

Testimony to:

Royal Commission on Genetic Modification

by

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Summary

Descriptions, analyses and evaluations of genetic change and its consequences are, of necessity, expressed within a special scientific conceptual framework, but they depend on a number of questionable assumptions. The limitations and uncertainties inherent in our current knowledge of molecular biology, ecology and evolution severely constrain our ability to draw valid conclusions about the outcomes of genetic modification. This is so to the extent that we must regulate with the utmost caution any current human enterprise in this field.

Regulation of genetic engineering and its products in New Zealand, especially by ERMA and ANZFA, gives overriding weight to a scientific perspective without recognising its fundamental limitations. While formal opportunities for public participation have expanded, no fair balance has been achieved between competing interests in the questions at stake. Many people feel powerless to have any real influence over decisions that have the potential for enormous effect in their lives.

Scientific and the Maori worldviews present incommensurate approaches to questions concerning genetic engineering. The disjunction shows up as a confused competition between differing senses of the value of life, conflicting interests in control over domains of culture and Nature, and incompatible visions for the future. Resolution of problems concerning genetic engineering will require a rapprochement between disparate constructions of the questions involved. Failure to take real notice of the incompleteness of science and the integrity of Maori is hindering progress from both sides of the divide.

The ambition of the biotechnological governmental-industrial-academic complex to bring the processes of genetic change under global human control is driven and supported by the misrepresentation of scientists themselves as a morally neutral egalitarian community of scholars who work for the common good. Scant consideration has been given by the broader scientific community to the overall effects of the enterprise of genetic engineering and its capability of transforming biological reality beyond historical recognition.

1. Perspectives from Biology

1.1 The character of genes

- 1 It is impossible to discuss the question of genetic engineering without first coming to some understanding of what a gene is. The classical definition of a gene is as a unit of inheritance, specifying some characteristic of an organism.
- 2 Since the discovery of the structure of DNA and the elucidation of the processes molecular biological translation (protein synthesis), a gene has been taken to be either
 - (i) part of a DNA molecule, or
 - (ii) a sequence of nucleotides (A, G, C or T),and it has been presumed that everything known previously about the processes of inheritance can now be understood in these terms.
- 3 This modern view is highly problematic, not only because of the ambiguity in the definition of the gene as matter (DNA) or as information (a sequence), but also because genes are not autonomous determinants of identifiable characteristics of organisms.

1.1.1 Material objects

- 4 If we take the view that a gene is a piece of DNA, then we will be concerned with its material origin and we may ask after the identity of the original, individual organism from whom the material used in any experiment was first acquired for sequencing or copying. There are marked cultural differences in the importance attached to the question of material origin.
- 5 The question of particular material identity, connection and continuity is of special significance to Maori, especially in relation to establishing the *whakapapa* of human trans-genes that have used in experiments in Aotearoa/New Zealand. By way of contrast, scientists conduct calculations of the simple stepwise dilution of the matter comprising any original sample. Material dilution occurs through succeeding generations of genetic replication whether *in vivo* or *in vitro*.

1.1.2 Informational sequences

- 6 If we take the view that a gene is a sequence of nucleotides, then it is information that can be transmitted and stored symbolically, by using electronic computers for example, and we are likely to be concerned with issues of intellectual property.
- 7 The extant connection between DNA sequences and the characteristics of organisms that sustain their stable existence within complex, interacting eco-systems has been established historically through four billion years of geographically dispersed evolution.
- 8 Claims that genetically engineered organisms are "inventions" amount to human arrogation of Nature's "prior art" of how genetic information can be used to record biological characteristics.

1.1.3 Operational view

- 9 The term "gene" is often used by molecular biologist to refer to a DNA sequence that encodes a protein product, taking into account that it may be fragmented in the actual genome of the organism (due to introns), that it may have an obligatory association with a promoter sequence and that it may contain unusual signals (*e.g.*, for ribosomal frameshifting¹). There is no simple universal set of rules relating genetic sequences to protein production in cells.
- 10 Molecular biology offers no convincingly detailed account of the connection between genetic information and organismic characteristics. The connection is treated as a quite arbitrary outcome of innumerable, unstructured historical events that have occurred and whose consequences have become entrenched during evolution. However, it is assumed universally that a firm, orderly connection exists.
- 11 What has been discovered by molecular biological investigation is not the causal connection between genes and characteristics but rather an appreciation of the manner in which minor genetic variation gives rise to the variation in organismic characteristics *all else being equal*.
- 12 The qualification "all else being equal" is constitutive of the definition of genes as information. The association between variation in a particular gene and variation in a corresponding trait, and thus the supposition that "gene X encodes characteristic y", depends on innumerable other contingencies which are themselves subject to arbitrary variation capable of annihilating the perceived association.²

1.2 The genotype-phenotype relationship

1.2.1 Complexities of the relationship

- 13 There is no simple one-to-one relationship between genes and biological traits.³
- 14 Many genes within the population of a species display *polymorphisms*, meaning there are different versions of the gene in different individuals (or different alleles of a single individual). Sometimes the effect of a polymorphism is clearly recognisable. In other cases it can appear to be "neutral".
- 15 Genes can display *pleiotropy*, meaning that a single gene may be related to multiple, seemingly independent characteristics of the organism.
- 16 *Polygeny* refers to the common observation that the expression of (or alterations in) more than one gene contributes to a single characteristic.

¹ A case in point: HIV cannot replicate without breaking the normal rules of protein synthesis connecting genetic sequences to protein sequences.

² A dramatic molecular biological example was provided by the discovery (in which I participated) of an otherwise silent polymorphism in the human gene for PrP modulating the effect of a remote mutation and differentiating fatal familial insomnia from an inherited form of Creutzfeldt-Jakob disease. See *Science* 258, 806-808 (1992).

³ Many of the effects I mention have been given detailed and cogent consideration by Andreas Wagner in a series of recent Working Papers of the Santa Fe Institute (Nos. 00-02-14, 00-02-15, 00-02-16, 00-03-18).

17 Many genes appear to be *redundant*. There can be multiple encodings, not necessarily identical, of a single protein product. However, in many cases the expression of redundant genes appears to confer some advantage on the organism, not just in respect of being able to lose a functional protein as a result of mutation and still survive.

1.2.2 Character of the relationship

18 The relationship between genetic information and its expression in terms of biological traits is exceedingly complex. It is the view of many theoretical biologists (including myself) that this relationship is *irreducibly* complex.⁴

19 An organism cannot be constructed from knowledge of its inherited (genetic) information alone. It seems likely that the amount of information needed about the process of construction (what you might call the "algorithm") is of the same order as the amount of information in the genes.

20 When thinking about manipulating the relationship between genetic information and its expression in biological characteristics, we must consider the effects our actions have on determinants of events that are *not* encoded in the genes that are being subjected to alteration.

1.2.3 Relevant research

21 Work I have done in two fields of theoretical biology,
 (i) the replication of prions, and
 (ii) the origin of genetic coding,
 illustrates that assessments of the consequences of genetic change based on the accepted ideas of molecular biology and evolution (the "modern synthesis" of Darwinian natural selection and Crick's Central Dogma) face profound difficulties. The validity of such assessments are subject to very restrictive qualifications.

22 Work in progress in a further field,
 (iii) ecological population dynamics,
 casts doubt on the validity of some conclusions, such as those reached by genetic engineers and regulatory bodies like ERMA and ANZFA, starting from accepted principles.

⁴ By this it is meant that it cannot be summed up in any set of simple rules. To specify it one would have to describe the relationship in full detail.

1.3 Replication of Prions

23 Starting in the early 1980s I was a defender of Prusiner's idea, then held to ridicule.⁵ but now vindicated, that prions containing no nucleic acid, neither DNA nor RNA, are the aetiological agents responsible for the transmission of spongiform encephalopathies like ovine scrapie, "mad cow disease" and Creutzfeldt-Jakob Disease.

24 I defended Prusiner because it was clear from my own theoretical work, contrary to the thinking of the vast majority of molecular biologists, that proteins, like genes, could possibly act as semi-autonomous determinants of inherited biological characteristics

25 This possibility flew in the face of the Central Dogma of Molecular Biology which states that the flow of biological information is generally one-way, from DNA and RNA to protein, but more particularly, that "once information has got into protein it cannot get out again".

1.3.1 Proteins equal genes equal organisms?

26 The existence of forms of proteins (also dubbed "prions") that determine certain stable phenotypes of yeast and fungi by transmitting information from mother-cell to daughter-cell in proteinaceous form is now an established fact. In this context prions are considered to be genes.

