return they might get sequencing a long portion of DNA and finding just three genes. This might earn a page or two at the back of a journal such as *Nucleic Acids Research* but there would be "plenty of work involved in two pages".

These comments bring together the choice of scientific and professional strategies and draw out the difficulty that the scientists perceived as accompanying gene mapping. In theoretical terminology, there is an interruption to what Latour and Woolgar have called the *credibility cycle* the requirement to undertake research by converting: (1) grant money into (2) equipment and personnel into (3) data/arguments into (4) articles into (5) recognition (which in turn wins grant money and starts the cycle over again).[19]

The interruption, at the stage of converting data into publications, seemed to provide a strong disincentive to adopting full-scale mapping 'for its own sake' as a research direction. It would certainly seem to have prevented any Australian laboratory making this its only strategy. The significance of this point is that the style of mapping favoured under the social structure of the profession is not the style of gene mapping built into the mission of the global human genome project.

Despite the problems associated with engaging in gene mapping, many of the researchers were quite adamant that Australia should have either a Human Genome Project or some sort of prioritization of the field, although they were equally insistent that it should not cut into funding of other areas of research. In respect to this situation, the position of the Australian mappers regarding the international scene was of particular concern to several of the scientists. With the large number of projects giving impetus to the activity abroad many feared that they would fall behind in the world stakes.

One scientist explained how they had attended an international meeting where the other scientists virtually asked "what gives you the right to sit down with us?" It transpired that when it came to collaboration, scientists from other countries were looking for an equal exchange and were not prepared to act as props for other people's under-resourced work. This scientist summed up this point by saying that "you have to keep pace with these people or drop out [as] eventually the faxes stop coming".

In short, the gene mappers faced a dilemma. If they had chosen to engage in full-scale gene mapping in Genome Project style, especially without an official genome project, it could have been costly in terms of recognition, career prospects and future funding. On the other hand, the scientists saw it as imperative to join the international race, a race that genome projects had accelerated, in order to maintain a competitive position with the gene mapping that they were already engaged in. For this to occur, they needed the support of one or another funding institution or

scheme. At least three possibilities explored by various scientists were those offered by the NH&MRC, DITAC or the Cooperative Research Centres initiative.

THE NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL

The National Health and Medical Research Council (NH&MRC) is the main source of public money for biomedical research in Australia. If there were to be any sort of Human Genome Project in the country then the NH&MRC would be the obvious body to take responsibility for such an initiative. This is partly because the Council already funds individual projects involving gene mapping and because, in those countries with genome projects, organisations with parallel responsibilities support such co-ordination.

The Murdoch Institute for research into birth defects in Melbourne is the NH&MRC's main centre for genetics research. Its aim is the "investigation and treatment of children with serious birth abnormalities, and [to do] relevant basic research".[20] The Institute, however, had a conscious policy of not undertaking any genome mapping. Mapping was avoided partly because researchers at the Institute saw the work as boring and routine and partly because it was not seen as an appropriate way of generating knowledge. In the words of the director:

> I really doubt whether this approach will actually speed up the acquisition of knowledge if one regards as real knowledge the understanding of the function of a gene as well as the recognition of its existence.[21]

This statement of institutional policy runs to the core of science - what is to count as worthwhile knowledge? It is clear that geneticists adopting the above position did not regard gene mapping for its own sake as 'real' knowledge.

It is also of note that the director of the Murdoch Institute was the chairman of the Human Genetics Society of Australasia. Seven scientists interviewed attributed the lack of promotion of gene mapping in Australia to the lack of interest from either or both of these two organizations. Two scientists, for example, talked about the Human Genetics Society and mentioned that they had only recently begun to include any molecular biological issues in their annual conferences.

Although the Murdoch Institute was not involved in gene mapping, the NH&MRC, in response to the growing number of international programmes in genome mapping, set up a Genome Working Party in 1991. At the time of the case study, the working party had only met once with a general aim of determining whether there were any special issues to discuss which related to genome work. However, one member of the committee informed me that the NH&MRC was generally loath to set up special structures to deal with particular areas on the grounds that "you can raise vested interests for any case you want to", not just for genome research. Consequently, genome research would have had to plead a highly persuasive case to be made a priority.