27 Under one instrument of international law, the Biological Weapons Convention, prions are categorised as "organisms" following New Zealand's raising of the matter at my instigation.⁶ Prions are not considered to be organisms in terms of the HSNO Act.⁷

28 More generally, prions demonstrate the complete inadequacy, with the potential for devastating consequences⁸, of analyses of biological causation in terms of a stable and fixed "genotype-phenotype" relationship. Even the universal genetic code, which is taken as providing an unshakeable foundation in virtually all analyses of the consequences of genetic engineering, gives no guaranteed way of understanding what may follow from genetic change.

⁵ New Zealand molecular biologists were generally slow to take the idea of prions very seriously. See, for example AR Bellamy & MC Croxson "Prions - Unconventional viruses?", *Patient Management*, October 1987, pp169-176. My own analysis was published in a series of papers in international journals, conference presentations and seminars

⁶ PR Wills, "Proposals for the BWC Review", Prepared for Public Advisory Committee on Disarmament and Arms Control, July 1991; "Prions, Naturally-Occurring Genetic Material and the Biological Weapons Convention", Prepared for Minister for Disarmament and Arms Control, July 1991

⁷ This question was resolved by an Order in Council after I raised it with ERMA when the Act first came into effect.

⁸ I refer to the British BSE epidemic and the transmission of this disease to humans as nvCJD.

1.4 Origin of coding

29 Certain assumptions are inescapable in technical analyses of the consequences of genetic engineering. One of those assumptions is that there is a well-defined relationship between alterations to the genotype of an organism (the sequence of nucleotides in its DNA) and the manifestation of that alteration in the phenotype (identifiable characteristics of the organism).

30 For about 20 years I have concerned myself with the question of the molecular evolutionary origin and stability of this genotype-phenotype relationship.⁹

1.4.1 Determinants of the genotype-phenotype relationship

31 The main finding of work in the field of "the origin of genetic coding" is that the processes of biological self-organisation that guarantee the regularities and patterns that we observe in the genotype-phenotype relationship (thereby making genetic engineering *per se* possible),

- (i) are not encoded in genetic information,
- (ii) are fundamental to the origin and sustenance of all life, and
- (iii) have a continuous evolutionary development longer than that of organisms.

32 In two recent papers,¹⁰ I have discussed some of the semiotic (as opposed to physical) conditions that have to be fulfilled in a system before it is able display functions typical of biological processes. Molecular studies of genes and the characteristics that they encode are inherently incapable of shedding any light on such matters.

1.4.2 Lessons for GE regulation

33 Our lack of knowledge and understanding of the diffuse, intertwined processes of self-organisation on which all of life depends creates an over-riding uncertainty in analyses of the consequences of genetic manipulation and undercuts any confidence expressed in the relative value of the technology.

34 According to the standards of judgment that society generally requires be applied in making assessments which affect its members, the confidence expressed by genetic engineers in their inventions is groundless. They have achieved a perception to the contrary by hiding molecular biology's fundamental ignorance of the intrinsic interconnectedness and integrity characterising the many modes through which genetic information influences the living world.¹¹

⁹ The results of this ongoing work, in collaboration with others, have been published in a series of papers in international journals, conference presentations and seminars.

¹⁰ "Autocatalysis, information and coding", prepared for the Physics and Evolution of Symbols and Codes issue of Biosystems (in press); "Evolution of the molecular biological interpreter", prepared for the Complexity 2000 conference, Dunedin, 18-21 November 2000 (to be published online)

¹¹ By way of contrast, senior molecular biologists claim that there is no such thing as theoretical biology, implying a view that his subject is completely empirical and free of unproved concepts. I would be more inclined to say that the majority of the discipline's practitioners studiously avoid significant scientific ideas and resist any deep analysis of their art. In my teaching I continually contrast the intellectual honesty of post-war theology with the deficit of self-critical thought found in molecular biology.

1.5 Genes, ecology and evolution

35 Biological causation is such that dramatic effects can be very remote from the original change to which they can be attributed. A good example, the elucidation of which has been described by Ricard Solé,¹² is the extinction of the large blue butterfly (*Maculina arion*) as a result of the introduction of myxoma virus to English rabbit warrens. Competition between different types of grass selectively eaten by rabbits and consequent changes in the habitat of ants, symbionts of the butterflies, is concluded to have mediated the extinction.

36 All of the régimes that have been invented for the regulation of genetic engineering and the assessment of its environmental consequences rely on being able to forecast events of this sort in complex, natural and domestic ecosystems. The example gives only a hint of the true complexity of ecosystems and their modes of response to perturbation.

37 In many submissions to the Environmental Risk Management Authority I have stated that we scientists have a profound lack of detailed knowledge of ecological interactions and the manner in which those interactions depend on genetic factors. Any guess concerning the scale of biological change that seemingly innocuous genetic manipulation may ultimately cause could be wrong by as many orders of magnitude as the difference the KT event of 65 million years ago (loss of 70% of all species, including the dinosaurs) and the advent of melanism in moths (an apparently minor adaptation generally attributed to industrial smog).

1.5.1 Dynamic character of ecosystems

38 While we have a tendency to think of ecological systems in terms of “stability”, the idea is actually inappropriate to the way in which they function and change. All ecological systems are dynamic not only in terms of their constitution (perpetual variation in relative population numbers of different species) but also in terms of their adaptation to the ever-changing environment (both physical and biological).

39 On a very long evolutionary timescale, the only predictable feature of ecosystems is the constant pattern of adaptation and change. There are some simple regularities in the relative scale of different events. These regularities of scale characterise mechanisms of ecological and evolutionary change (speciation, extinction, displacement, etc) that are mediated by genetic variation and expression.

1.5.2 Scaling in self-organised systems

40 It has become recognised that an enormous range of phenomena¹³ (from stockmarket fluctuations, through the geographical distribution of human population to major extinctions during evolution) that depend on the combination of numerous individual small-scale causal events displays the same sort of scaling:

¹² RV Solé & M Newman (1999) "Patterns of extinction and biodiversity in the fossil record", Santa Fe Institute Working Paper 99-12-079

¹³ See SA Kauffman (1993) *Origins of Order* (Oxford University Press) and P Bak (1996) *How Nature Works* (Springer Verlag)

events with consequences of relatively large magnitude occur with relatively low frequency but on a long timescale events of all magnitude occur inevitably with characteristic unpredictability and irregularity.

- 41 In the last few years we have begun to glimpse how the regularities of scale observed in ecological and evolutionary change are related to genetic variation.¹⁴ It is suspected that the maintenance of stable patterns of ecological and evolutionary change depends on the maintenance of stable patterns of genetic change. This is currently being investigated by theoretical biologists like Ricard Solé¹⁵ and myself.

1.6 Consequences of genetic changes

- 42 Of central importance in assessing the consequences of genetic engineering are considerations of:
- (i) the character of the desired genetic alteration,
 - (ii) the process causing the alteration,
 - (iii) collateral genetic alterations
 - (vi) genetic network effects
 - (v) potential non-genetic (“environmental”) changes.

1.6.1 Changes sought by genetic engineers

- 43 Genetic engineering can have many purposes. It is possible to engineer organisms so that they amplify genes, produce proteins or have new characteristics. The new characteristic sought may be defined in purely genetic terms (as in "gene knock-out" studies) or it may be some phenotypic characteristic.
- 44 Here I concern myself only with the consequences that ensue from genetically engineered organisms being released or escaping into the environment, ignoring for the moment problems of containment or ethics involved in the regulation of genetic engineering in the laboratory.
- 45 In the case of crops, for example, the change sought by the engineer may be herbicide resistance, vitamin synthesis, altered metabolism or some other characteristic. Usually, a new gene is inserted into cells of the organism in the expectation that a new protein will be produced in its cells (or synthesis of a normal protein suppressed) conferring the desired characteristic.
- 46 Intracellular expression of a protein with a particular function can often be associated quite unequivocally with some organismic characteristic, as in the case of the enzyme EPSPS¹⁶ and resistance to the herbicide glyphosate (Monsanto's Roundup).
- 47 It is impossible to know in advance all of the functions a protein may have when it is expressed in a new biochemical milieu. For that matter it is not possible to know all of its

¹⁴ See, for example, W Fontana & P Schuster, *Science* 280, 1451-1455 (1998).

¹⁵ RV Solé & JM Montoya, "Complexity and Fragility in Ecological Networks" (submitted manuscript)

¹⁶ 5-enolpyruvyl shikimate-3-phosphate synthase

functions in its natural milieu. That is why extensive testing of genetically engineered organisms is needed to characterise their properties once they have been created.

1.6.2 The engineering process

48 Genetic engineering is exact in only one limited sense, that of the extent of our knowledge of the change in DNA sequence that is effected. This can be determined very accurately. In every other respect genetic engineering is a very haphazard process.

49 In almost all cases it has so far proved impossible to achieve any precision in the process of inserting new genes into the genomes of host species. Incorporation of transgenes usually occurs more or less at random, *as far as we can determine*.¹⁷

50 Even if perfect control over transgene insertion were achieved it would still be necessary to investigate the effects of the engineering process by characterising thoroughly the new organism.

1.6.3 Effects of genetic transposition

51 Transgene insertion can disrupt virtually every kind of genetic function in a cell: transcription, translation, promotion or suppression of expression, replication, recombination, *etc*. Furthermore, the effects of any disruption may not be particularly evident until the organism is placed in a particular environment.

52 In addition to potential disruption of normal genetic expression due to the presence of a transgene in the genome, expression of the transgene can alter existing cellular functions or give rise to new ones, quite apart from the desired change.

53 Extensive testing and selection of genetically engineered organisms is necessary - to find those on which the transgene has conferred optimally the desired characteristic without other deleterious effects.

1.6.4 Genetic network effects

54 Genes continually switch one another off in complex dynamic patterns that have so far not been characterised to any great extent and are not very well understood. There has been some theorising but there is precious little data against which to test theoretical predictions.

55 No gene's function can be defined in isolation from those of other genes that are simultaneously expressed. Ultimately the way in which a cell with a particular genetic makeup behaves under any circumstances depends on the complex response of its genetic network.

¹⁷ This statement requires careful qualification. It is most likely that the points of incorporation are biased in all sorts of ways by the technique of genetic transposition used; it is just that such biases have not been investigated or characterised. Knowledge of such biases could be used potentially to devise some degree of control over the point of insertion of a transgene.

56 The insertion of a transgene is inherently capable of altering the characteristic dynamic states of a cell. These changes could be quite subtle and could have consequences that are difficult to detect but nevertheless of some importance to the internal functions of the organisms cells or the interaction of the whole organism with its environment.

1.6.5 Interactions with surroundings

57 Any change to the phenotype of an organism is likely to alter the manner in which it interacts with its surroundings, both its response to the physical environment and its ecological relationship to other organisms. The change can affect its rate of reproduction ("fitness") as well as that of other species.

58 Small changes in fitness can be of enormous evolutionary significance and may be mediated through some seemingly minor rearrangement within a habitat.

1.7 Effects of genetic engineering

59 There is no basis in either theory or observation for the assertion that patterns of genetic change effected by genetic engineering are of the same character, in respect of their effect on ecosystem dynamics and adaptation, as past evolutionary patterns of genetic change.

60 Genetic engineering changes the characteristics of organisms. That is the only reason for doing genetic engineering, even if the goal is art¹⁸ rather than medicine, pharmacy, agriculture, environmental modification or warfare. Assessing the ecological consequences of introducing an organism with new characteristics into the environment requires consideration of every function of the organism and the way in which each functionality is affected by the new characteristics that the organism has acquired.

61 The task is essentially impossible. First, not every functional effect of a genetic change can be detected and assessed. There are simply too many minor effects to be considered. Second, novel functional effects, not evident in the original organism, can emerge from cooperation between the change made and other functionalities already present. This is because there is not a simple one-to-one relationship between genes and traits.

1.7.1 Justification for genetic engineering

62 The main assumption of genetic engineering is that genetic changes made artificially are no different in character from those that occur naturally.

63 According to the genetic engineer's way of thinking, all of the restrictions and limitations imposed on genetic transposition by natural reproductive processes are purely arbitrary. Any gene could, at least in principle, end up in any organism. If the functional genes were all scrambled between species we would have a different set of organisms inhabiting the biosphere, but we would still have the same sort of well-adjusted world (after an appropriate settling-down period).

¹⁸ Eduardo Kac claims to have produced, solely as a work of art, a transgenic rabbit that glows in the dark. See <<http://www.ekac.org/>>.

64 Genetic engineering produces new organisms with constellations of genes in arrangements that have never occurred before. In one sense, natural reproduction and evolution produce the same result. However, the results of natural reproduction and evolution are restricted by the limitations of the processes of genetic change that can take place as a result of mitosis, meiosis, mutation, selection, horizontal gene transfer and other natural mechanisms.

65 Genetic engineers argue that the natural limitations and restrictions on gene transfer are of no significance, that genes can be transposed with impunity, that only immediately recognisable functional effects of a genetic transposition are of significance. They argue that what is possible in Nature is restricted and limited only by extraneous incidental effects, what organisms can mate with what other organisms and so on.

1.7.2 Analogy to species transposition in ecology

66 In assessing the possible validity of this assumption as a basis for evaluating the consequences genetic engineering it is reasonable to draw an analogy to the transposition of species across geographical boundaries that humans have effected, especially during the last few centuries.

67 The ecological damage caused by mammalian pests in New Zealand provides a prime example of the unrecognised hazards entailed in human actions. Stoats and other predators would not be any threat to our native birds if they had other, more readily available, desirable food and their numbers were adequately restricted by other ecological factors. However, within the functional context of our native bush habitat they have, over the course of a century or so, caused a disaster.

68 Adjustment to perturbations of the scale inflicted by human activity has amounted to a complete transformation of our natural ecosystems where they have not been completely destroyed. The evolution of new species comparable with those driven to extinction, if it can occur, will require times many orders of magnitude longer than the duration of the perturbation that caused the extinctions.

1.7.3 Comparison with selective breeding

69 It has often been argued that genetic engineering is no different from selective breeding (of crops and animals) that has been practised by human societies for millennia. It has even been argued that genetic engineering is safer than selective breeding because of the greater control which engineering offers over what genes actually end up in the new organism.

70 It is false to say that genetic engineering is a way of achieving more quickly what can be achieved by selective breeding. Evolutionary processes have led to results that are absolutely unique, on any cosmic scale of reckoning.¹⁹ and the means of genetic

¹⁹ One need only consider how many different possible proteins of even moderate length there are (the number of elementary particles in the known universe pales into total insignificance in comparison) and how many proteins could ever conceivable have been encoded in genes.

transposition through selective breeding and horizontal gene transfer are extremely limited.

- 71 One can only maintain that genetic engineering and selective breeding are the same on the *a priori* basis that the uniqueness of evolutionary precedents is of no cellular, organismic, ecological or evolutionary significance. In my judgment there is every reason to believe that the relationship between evolutionary precedents is what maintains order and structure at all levels of biology and is therefore of the utmost significance.
- 72 The argument concerning the safety of genetic engineering in comparison with selective breeding is similarly spurious. Any new hazards (whether to consumers or within the ecology of the organism in question) associated with the new constellations of genes that can arise as a result of selective breeding are limited to those that can propagate by means of the similarities between organisms that allow them freely to exchange genetic material - sexual reproduction essentially.
- 73 Genetic engineering places no restrictions on the new constellations of genes that can be created in an organism and then all of the normal means of propagation are available to disperse any new hazard throughout populations of species with which the engineered organism exchanges genes.

2. Issues of science and regulation

2.1 Regulation of genetic engineering in New Zealand

- 74 We have invented permissive regulatory charades that provide a semblance of rigour by concentrating on the obvious and immediately observable effects of the designed genetic change. Thus committees, authorities and commissions are easily able to persuade themselves that they are much wiser than people were a century ago and now they would never permit an action anything like the small-scale introduction of possums into New Zealand for commercial purposes. This is believed, in spite of our complete lack of experience of the longterm consequences of artificially causing radical changes to the genetic constitution of species.
- 75 The régime set up under the HSNO Act to regulate genetic engineering is very comprehensive, by international standards. It provides for extensive public participation. The implementation of these provisions of the Act by Environmental Risk Management Authority (ERMA) have been exemplary, including the establishment of a separate Maori advisory body, Nga Kaihautu Tikanga Taiao. On the other hand, the public, including Maori²⁰, have had little influence on decisions of the Authority. Consultation with the public has been a matter of form rather than content.

²⁰ ERMA member, Dr Oliver Sutherland, in an email message dated 2 October 2000, expressed the view that the Authority could deal with the Maori dimension of many matters without input from members of Nga Kaihautu.

76 The dominance of expert scientific opinion has been even more marked in the functioning of the Australia New Zealand Food Authority (ANZFA). The doctrine of "substantial equivalence" on which all of its decision-making is based precludes any consideration of broader implications of genetic engineering and alienates non-expert members of the public from the decision-making process. New Zealanders have been disenfranchised as a result of an international agreement that was entered into without Parliamentary approval.

2.2 Laboratory microbes

77 In New Zealand, as elsewhere, there is much more genetic engineering of microbes, by a factor of a hundred or perhaps a thousand, than of higher organisms. This activity has been conducted increasingly over the last two decades to the extent that it is now absolutely routine in molecular biology laboratories, schools even, all over the world.