Because of its infancy, the working party had not formulated any NH&MRC policy on genome mapping. Another member mentioned that they would be examining the 1992 grant applications to see if those within gene mapping fared any worse than others, saying that:

> [previous other types of grant] ...weren't able to get up in this competitive peer review system, because applications, normally speaking, to set up reference laboratories and things like this... have never been particularly successful because they can't compete on a peer review basis - of scientific excellence - because of resources it seems.[22]

This comment raises the possibility, which will be explored in the next section, that the normal NH&MRC peer review mechanisms run against genome mapping.

SHAPING RESEARCH THROUGH FUNDING AND PEER REVIEW

The NH&MRC's policy for funding research is stated in the first item of its public statement of values:

> World class research is best attained through an investigator driven process, with evaluation by experts for high quality.[23]

The statement, which places great value on the autonomy of scientific researchers in setting the research agenda, is put into practice through the granting schemes and peer review process of the Medical Research Committee. The committee awards grants on an 'investigator-driven' basis, although there are certain areas of research designated as Special Initiative Areas.

Special initiative grants are awarded to promote activity in areas of perceived need. Applications in these areas are assessed through the standard peer review procedures but should they fail to qualify for a normal project grant they may still be considered for funding. Special initiative areas, because they are topic-led rather than investigator-led, constitute the only 'trans-institutional' grants awarded by the NH&MRC. It might be expected, and was suggested by some interviewees, that human genome mapping could be made into a special initiative area. However, a look at the current special initiative areas (Table 2) shows that the areas are not organized around problems raised within scientific disciplines and instead are defined with respect to particular areas of social concern and political sensitivity.

TABLE 2
SPECIAL INITIATIVE AREAS OF THE NH&MRC

Aboriginal Health
Addictive Behaviour
Ageing
AIDS
Alcohol Abuse
Asthma
Behavioural Medicine
Environmental Toxicology
Health Care Evaluation
Public Health
Rehabilitation
Menopausal Health
Dentistry and Dental Health

Source: NH&MRC, 1991.

The difficulty that gene mapping might have in gaining special initiative status was made clear in an interview with an NH&MRC policy-maker. In order to show that gene mapping was worth designating as a special area it would have to be demonstrated that, as well as being a neglected topic, it was in the national interest to prioritize it. Judging from the areas designated as priorities, a case for genome mapping would also have to emphasize the end results - i.e. the health benefits - of the project. Most scientists working in the field regard these benefits as both long-term and more general than addressing any particular social problem. Whatever long-term benefits might arise from genetic mapping, the problem-orientated categories, rather than gene mapping itself, would be likely to become the theme of any future special initiative area.

All project proposals, whether special initiative or not, undergo a rigorous process of peer review with a number of conventional and unconventional features.[24] Assessment of research proposals for project grants is made in two stages: referees' comments and interview. Initially, all applications submitted are reviewed by three referees. The proposals are evaluated at this stage on the basis of their scientific merit and the track record of the investigator. Merit is broken down into four categories: originality of hypothesis, substantiation of objectives, soundness of research plan/methodology and feasibility. The next step of the procedure is to move to interviewing the majority of candidates using regional interview panels.

The reviewers at both the written and interview stage of the examination are looking primarily for 'scientific merit'. What constitutes this tacit and elusive notion of scientific excellence in the NH&MRC's peer review procedures has been explored in Harman's substantive observations of the system in action.[25] Harman divides the components of scientific excellence, for analytical purposes, into technical, normative and intuitive categories. A number of technical criteria that she identified are detailed in Box 1.

BOX 1.

SOME CRITERIA OF 'SCIENTIFIC MERIT' USED BY NH&MRC REVIEWERS

- a clearly defined purpose and sense of direction – knowing exactly why the study is being done and *having a good idea what is expected to happen* or, as expressed more crudely by one experienced interviewer "'*have technique will travel' will not work*".
- methodological and conceptual 'rigour' – as evidenced by a superior level of conceptualization of problems and methods, *clearly stated hypotheses*, tight logic and methodological soundness.
- significant discoveries that 'radically change what is in the text-books', lead to new directions, generate new knowledge or are *'proof of refutation of established dogma'*.

Source: Harman, 1991, p. 34 – emphasis added. See fn. 24.