78 Approval for the conduct of much of this genetic engineering is delegated by ERMA to Institutional Biosafety Committees. There are rules concerning the species of microbes that can be used for approved experiments and the manner in which material must be handled and disposed of.

2.2.1 Potential hazards

79 It is a matter for some concern that humans are introducing an extremely wide range of genes from diverse taxa into laboratory microbes. These microbes are "crippled" so that their chances of living in the wild should be virtually non-existent and live material is not supposed to be released into the environment. However, it is not at all inconceivable that genes introduced into laboratory microbes, or parts of them, could be transfected into wild microbes as a result of laboratory disposal. Possible dangers arising from such events were discussed in the mid 1970s by authors such as Chargaff²¹ and Sinsheimer.²²

80 It is difficult to determine what impact the last two decades of human genetic engineering have had on the evolution of microbial flora. It would be foolish to think that there has been no impact. Human activity has made functional DNA sequences from other taxa available for transfection into wild microbes through pathways that have never been available before.

81 The scale of the potential problem bears relation to the frequency with which microbes are genetically engineered and the diversity of taxa from which transgenes are derived. The pattern of possible horizontal gene transfer into microbes has been changed, perhaps markedly.

2.2.2 Recommendations

82 I would advise that rules for the disposal of DNA from genetically engineered laboratory microbes be revised with a view to minimizing further the possibility of transfection into

²¹ E Chargaff (1976) "On the dangers of genetic meddling", *Science* 192, 938-940.

²² R Sinsheimer (1977) "An evolutionary perspective for genetic engineering", *New Scientist*, 20 Jan 1977, pp150-152.

wild microbial flora. There are lessons to be learned from the evolution that microbes underwent in response to the widespread use of anti-biotics by humans.

83 Such a suggestion is not incompatible with the desire of laboratory scientists to be freed from unnecessary bureaucracy in respect of gaining permission for experiments deemed to be of low risk.

84 I would advise that if the procedures governing the granting of approvals by Institutional Biosafety Committees (IBSCs) for low-risk laboratory experiments are to be freed up, then the IBSCs should be constituted so that those making decisions and granting approvals should be much more independent of the scientists wanting to do the experiments.

2.3 Concerning ERMA

85 The HSNO Act requires ERMA to make decisions based on technical risk analysis. Sections 5 and 6 of the Act require that various ecological and social factors be considered, including the relationship of Maori to their *taonga*, and Section 7 requires that a 'precautionary approach' be adopted. Section 9 requires ERMA to develop a methodology for dealing with risks, weighing costs and benefits.

2.3.1 Treatment of "general concerns"

86 In practice, ERMA has been increasingly flooded with submissions opposing applications for field trials of genetically engineered organisms.²³ Most of the reasons given for opposition to applications are described by ERMA as "other" because they do not fit into any of the categories that are afforded weight under their interpretation of the HSNO Act.²⁴

87 I have argued in submissions that the weight of general concerns would justify the rejection of applications for field trials, but all such concerns have been relegated to the irrelevant periphery of the decision-making process.

88 In its decision²⁵ on AgResearch's application for field trials of transgenic cattle the Authority ruled that the matters raised by submitters under Sections 5(b) and 7 of the HSNO Act were not particularly relevant to the conduct of research in containment. In its latest decision²⁶ on AgResearch's application grow a flock of transgenic sheep, no consideration is given to general concerns except to note in relation to Section 5(b) of the HSNO Act, that the risks to New Zealand's 'clean green image', export relationships and organic farming "are negligible for current and future generations alike".

2.3.2 ERMA's permissiveness

²³ ERMA's Summary Analysis of Submissions on Applications GMF99001/5 (21 September 2000) states that of 735 submissions 96.5% opposed the applications.

²⁴ See graph 9, p31 of the Summary Analysis of Submissions on Applications GMF99001/5.

²⁵ ERMA Decision on GMF98009(MBP) (AgResearch Transgenic Sheep), 25 July 2000

²⁶ ERMA Decision on GMF99004 (AgResearch Transgenic Sheep), 26 October 2000

- 89 Having satisfied itself that there are no hazards described in scientific, technical terms that cannot be mitigated by appropriate measures, ERMA has approved (with controls) every application that it has considered for field trials of genetically engineered organisms.
- 90 So permissive has ERMA been that it has given approval for field trials of genetically engineered organisms not even known to exist. Applications GMF98007/8 described hypothetical transgenic potatoes²⁷ that had not been created, but the Authority considered them well enough defined in terms of their intended genetic constitution to approve field trials to be conducted, should they be successfully created.
- 91 ERMA's latest decision acknowledges that the applicant changed the emphasis of the purpose of the application (from agricultural to medical research benefits) after submissions were received and before the hearing took place. The Authority argues that it had to consider this change of emphasis as irrelevant, lest it "encourage applicant's (*sic*) to misrepresent potential benefits".²⁸
- 92 The decision records no consideration of the possibility that the change in emphasis was disingenuously constructed to undermine the thrust of submissions opposed to the application. I have received anonymously information to indicate that in a previous case the same applicant (AgResearch) was less than frank with ERMA about the origins of and motivation for a similar project to create transgenic farm animals.

2.3.3 Gap in Jurisdiction

- 93 In relation to a legal argument concerning animal welfare that I raised in submissions, ERMA has acknowledged that there is a jurisdictional gap that needs to be addressed by government²⁹. I had already raised this matter with the Prime Minister in relation to the Warrant of the Commission and the associated moratorium on applications for field trials.³⁰
- 94 The point³¹ is that the *creation* of transgenic sheep is a matter that ERMA delegates to the AgResearch Biological Safety Committee, who are answerable to the Ruakura Animal Ethics Committee in relation to matters covered by the Animal Welfare Act 1999. However, that Act does not apply to foetuses during the first half of a term of pregnancy.
- 95 Thus, a genetic engineer has no responsibility for any suffering which the act of creating the animals causes. Such suffering, even if reasonably envisaged, concealed or ignored, is a *fait accompli* that confronts the relevant Animal Welfare Committee in the second half of gestation, or ERMA when an application comes forward for field trials.
- 96 I do not accept that the stop-gap measure,³² whereby ERMA assures the public that their concerns have been met by the relevant Animal Ethics Committee, is adequate.

²⁷ Some of the potatoes are intended to contain a synthetic gene encoding for production of a toxin from the African clawed toad.

²⁸ Page 7 of the Decision.

²⁹ Page 18 of the Decision; again on Page 20 of the Decision.

³⁰ Letter to Rt. Hon. Helen Clark from Peter Wills, 28 March 2000, available at <<http://www.phy.auckland.ac.nz/staff/prw/Moratorium.html>>.

³¹ My submission to ERMA is at <<http://www.phy.auckland.ac.nz/staff/prw/Sheep8Sept.html>>.

³² Page 18 of ERMA Decision on GMF99004.

2.4 Inadequacies of quantitative risk analysis

97 The methods of quantitative risk analysis that are recommended so highly for assessing potential problems with genetically engineered organisms are fraught with conceptual and practical difficulties. This is especially true when they are applied to events which are rare, poorly defined, or catastrophic on a large scale (worst case scenarios).

98 Genetic engineers and regulatory authorities tend to dismiss worst case scenarios as scare-mongering and ascribe them no credibility.³³

2.4.1 Risk and hazard

99 Practitioners of risk analysis usually fail to make a proper distinction between “risk”, which is the probability of an event occurring, and “hazard”, which is the scope for harm entailed in conducting some activity. The best known applications of risk analysis to worst case scenarios are to nuclear catastrophes.

100 Comparisons are usually made by multiplying the risk by some assessment of the hazard (like number of deaths). According to such analyses a steady death rate of one person every decade from radiologically induced cancer within a given population is considered equivalent to a hundred thousand deaths from a large-scale disaster which has a probability of one in a million per year and, when it occurs, affects a large sector of the population living at that time.

101 Risk analysis is unable to give satisfactory measures of the absolute probabilities of different harmful events. It is now widely acknowledged that the multiplication of different probability factors gives estimates of low risks which are useful only for comparing relative probabilities in closely similar situations. This is relevant to the use of the Brenner scale to assess the risks associated with the production of transgenic micro-organisms.

102 A claim of the form "The actual chance of causing physiological damage to any individual as a result of creating this transgenic organism is smaller than one in a billion" must be regarded as meaningless for practical purposes and should certainly not be used as the basis for judging the wisdom of taking the risk, especially if it entails the potential creation of a novel pathogen.

2.4.2 Interdependence of risk factors

103 Another source of difficulty with risk analysis is that probabilities can be assigned only to events described in purely mechanical terms. The multiplication of the probabilities is then valid only if the different failure modes are truly independent.