What is being alluded to in these criteria is a Popperian falsificationist model of scientific method. Basically, and very crudely: set up a hypothesis predicting the outcome of an experimental manipulation, carry out the experimental manipulation, if the outcome is not what was hypothesized discard the hypothesis, if the outcome matches the hypothesis go on to construct further tests.[26] The adequacy of this model is much debated within the philosophy and sociology of science.[27] The important point in this context is that the NH&MRC peer review committees operated with a particular, albeit loosely articulated, model of what constituted good science. Whether or not this conformed exactly to Popperian falsificationism is less relevant than the fact that the NH&MRC version is not the *only* possible model of scientific methodology. It appears, moreover, to have been used as a corporate level filter, to legitimate certain types of science and to condemn others.[28]

Seven of the scientists and policy-makers interviewed felt that a proposal to map genes, particularly one which involved mapping regions rather than looking for a specific gene, would run up against this methodological paradigm within the NH&MRC. The general way that it was expressed was as part of the "unwritten rules" of the NH&MRC that proposals should be about testing a clearly articulated hypothesis. Such typical comments included:

> ...because it's a competitive peer review system the evaluation process is very dependent on *hypothesis testing* and therefore the perception of collecting information for the sake of collecting information is likely, in my view, not to be as well accepted by a committee as someone who has a specific hypothesis that a particular area of a chromosome is responsible for whatever.[29]

> You can apply to the NH&MRC for funds... and there's no specific advantage given to genome projects or anything like that, in fact there are probably disadvantages because it's *often seen as not being hypothesis driven research*.[30]

> ...the *majority of mapping projects are not hypothesis driven*...the granting agencies are hung up on this [so that genome projects] are already starting on the wrong foot.[31]

What is being argued here is that gene mapping 'for its own sake' fell short of the methodological requirements and ways of seeing science that find expression in the NH&MRC peer review system. This is a phenomenon akin to what Travis and Collins call cognitive particularism i.e. the sharing of a particular outlook on science, in their study of peer review.[32] They differentiate this from *institutional particularism,* i.e. the 'old boy' network.

It is not the purpose of this paper to evaluate the pros and cons of alternative methodologies in science. The important point from a policy perspective is the mismatch between, on the one hand, the way the NH&MRC has institutionalised one particular notion of which scientific methodology produces good science, and on the other hand, the gene mappers' way of seeing their work. It is this mis-match which explains why the NH&MRC have not funded more HGP-type projects, or shown any enthusiasm for a specially co-ordinated national effort. Together with the difficulties involved with publishing the research, *cognitive particularism* also explains why scientists were reticent about applying for support for such projects and, to some extent, why they felt that a special initiative was necessary.

ECONOMIC UTILITY AND INTERNATIONAL SCIENCE: THE DEPARTMENT OF INDUSTRY, TECHNOLOGY AND COMMERCE

Within the public service one department in particular, the Department of Industry, Technology and Commerce (DITAC), adopted policies towards gene mapping. The main concern of the department was with industrial economics and their interest in, and support for, science and technology was justified as a part of the ministry's responsibilities only where it was of direct relevance to industry.

Although DITAC's involvement in science is industry-orientated, genome research was not addressed primarily as an area of immediate commercial significance by the department. Rather, gene mapping initially gained attention as an issue of importance in the international arena. As gene mapping projects began to take shape in a number of countries, by late 1989 DITAC had received several requests from Australian scientists who were keen to receive assistance and become involved in the burgeoning international scene.

One way in which DITAC was able to respond to this demand was through a "Tripartite Agreement for Science and Technology Collaboration". This arrangement was established in 1989 between Australia, New Zealand and the UK with $AUD150,000 set aside for enabling collaborative research. Within the biological sciences eight areas were selected as priorities, including the "mapping of complex genomes". Funding through this scheme was mainly in the form of small travel bursaries of up to $AUD10,000. Applications specifically pertaining to the selected areas were advertised for and judged on the dual criteria of scientific merit and potential benefit for Australia. In March 1992, DITAC could identify 11 projects in various areas of gene mapping that had received support in this manner.[33]

Apart from this scheme it was still not clear within DITAC what was going to happen with regard to the prospects for a full-scale Australian gene mapping project. The involvement of Australia in various genome related international programmes was discussed in October 1989 by the inter-departmental Co-ordinating Committee on Science and Technology (CCST). As a result of these discussions, Michael Pitman, the Chief Science Adviser and deputy chairperson of CCST, arranged a meeting with about twenty scientists involved in the area.

Four recommendations arose from the meeting. Australia should participate in an international comparative mapping programme, there was a need to consolidate access by Australia to the international genomic database, Australia should consider participation in HUGO's activities and there was a perceived need for raising public awareness of the benefits of the research. The recommendations went back to the CCST and Michael Pittman was asked to oversee all but the issue involving HUGO.