³³ In submissions I made to ERMA in respect of the PPL application to conduct field trials of h-AAT sheep in the Waikato GMF98001, I considered the extraordinary possibility of the activity causing the creation of a new prion-like disease. The Authority evaluated my hypothesis, but then gave it no weight, concluding in its decision "Overall, the probability ... is considered to be negligible".

104 However, engineering catastrophes tend to occur when human actions put the system under consideration into a mode such that the probabilities of different failures are drastically altered and the prior analysis no longer gives any worthwhile indication of the real risks associated with various hazards. Factors which are considered to be independent from an engineering point of view turn out to have unforeseen dependencies imposed by human actions.

105 In biology the problem is much worse because human intervention is not necessary to produce "quirkish" interdependence between particular members of different classes of events. New phenomena can appear that are so novel that their character cannot even be guessed at in advance.

2.4.3 Risks peculiar to biological systems

106 No matter how we classify biological events and entities, we will have no guarantee that rare members of apparently independent categories will in fact interact to produce a new self-sustaining phenomenon. Prions are entities that defy normal categorization,³⁴ but they have caused a catastrophe on British farms and BSE has now been transmitted to humans. This could probably have been avoided if more stringent measures were imposed in about 1990.

107 The risks associated with the creation of novel biological situations cannot be measured. The integrity of the defined categories of events and entities which underpin risk analysis cannot be guaranteed to the same extent in biology as in physical and chemical engineering. To make matters worse, many biological events are threshold-regulated. No risk analysis could have assigned a probability to the possibility of the BSE epidemic prior to its occurrence

108 We should regard the conspiracy of events to produce unusual and unpredictable outcomes as a characteristic of biological systems and be extremely wary of analyses based on the sort of reasonable common sense with which committees and Commissions function, especially when dealing with the novel creations of genetic engineering.

2.5 Concerning ANZFA

109 There is no mechanism within the whole process of ANZFA's function that allows any consideration to be given to what might be called the "intangible" aspects of matters within its field of jurisdiction. The principle on which it judges food comprised of, containing or derived from genetically engineered organisms is that of *substantial equivalence*. The matters of substance in terms of which equivalence between GE food and traditional food is judged all fall into areas that are framed by scientific, technical enquiry.

2.5.1 Substantial equivalence

110 Three dictionary definitions³⁵ of "substantial" are of relevance:

³⁴ See footnotes 3 and 4.

³⁵ Concise Oxford Dictionary, 1964.

- (i) "having substance, actually existing, not illusory",
- (ii) "of real importance or value", and
- (iii) "deserving the name in essentials, virtual, practical".

111 The first meaning is not what is intended. ANZFA has declared foods with different chemical compositions to be substantially equivalent. Monsanto's genetically engineered Round-up Ready Soy (RRS) has been found to be substantially equivalent to their parental lines³⁶ even though RRS contain a protein ingredient novel to soy, the enzyme EPSPS.

112 Neither is the second meaning what is intended. For reasons of real importance and value to a very large number of people, RRS is not equivalent to ordinary soy. This perceived non-equivalence of genetically engineered food to ordinary food has nothing to do with scientific analysis directly. It is a matter of personal, perhaps ethical, choice. If ANZFA were to take this definition of "substantial" then they would simply be dictating that people cannot expect to exercise personal or ethical choices in respect of the food they eat unless the choice is provided by the Authority. In effect that is the attitude ANZFA has taken.

113 It is the third definition on which ANZFA actually relies and the Authority has taken control of what deserves to be called "essential", or what is "practical" in terms of differences between foods. The only questions of considered relevant by ANZFA are those of safety (including allergenicity), nutritional quality (wholesomeness), composition, and end use.

³⁶ Full Assessment Report and Regulatory Impact Assessment, A338 - Food derived from glyphosate-tolerant soybeans (undated, ~1999).

2.5.2 Problems of "substantial equivalence"

114 People who wish to have nothing to do with food derived from genetically engineered organisms are not opposed to the ANZFA's regulation of these important factors, but they can rightly complain that ANZFA is telling them what to think and denying them the opportunity to exercise freedom of expression when they are told that two foods are "substantially equivalent" when one is genetically modified and the other is not.

115 The 1989 poisoning of hundreds of people with Showa Denko's preparation of tryptophan from genetically engineered microbes is an illustration of how the principle of "substantial equivalence", even in ANZFA's interpretation, can fail.³⁷

2.5.3 ANZFA bias

116 ANZFA has shown open bias in favour of industry interests. This bias is demonstrated, by way of example, in its Assessment³⁸ of the use of RRS in food.

117 The Assessment contains two tables. One shows absolutely no benefit, to government, industry or consumers, but potentially high costs to all, associated with the option of banning the sale of RRS food. The other shows universal benefit and tolerable costs associated with the option of permitting the sale.

118 However, the categories of costs and benefits used to compare the two options are not at all equivalent. For example, the benefit to consumers from permitting sale of RRS food is said to be that they "can be assured that [RRS] have been through a premarket assessment and found to be as safe for human consumption as conventional soybeans", but there is no corresponding assurance (that ANZFA has protected the consumer) registered as a benefit against the option of not permitting sale of RRS food. With this rather blatant stacking of the evidence, ANZFA's approval of RRS was a foregone conclusion.

2.5.4 Inadequacies of industry testing

119 Of equal significance is the manner in which ANZFA bases its assessments of food safety on studies that come from almost exclusively from the applicant seeking approval for the sale of a novel food. In relation to the assessment of RRS, ANZFA reports³⁹:

"A full data package for [RRS] was submitted by the applicant for assessment. Quality Assurance certification was provided that the studies were done in accordance with Good Laboratory Practice and that the information presented in the application accurately reflects the raw data generated during the studies."

120 I do not believe that any serious scientist would give very much weight to data which was presented in such a manner. In the case of testing for drugs there are three phases of

³⁷ The toxin that caused the deaths and maimings due to eosinophilia-myalgia syndrome was unknown, it was present only in minuscule quantities and there was no regulation requiring product testing capable of detecting the hazard.

³⁸ pp26-28 of the RRS Assessment.

³⁹ p2 of the RRS Assessment.

carefully designed clinical trials that involve the (often blind) judgments of independent physicians. Even so, there is often residual suspicion that large pharmaceutical corporations are able to wield undue influence at various stages of the regulatory process.

- 121 In the case of ANZFA's assessments, safety considerations are finally weighed against financial concerns⁴⁰ "Good Laboratory Practice" allows researchers enormous leeway in determining what experimental results are accepted as raw data.
- 122 Inconvenient results are routinely cast aside when investigation detects some irregularity in experimental protocol. Convenient results do not demand the same investigation. Really "clean" results, that would be obtained exactly if the experiment were carefully repeated by independent researchers, cannot usually be obtained in studies looking for marginal biological effects without the honing of experimental conditions over a considerable period of time and many repetitions of the same protocol.

3. Issues of scientific and Maori epistemology

3.1 Disparity of worldviews

- 123 The regulation and control of genetic engineering's role in our national life has been dominated by technical, scientific considerations. However most of the public discussion has relied on a context in which political, ethical or cultural values are of greatest importance. This has been particularly so in relation to the contribution that has come specifically from Maori.
- 124 New Zealand society faces the unresolved generic problem of deciding how fairly to give the proper weight in decision-making to the cultural perspective of the Crown's treaty partner - Maori. In the case of genetic engineering the problem is exacerbated because the terms used in the discussion are defined from a perspective that is foreign to Maori. This disparity of perspective, coupled with the claim of science to deal in universal truths, has marginalised the contribution of Maori. Maori are seen as expressing concern for what is in the realm of the "intangible".
- 125 Non-Maori with non-scientific reservations about genetic engineering have experienced similar treatment of their concerns. However, some success has been achieved by Maori through effective political action, but it has been impossible to draw official discourse and decision-making into the context of what might be called a "Maori worldview" or "Maori epistemology".
- 126 The discussion of genetic engineering from Maori perspectives can do much to illuminate hidden assumptions, especially in analyses that seem purely scientific and technical.

⁴⁰ As in the two tables comparing the costs and benefits of options in the RRS Assessment.

3.2 The universal versus the particular

- 127 Science seeks to explain phenomena in terms of order and structure that is permanent and fixed, not contingent on anything local or historical. Traditional Maori express a sense of order and structure that is intrinsically local and historical, contingent on events and relationships established by precedent, not given unalterably.
- 128 Scientific analysis relies on the prior establishment of universally applicable categories that can be used to describe things and events. These categories may specify things like "electron" or "gene" or events like "chemical reaction" or "translation of genetic information".
- 129 Scientific categories are abstract constructs that have been built up and refined through a process of observation and experimentation. The definition of the categories and their relationships is always, at least formally, open to question. However, in their day to day work scientists treat basic categories of description as if they gave a true representation the one and only physical reality. That reality is taken ultimately to be "given" by unalterable laws of Nature and to have universal properties.
- 130 In Maori tradition knowledge of something is concerned with achieving a proper perception of its location in time and space. Knowledge of things and events is concerned with the particularities of *whakapapa* - layers of genealogy and lines of descent, their patterns and linkages.
- 131 For Maori, everything is ultimately related to everything else, but the true character of something belongs to the particular thing itself and its historical origin. The character of things is not described as a set of properties derived from an abstract world beyond what is here and now.
- 132 For Maori, everything is rooted, not only to its origin in time, but also to its origin in space - the place and tradition of the *tangata whenua* to which it belongs. This relationship with the earth and its local geography, something amounting to an umbilical connection⁴¹, is of particular poignancy in the contrast between scientific and Maori explanations of the causes of things.

3.3 Mechanism versus agency

- 133 The most fundamental character of reality in Maori cosmogony entails a conception of agency within Nature that has been systematically exorcised from intellectual discourse within the Western scientific tradition.
- 134 In science, the final explanation of things, events and possibilities is expressed in terms of what "happens" and its mechanism. Everything we observe derives from the properties of a single, unchanging material substance (which physicists, since Einstein, have identified as *energy* rather than atomic matter).

⁴¹ I refer to the dual meanings of *whenua*, either as *the land* or as *placenta*.

- 135 In the original conception of the Ancient Greeks, this material Nature, *physis*, was not distinguished from the divine power that was thought to pervade it. Later Aristotle expressed the idea that everything in Nature had an internal goal-directed drive, *telos*, to find its rightful place.
- 136 Only in the seventeenth century did Galileo and Newton come up with a purely formal, mechanistic description of motion. There was then no need to think of Nature as being alive with any of the attributes we now associate with subjectivity or conscious intent.
- 137 Darwin dealt the final blow to any scientific idea of *élan vital* by describing the entire history of life in terms of the mechanistic principle of natural selection.
- 138 In Maori tradition, things, events and possibilities cannot be reduced to the properties of a material substance and mechanistic laws. Marsden and Henare⁴² identify *Tua Uri*⁴³ as a representation of the ‘fabric of the universe’ in which *whakapapa* begins with *mauri*, divine power or agency.
- 139 *Mauri* precedes *hihiri*, pure energy, in the cosmological genealogy and *hihiri* is refined to give rise to *Mauri-ora*, the life principle, and thence *Hau-ora*, the spiritual breath of animate life. These precede shape, form, space and time.

3.4 The secular versus the sacred

- 140 The defining political event marking the advent of modern science was the trial of Galileo (now the subject of a New Zealand opera of bicultural origins⁴⁴). Through his refusal, on the basis of scientific judgment, to capitulate to ecclesiastical power Galileo emancipated ‘natural philosophy’ from arbitrary strictures imposed by parties for whom the truth was predetermined. Science then established for itself an intellectual authority that transcended the foundation on which the Church had relied.
- 141 Theology itself eventually underwent a revolution⁴⁵ of ‘secularization’ in which Christian belief was fully accommodated to scientific methodology. Although scientific findings are regarded as being independent of cultural or ideological bias, scientific research is still subject to general ethical and regulatory controls.
- 142 There is nothing internal to science that associates a value, according to any scale whatsoever, with any thing, event or possibility.
- 143 Everything in the Maori world is imbued with a natural sanctity or *tapu*. The *tapu* ascribed to things is derived from divine association and establishes a *prima facie* untouchability that humans are bound ritualistically to propitiate in all of their actions. There is no exemption within the sphere of Maori influence.

⁴² Maori Marsden & Te Aroha Henare (1992) *Kaitiakitanga: A Definitive Introduction to the Holistic World View of the Maori* unpublished manuscript, Department of Maori Studies Library, University of Auckland)

⁴³ Marsden and Henare give the translation “beyond the world of darkness”.

⁴⁴ By composer John Rimmer and writer Witi Ihimaera.

⁴⁵ Dietrich Bonhoeffer could be identified as having sparked a Protestant revolution that was led by others who survived WWII, such as Karl Barth, Paul Tillich, Reinhold and Richard Niebuhr, *et al.*. The controversy surrounding the writings of John Robinson in Britain and Lloyd Geering in New Zealand were local manifestations of the upheaval.

- 144 The contrast with the perspective of science could not be starker.
 For Maori: everything is in some sense intrinsically sacred and a demand for respect arises from the very nature of things.
 For science: nothing at all is sacred; no attribute could be more foreign to physical reality.

3.5 Politics of rapprochement

- 145 The crux of the problem in relation to genetic engineering and Maori is to find a way of giving force to considerations of *whakapapa*, *mauri*, *tapu* and other precepts of tradition without their remaining a sideline to the recognised discussion based on scientific principles and analysis. What is done in New Zealand to solve this problem will have implications far beyond our shores.
- 146 It is not just a matter of whether Maori are given some measure of political power in decision-making. Much more is at stake in what humans decide to do with genetic engineering and we should act according to the best principles that we can conceive from our uniquely bicultural constitution.
- 147 Up until now contributions to debate about genetic engineering from alternative scientific and Maori perspectives have amounted to competition for control over domains of culture and Nature.

3.5.1 Dialogue between scientists and Maori

- 148 Maori have been consulted in various fora (like ERMA's Nga Kaihautu committee and the Patenting of Life Forms Focus Group of the Ministry of Commerce) but there has been little attempt to forge agreement, common understanding and joint action based on an appreciation of the real differences in worldview. This cannot be done quickly simply to facilitate business interests, as has been attempted in processes of "consultation" by parties applying to ERMA.
- 149 Ammunson and Cairns⁴⁶ recommend bringing together for dialogue those separately well-versed in biotechnology and *tikanga*. While such dialogue between scientific experts and *tohunga* would be important, it would be limited in two very important respects. First, it would not engender the kind of criticism that is needed to get to the fundamental assumptions that separate the parties. Second, the approach is gratuitously elitist and would exclude virtually all opponents of both Ammunson and Cairns⁴⁷ and their biotech-industry sponsors.
- 150 Opinion about genetic engineering is divided among Maori as well as among non-Maori. True dialogue requires that the division of opinion among Maori inform scientific understanding and that the division of opinion among non-Maori inform the practice of *tikanga*.

⁴⁶ Paora Ammunson and Tamati Cairns (2000) Witness brief for the RCGM on behalf of the NZ Life Sciences Network (Inc), paras. 55-63.

⁴⁷ Especially the women Ammunson and Cairns criticise as simplistic and superficial: see para. 8 of Section I and 4, 24, 56 of Section II of their brief.

3.5.2 Potential contribution of Maori thinking

151 Maori bring to the debate about genetic engineering a coherent and integrated perspective in which the ‘intangible’ world of culture cannot be separated from the description of the phenomenal world. This should challenge scientific analyses that are limited to talk about pieces of DNA and the material consequences of transposing them from one organism to another.

152 Scientists are very quick to dismiss or ignore any discussion based on premises that are inconsistent with the accepted wisdom of their own disciplines. When they have to take serious account of concerns for *whakapapa*, *mauri* and *tapu*, whether these are expressed by proponents or opponents of genetic engineering, they may appreciate some worth in what they have eliminated from their own descriptions of the world.

153 There is good reason to believe that the facts of biology (and therefore the consequences of genetic engineering) cannot be explained adequately, even from a scientific point of view, without the development of concepts akin to *whakapapa*, *mauri* and *tapu*.

3.5.3 *Whakapapa*, *mauri* and *tapu* in relation to biological systems

154 The structure of the biosphere, the ever-adapting species it contains in ever-changing habitats, has been shaped by sequences of countless inter-related events (cf. *whakapapa*). Orderly patterns of interaction and adaptation that have now emerged derive from historical precedent, not permanently given laws of Nature governing the molecular structure of DNA or any other material substance.

155 Whether we look at the level of a single cell, a whole organism, an ecological community or the whole biosphere, we find that the functionalities of the various parts are defined in terms of the integrity of the whole system. Functional interactions are the practical determinants of events and the formation of new structures, conferring on entities the capacity (cf. *mauri*) to act as agents of change in some characteristic way.

156 The functional relationships between molecules in cells and species in ecosystems are deeply entrenched and are maintained by natural restrictions and limitations (cf. *tapu*). While it is true that we now have the means of setting some of those restrictions aside through genetic engineering, we should not do so with impunity because we will bear the consequences.

157 By insisting on the validity of the context they use to frame their thinking, Maori can make a seminal contribution to the debate about genetic engineering, even when and where considerations of a purely technical character have been given dominance. For their part scientists need to undertake a critical analysis of their fundamental philosophical assumptions and establish new ways of thinking about biological phenomena, dropping insistence that their description of the facts is correct and complete.