Three main courses of action followed. The first was to undertake a survey of the health of genome research in Australia.[34] The second was to provide resources for sequencing the genome of the thale cress, *arabidopsis* which was proposed as a model plant organism. Moves to set up database facilities were also made and these resulted in the establishment of the Australian National Genomic Information Service (ANGIS) at the University of Sydney. These activities were commis-

sioned under the auspices of the department's International Science and Technology Program. In addition, a group was set up to look at the publicity issue and they assembled material on the project with which to brief the Government.

The policy that emerged from the meeting can be interpreted in the light of DITAC's commercially orientated concerns. It was argued in the 1989 meeting that the applications from human genome mapping would be largely in the pharmaceutical area whereas animal and plant mapping would give a comparatively rapid return to the agricultural industries. With Australia's traditional strengths in the latter sector and its relatively weak pharmaceutical industry, DITAC decided to concentrate on non-human species. Furthermore, as one member of the department recalled in an interview, they were "frightened off by the cost and time involved" in human mapping. In effect, sustained financial support for human genome mapping was marginalized within DITAC in favour of non-human species. A further point is that the decision to provide support for the model organism project was made despite the fact that concern over international *human* genome projects first put the general issue onto the department's agenda.

At the time of the case study, DITAC were maintaining an interest in genome research, primarily in non-human work. They were represented on the management board of ANGIS and had committed support to the *arabidopsis* programme until the end of the 1992-3 financial year. The department saw itself as having played a catalytic role and were keen for the topic to be picked up by other funding agencies. One person from DITAC summed up their role as "principally to identify R&D which needs a flick of the whip... and then DITAC can stand back and let the system roll on".

DITAC's involvement and subsequent non-interventionist stance towards gene mapping can best be understood in the context of its institutional position within the science policy system. First and foremost, its commercial orientation explains its policies for human genetic mapping. Although it was the advent of international human genome projects which placed the subject on the agenda, and despite the perception of a number of the scientists working on humans that the plant and animal people had "hijacked" this agenda, in order for DITAC to take it up for any support there had to be a clear short-term spin-off on the horizon.

It is also important to understand that DITAC played only a secondary role in supporting research activities. The primary responsibility for funding research in Australia falls to the Australian Research Council, NH&MRC and other such organizations. All of the research agencies have clearly demarcated roles and institutional mechanisms to cope with overlap. It is more than a matter of institutional 'good manners' not to infringe upon the responsibilities of other agencies, it is important both for institutional autonomy and credibility. An agency cannot appear to be doing the work of any other or be thought of as selecting their priorities for them. The position of *arabidopsis* with regard to other granting sources meant that DITAC did not fund work which was obviously within the remit of another funding agency.

COOPERATIVE RESEARCH CENTRES

The 1991 world-wide survey of genome research identified the major strategic thrust for an organized genome project in Australia as hinging on a proposal to set up a Cooperative Research Centre on Mammalian Genome Research.[35] This was to bring together groups in Adelaide, Rockhampton and Brisbane working on humans, livestock and mice, primarily - but not exclusively - to enhance genome mapping.

The Cooperative Research Centres scheme was administered by the Department of the Prime Minister and Cabinet. Its initial aim was to foster partnerships between public and private resources by concentrating research effort in particular areas of long-term (strategic) research. The areas fostered were deemed to be of national economic and social concern.

Applications were submitted through the university administration (thus providing an initial level of screening) and then to peer review. If successful thus far, applicants were called for interview. The proposals were assessed at the peer review stage on the basis of eight criteria: likelihood of enhancing and building on existing links; quality and feasibility of proposed research; research capabilities of main participants; extent to which main participants were involved in education programmes; degree of involvement of potential research users in the Centre; potential for national social or economic benefit; appropriateness of resources and budget; and management abilities of key participants. There is a sense in which these eight criteria and their subsequent interpretation by reviewers constituted what it meant to be 'collaborative' and thus merit support within the context of the scheme.

The proposed Centre for Mammalian Genome Research was submitted as a first round application. At that stage the competition for support was severe, with the scheme attracting 120 applications of which only 15 were successful. Within the biological sciences there were 11 applications of which only 1 was successful.[36] The Mammalian Genome CRC received reviews from five anonymous referees but did not get as far as the interview stage of the procedure. The reviews specifically addressed the eight criteria listed above. The applicants were supplied with the referees comments and so were able to provide reasons for their failure to secure funding. There were three points that stood out in the comments.