3.6 Stages of colonisation

158 The Treaty of Waitangi is taken by Maori and Pakeha alike as the founding document of the nation of New Zealand. In recent times it has been construed as an obligation of partnership between Maori and the Crown which, if honoured, serves as a basis for just governance and power-sharing. The Treaty is often portrayed as a model of how different peoples with different interests can live side by side.

3.6.1 Realities of colonisation

159 The reality of our nation's history is very different from what the Treaty would imply. Maori and the land of Aotearoa, albeit to a lesser extent than some peoples and lands, have suffered typical effects of colonisation by a western power. British immigrants transposed their way of life as best they could to new surroundings and went about commodifying everything available.

160 Ancient forests were felled for timber, as much as possible of the land was domesticated and a system of administration based on western morés was instituted and given the force of law. The immigrants felt no need to learn and act according to the language, culture and customs of the prior occupants of the land. Their way of life simply dominated.

3.6.2 Genetic engineering as colonisation of Nature

161 Genetic engineering can be understood as a process of colonisation. Territory that has remained effectively undisturbed from the direct effects of intentional human actions for approximately four billion years is now being manipulated to produce desired outcomes. The territory in question is the genetic repository of the biosphere. The manipulation involves insertions into and rearrangement of the contents of Nature's genetic information bank and the extraction of advantage for minority interests.

162 The character of the human interests for which genetic engineering is by and large being performed reveal the activity as colonisation of Nature. Humans are not simply using the fundamental processes of Nature as a resource. We are attempting to transform them into artefacts⁴⁸

163 There is not much of the planet left finally to be dominated by commercial industry and scientific technology. The global takeover has been careless of the rich biological and cultural diversity that previous evolution had produced. Aotearoa⁴⁹ and Maori have suffered together.

164 Now that humans perceive the new natural territory of genetic information inside organisms they should enter only with the utmost respect for what it may hold, especially the established precedents of its own mode of organisation, function and expression.

3.6.3 Dangers of further human colonisation

165 The failing of colonists is that they do not appreciate the true character of the territory they have come to visit and they use what they find according to their own inappropriate

⁴⁸ The only grander scheme ever conceived by scientists is the idea of Copenhagen physicist Holger Nielsen to construct a device that would begin the whole process of creation again, starting with a new "Big Bang".

⁴⁹ I distinguish between the land of Aotearoa and the country of New Zealand.

definitions and perceptions. The territory soon loses its previous character and becomes a part of a much more narrowly conceived project of the colonisers.

166 We are in danger of doing to Nature's genetic heritage what we have done to the face of the planet.

3.7 Wai262 claim

167 Because of its importance in relation to genetic engineering and the Treaty of Waitangi, I consider briefly some aspects of Claim Wai262 for ownership of the indigenous flora and fauna of New Zealand. We need to take account of two aspects of potential ownership

- (i) possession, and
- (ii) intellectual property rights.

These two aspects of ownership have become confounded lately because of the recognition given under law to intellectual property rights over organisms. In New Zealand it is possible to take out a patent over an organism⁵⁰

168 The Maori claim to sovereignty under the Treaty of Waitangi does not coincide with legal concepts and precedents that had been previously established under British law. *Rangitiratanga* must be interpreted in terms of Maori cultural practice which would not appear to allow ownership, in the Pakeha sense, of a species of organisms like rimu, tuatara or huia.

3.7.1 Character of the representation

169 When members of iwi appear before the Waitangi Tribunal they seem, according to their traditions, to be representing the people now living, the ancestors who have passed on, the flora and fauna, the land, the whole and every part of who they are as iwi. Therefore, in asserting ownership of flora and fauna the Wai 262 claimants could be said to be representing the flora and fauna themselves. In that case, the claimants would be asserting ownership, not *of* the flora and fauna, but *on behalf of* the flora and fauna.

170 The plants, birds and animals that are part of iwi cannot themselves appear before the Tribunal to assert ownership of themselves. However, as *tangata whenua* iwi can come to the Tribunal and, by exercise of their *rangitiratanga*, claim that ownership of the flora and fauna, for the iwi, on behalf of the flora and fauna. New Zealand law will ultimately accommodate Maori cultural practice in this respect or it will force Maori to conform to western concepts of ownership.⁵¹

3.7.2 Extent of the claim

171 The Crown could require that Wai262 claimants specify the extent of their claim in terms of the genetic constitution of the organisms concerned, rather in the manner in which

⁵⁰ New Zealand was one of the first countries to grant Genpharm International a patent NZ Patent 236310, 27 September 1993) over Herman, the celebrated genetically modified bull that had been created in the Netherlands.

⁵¹ There is every indication that such a process is on the Government's agenda. Two papers from the Ministry of Commerce in 1999 ["Patenting of Biotechnological Inventions" & "Maori and the Patenting of Life Form Inventions"] are based on the premise that western notions of property, including intellectual property, will not be inconvenienced by anything of substance that may come from the Waitangi Tribunal's recommendations in respect of Claim Wai262.

ERMA now operates. In that case the claim is likely to be for ownership of all indigenous species of plants, birds, animals, insects and other organisms.

172 However it would appear that the claims of iwi are actually specified in terms of ownership of all flora and fauna which have ever flourished on land over which they as *tangata whenua* exercise *kaitiakitanga*, and all the flora and fauna descended therefrom.

173 The iwi claim ownership of their flora and fauna as *kaitiaki*. That those flora and fauna may currently grow on land recognised under law as having private ownership, and therefore belong to other legal persons, is irrelevant to the role of iwi as *kaitiaki*. In that role, iwi have taken the responsibility, as well as the right, to control the destiny of the flora and fauna within their domain of *rangitiratanga* from time immemorial.

174 The role of *tangata whenua* as *kaitiaki* is under threat from the legal system which allows ownership over genetic information for which some use is proposed. By taking DNA from an organism and determining its sequence, any legal person (an individual, a group, a corporation, a Crown Research Institute, etc.) can effectively take control over a species and its destiny. This applies to the native flora and fauna of Aotearoa, contrary to the guarantees of *rangitiratanga* afforded Maori under the Treaty of Waitangi.

3.7.3 What is at stake in the Claim

175 Iwi have legitimate fears that the very constitution of their *taonga* is under threat from the actions of biotechnologists who may see some advantage in creating genetic modifications of them. New Zealand law allows organisms to be genetically modified and then recognises those genetically modified organisms as inventions which are the intellectual property of their creators.

176 My interpretation of Claim Wai262, which I support, is that it is an use of the legal system by iwi to maintain their *kaitiakitanga*, *mana* and *ora*. Granting ownership by outsiders of genetic information pertaining to the flora and fauna of iwi could be interpreted as the final *raupatu* - the confiscation of *whakapapa*.

4. Issues of science and ethics

4.1 Military influences

177 The most problematic ethical issue to face scientists in the twentieth century was the relationship between their discoveries and the capacity of humans to effect gross intentional destruction, on one another and collaterally on Nature. Thus, by the mid 1980s it had become the currency of public discussion that the survival of life on the planet was under threat from arbitrary human decisions: nuclear war was capable not only of destroying most of humanity but also of producing climatic change on a global scale (the so-called “nuclear winter”).

178 The building of nuclear arsenals comprising tens of thousands of weapons was not accomplished as a way of meeting any simple military or political imperative. The initial construction of nuclear weapons during WWII was the idea of scientists and they solicited from the United States government the economic and other means needed to achieve their goal.

4.1.1 Misdirection of scientific effort

179 In whatever way one views the ethics of that enterprise and the immediate use of the weapons against an alternative enemy, the ever-increasing diversion of resources into its continuation during the next forty years was an aberration of the initial intent of Einstein and others who first proposed construction of an atomic bomb and it severely distorted the character of science.

180 By the 1970s science funding was so completely dominated by the requirements of the military-industrial complex that the career choice of anyone wishing to continue in the physical sciences beyond the tertiary level of education was skewed toward research that had military applications. The work of scientists had created a situation in which they themselves were effectively deprived of authentic ethical choice and they resigned themselves to political justifications for what they did: American scientists built bombs to keep the Evil Empire at bay and Soviet scientists with the same training build bombs for Patriotic Defence.

4.1.2 Effect on biological research

181 Those who wished to pursue the life sciences could take refuge in medical research, but the military budgets of the superpowers were such that it was advantageous even for biologists to participate in research that served national military goals. It was within this context that genetic engineering was invented and the Biological Weapons Convention (BWC) was signed in 1972. The BWC was ill-equipped to deal with subsequent advances in biotechnology and its provisions for “defensive measures” under the Kissinger interpretation allowed much research to go ahead unabated.