Firstly, the centre was not deemed to be collaborative enough. As one of the applicants phrased it, the centre was thought to be "a marriage of convenience" with three geographically separated groups pursuing disparate aims, the only unity was provided by a common set of technologies and methods. A second related point was that the work was not "good science" but technology. Finally, although it was not a strong stipulation in the first round, the need to involve private companies and the lack of any such participants in the proposed centre was felt to have counted against the proposal.

So, a unity based on common methodology or technology appeared to be a fragile one. It was not co-operative enough to receive support from the Co-operative

Research Centre's scheme and it was a fragility based on the research interests of most Australian scientists working in genetics - the primacy of different diseases or species over the underlying ways of working on them.

DISCUSSION: MAKING POLICY, MAPPING GENES.

Policy-makers cannot go out into the laboratory and experience every aspect of the science they have to manage. Scientists, likewise, cannot sit all day at the desks of the bureaucrats. What inevitably happens is that external issues and objects are brought into an institution by being reduced to an administratively expedient minimum.[37] In this case, what gene mapping is and what it ought to be inevitably became simplified. This process did not take place at random, it took place relative to the position of the policy-maker or scientist in the policy environment. To summarize the situation in Australia:

1. The choice to map genes in a particular way was related to the professional structure of science and the social relations of scientists with each other:

The majority of Australian scientists who were interviewed regarded gene mapping as a tool to get at a disease or to understand some larger biological process. Few were interested in DNA *per se* and organized mapping programmes were seen as a way of maintaining a competitive position in the international context. The disincentives to pursuing mapping 'for its own sake' were also bound up with professional strategies and career aspirations, including what was likely to be published or funded. From this perspective, the 'best' scientific strategy was at the same time the 'best' professional strategy in terms of moving through the *credibility cycle.*

2. Favoured methodological paradigms in the NH&MRC peer review system influenced the reviewers expectations of what was to count as science worth funding:

The NH&MRC fund 'excellent science'. One component of this notion was that excellent science involved testing hypotheses, so that any research proposal which planned to inventory what was in the genome ran against this institutionalized norm. It might be possible to argue that the norm functioned in order to keep out substandard science, however the gene mappers interviewed would be expected to disagree passionately with such a diagnosis.[38] By adhering, nevertheless, to a particular model of how science is done, the peer review system affected the direction of research by favouring some methodologies over others.

3. Expectations of the lead-time to commercial exploitation of gene mapping affected its attractiveness as an area for support:

DITAC looked at genome mapping, as at any other issue, for its potential commercial importance and, more specifically to genomics, for its international significance. The department was also constrained by having no real role as a funding agency and no desire to interfere too directly in what might easily be the affairs of other organisations. Human genome mapping, although of international importance, was not deemed to have enough short-term potential to warrant attention. *Arabidopsis* did, with the added bonus that was unlikely to be funded from any other sources.

4. The criteria used to determine whether a proposal was collaborative enough to merit support as a CRC favoured some types of collaboration over others:

The CRC scheme also had its own terms of reference which included funding work that was collaborative in terms of its ends (not just the means to achieve different ends). The scheme also placed emphasis on a visible end-product. The proposed Mammalian Genome Centre was, according to the referees, unable to meet either of these criteria. The CRC scheme also highlighted the fact that Australian researchers from a range of disciplines were not in a position to organize their case around particular organisms, diseases or geographical locations. Instead, they based their proposal on shared techniques and tools.

The study has shown how Majone and Strickland's notions of policy as 'benign neglect' and 'implicit theories' operate in shaping a national research agenda. With regard to 'benign neglect', in Australia human genome mapping in the style of the international project has - for better or worse - fallen between the requirements of the various schemes or agencies which may otherwise have supported it. For each instance the policies, or non-policies, adopted towards genetic mapping were made with reference to more general aims and values. What is important here is not that the NH&MRC, DITAC or whoever acted in such and such a way, but that making policy with respect to more general criteria (economic utility, preferred research style etc.) produced different effects on the direction of scientific research. In Australia different institutional remits and 'ways of seeing' gene mapping have played a role in shaping research in ways that maintained the marginality of Genome Project-style mapping as a research practice.[39]

Majone's 'theories about the world', the criteria which are adopted as ground over which policy grows or is made, appear to have a critical effect on the outcome of policy. This situation suggests, moreover, that in order to have been successful, the putative genome project would have had to be presented as sufficiently commercial for the civil servants in DITAC, co-operative enough for the reviewers on the CRC scheme, or Popperian enough for the reviewers and administrators in the NH&MRC. Shifting the criteria in either case may well have induced a different outcome.

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