182 In 1988 I attended a conference at Fort Detrick, Maryland where I listened to US Army researchers describe how they were using techniques of genetic engineering to investigate the immunological properties of Hanta viruses⁵² and their mechanisms of dispersal in aerosols.

4.1.3 NZ and military applications of GE

183 Briefing papers that I obtained from the Army under the US Freedom of Information Act cited collaboration with New Zealand under the Technical Cooperation Program (TTCP) as indicating that US biological warfare research had wide allied support.

184 As far as I know the New Zealand military conducts no research that involves the use of genetic engineering, but I cannot exclude the possibility that individual medical officers on military contracts use laboratory GE for work they do on behalf of the armed forces. There are no military institutions who have “Interested Person” status with the Commission.

4.1.4 Prohibition of military applications of GE

185 Consideration should be given, as a way of ensuring that genetic engineering is used only to serve humanity as a whole and not the partisan goals of single nations or blocs, to the possibility of amending the NZ Nuclear Free Zone, Arms Control and Disarmament Act, beyond our obligations under the BWC, to exclude the use of GE for military purposes within New Zealand and by persons under New Zealand’s jurisdiction.

186 It is worth considering what the effect of such an exclusion might be on goal as worthy as the clearing of landmines. US military personnel have hatched a plan to detect buried mines by using bacteria that have been genetically engineered to glow in the dark when they metabolise TNT.⁵³

⁵² Hanta viruses cause fatal haemorrhagic fever, quite similar to Ebola.

⁵³ Permission to conduct open field trials of such bacteria would probably be difficult to obtain within the US, so it is proposed to conduct tests in Croatia where there have been more pressing concerns than the establishment of regulations for the use of genetically engineered microbes. The plan does not seem to have been changed since the discovery of naturally occurring bacteria with similar properties.

187 While I would oppose such a use of genetically engineered bacteria on general ecological grounds, I could conceive of there being an international body which deemed that the risks involved in the environmental release of the bacteria was outweighed by the good which could be achieved by clearing the minefields. New Zealand military personnel could then have a mandate from the United Nations to use the genetically engineered bacteria.

188 Under those circumstances I believe that New Zealand personnel involved in the work should be released from the special obligations to their employer (the New Zealand government) arising from their military contracts. In other words we should see to it that GE is never used by persons who are mandated, for the perceived benefit of this country, to compromise the vital interests of members of other countries.

189 We should move finally to make the ethical conduct of science and the use of its inventions incompatible with all preparations for potential armed combat between opposing military forces, even when such readiness appears to be only a matter of form. Putting such restriction on scientific development would be a most salutary act of internationalism.

4.2 Declining autonomy of scientific activity

190 Soon after the most basic techniques of genetic engineering were invented a group of leading molecular biologists gathered at Asilomar, California and proposed a voluntary moratorium on certain uses of the new technology. This act of self-regulation has long been touted as a prime example of the sense of ethical responsibility exercised by the scientific community and of the lack of need for tight controls over scientific research.

191 When many of the same group of scientists reconvened at Asilomar in February of this year they described a quite different picture of research within their field. It was noted that "there a few pure academics left".⁵⁴ Most senior researchers have ties to biotechnology companies. The discussion was dominated by recognition of public suspicion of many products of genetic engineering and the effect that commercial pressures now exert on research.

4.2.1 Developments since the invention of GE

192 What has happened in the last quarter decade is described accurately by Dorothy Nelkin:⁵⁵

“The social contract between science and the state that formed after World War II included agreements about the terms of scientific autonomy. The government would provide research support unfettered by requirements for accountability if scientists would work in the interests of progress and effectively regulate themselves. The unusual degree of autonomy granted to science reflected the public image of

⁵⁴ M Barinaga (2000) "Asilomar Revisited: Lessons for Today?", Science 287, 1584-1585.

⁵⁵ Dorothy Nelkin, "The Science Wars: What is at Stake?", Chronicle of Higher Education, July 26, 1996. Available at <<http://www.drizzle.com/~jwalsh/sokal/articles/dnelkin.html>>.

scientists as apolitical, unbiased, and therefore reliable as sources of truth. It also reflected public trust in the ability of the scientific community to control its internal affairs. Under these conditions science flourished and scientists took autonomy for granted as their due. In the 1990s, however, the terms of contract appear increasingly obsolete, and the harmony that had long marked the partnership between science and the state has deteriorated. Both sides have failed to meet their side of the bargain. Government is cutting back on funding and scientists, often working in the interest of private profit, are facing the problems of self-regulation.

193 “The strains on science funding are, in large part, a consequence of world events--the end of the Cold War, the cutback in defense related research, and the national deficit. But also, the extraordinary optimism about the future of science that maintained the social contract has dissipated, and scientists like other institutions and most people these days must cope with fewer resources and greater accountability.

194 “The scientists' side of the contract, their promise of self regulation, has also deteriorated. It has become increasingly difficult to maintain control over the large number of scientists working in specialized fields in a climate of intense competition. The widely reported incidents of fraud have become a major concern for journal editors and scientific associations. Some scientists regard fraud as an aberration: others as revealing basic structural flaws in the organization of science. But fraud strikes at the moral roots of the scientific enterprise, and presents a serious challenge to the ability of the community to regulate itself.

195 “...changes in science also reflect growing corporate influence on research. As economic competition overshadows military goals, many scientists are shifting their priorities to commercially relevant research devoted to the solution of short term problems. Predictably, corporate sponsors demand research in the interest of profit. Thus, the vision of science as driven by scientific curiosity has been clouded leaving the impression that scientific information is less a public resource--the basis after all of the original contract-- than a private commodity.

196 It is within such a context⁵⁶ that questions of scientific ethics concerning genetic engineering must be addressed. There has emerged a biotechnological governmental-industrial-academic complex which aims to bring processes of genetic change under control for global economic gain. Virtually all molecular biologists have ties of some sort with parties whose interests are overtly commercial.

4.2.2 Scientists' conflicts of interest

197 Scientists cannot be trusted to speak as members of an egalitarian community of scholars who work for the common good. Bodies such as the Royal Society and IBAC seek to convey an impression that they act in such a manner, but it is a misrepresentation. The

⁵⁶ There are only minor differences between the scene in the US in 1996 and New Zealand in 2000.

information they convey to the public is tainted by a multitude of undeclared interests. Beliefs and opinions, especially about the connection between genetic engineering and economic growth, are presented as if they were facts. Legitimate public concerns about aspects of these activities are portrayed as being based on ignorance and scare-mongering.

198 The Royal Society's connections with the now-defunct Genepool is a clear illustration of how what is supposed to be science degenerates into public relations in support of commercial sponsors.⁵⁷

199 Professor Peter Gluckman resigned as Chair of the Independent Biotechnology Advisory Committee (IBAC) in March of this year declaring that he wished to avoid a conflict of interest, but it was not evident how his interests had been changed. He had been a key figure in planning the formation of the University of Auckland's biotech company Neuronz from the outset.⁵⁸

4.2.3 Official promotion of genetic engineering

200 Membership of the IBAC and much of the advice it has received has promoted the views and interests of those involved in using genetic engineering at the expense of those expressing a more critical point of view⁵⁹

201 Various other statutory bodies such as the Foundation for Research, Science and Technology (FRST), as well as arms of government such as the Ministry of Commerce⁶⁰, give overwhelming weight to the promotion of activities involving genetic engineering. They are given a great deal of help from scientists who are take the opportunity to raise the profile of their own research, thereby advancing their careers.

4.2.4 Exclusion of skeptics and critics

202 At no time, as far as I am aware, has any member of the scientific community who has expressed views fundamentally skeptical or critical of genetic engineering been appointed to any official body charged with evaluating or regulating aspects of genetic engineering in New Zealand.

⁵⁷ The analysis of Dr Judy Motion (University of Auckland) should be studied carefully.

⁵⁸ These problems are in no sense unique to New Zealand. The US National Academy of Sciences panel on genetically engineered foods leans overwhelmingly toward a pro-biotech position and includes members who are paid by the industry. Full details can be found at <<http://www.house.gov/kucinich/info/NASletter.htm>>.

⁵⁹ My correspondence with the Minister Maurice Williamson on the setting up of IBAC can be found at <<http://www.phy.auckland.ac.nz/staff/prw/LetterWilliamson.html>> along with my criticism of the University of Auckland's submission to IBAC at <<http://www.phy.auckland.ac.nz/staff/prw/IbacUni.html>>.

⁶⁰ In May 1995 the Business Policy Division conducted an enquiry into the patenting of biotechnological inventions, By February 1999 the Competition and Enterprise Branch had completed consultation with Maori on the issue.