Gene Technology Ethics Committee

Working Paper: Ethical Issues Arising from Trans-Species Gene Transfer

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Contents

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- Adviser to the working group, Dr Simon Longstaff; and
- Dr John Rasko, adviser from the Gene Technology Technical Advisory Committee.

1 Introduction

The Gene Technology Ethics Committee (GTEC) is a statutory advisory committee established under section 111 of the *Gene Technology Act 2000* to advise the Gene Technology Regulator and the Gene Technology Ministerial Council of Australia.

The *Working Paper: Ethical Issues Arising from Trans-Species Gene Transfer* is a result of GTEC's first meeting in December 2002, where GTEC resolved to consider a number of the ethical issues related to conduct involving genetically modified organisms (GMOs). GTEC thus formed a working group to produce a discussion paper on ethical conduct in the transfer of genes between kingdoms.

In March 2004, the scope of the discussion paper was extended to cover all trans-species gene transfer, following feedback from the Gene Technology Technical Advisory Committee (GTTAC) and the Gene Technology Community Consultative Committee (GTCCC). The GTEC working group was asked specifically to consider:

- what ethical issues arise from trans-species gene transfer;
- whether it is appropriate for GTEC to further consider these issues; and
- what output is expected from the work of GTEC on these issues.

This working paper and the ethical issues it discusses should be understood in light of the ethical principles as described in the *National Framework for the Development of Ethical Principles in Gene Technology* which has also been produced by GTEC. The purpose of the National Framework is to provide the Australian community, particularly scientists working in gene technology, with a national reference point for ethical considerations that may be taken into account when developing values and ethical principles relevant to environmental and health issues in gene technology, genetically modified organisms and genetically modified products. The values and principles set out by the National Framework apply to the situations dealt with in this paper. They are summarised in section 3.1.

1.1 Purpose

This working paper aims to encourage constructive discussion about the ethics of trans-species gene transfer by identifying the different approaches (including scientific and cultural or religious views) that can be used to consider the issue.

The principal focus of this paper is on ethical concerns related to gene transfer between organisms with different levels of similarity in structural DNA. This similarity can range from high (closely related species) to low (very distantly related organisms, such as those from different kingdoms). The paper uses the term 'trans-species gene transfer' to cover gene transfers between species, whether they are from the same or different kingdoms; however, 'trans-kingdom gene transfer' is used to refer specifically to gene transfers between species from different kingdoms.

This working paper is the first stage of the process in formally considering a range of ethical issues arising from trans-species gene transfer. The working group has focused on trans-species gene transfer in general, but has not focused specifically on gene transfer between humans and other organisms, which will be the subject of a separate paper. The focus of the working paper is on the environmental release of GMOs and not on those in contained environments.[1]

1.2 Audience

It is important for different groups within the community to work together to address issues of ethical concern relating to gene technology. Different community groups may include, for example, those trained in science and those who are not; those who are religious and those who are not; and those who come from different cultural and social backgrounds. For some people, combining these issues of ethical concern may mean being introduced to new scientific language and concepts. For others, it may mean learning about different perspectives on life, listening to various opinions on appropriate behaviours, or engaging in discussion about ethical concerns and social values that differ from their own experience and beliefs. This will require some work, but it is important that an effort is made to do this. This paper therefore aims to address a number of different community groups simultaneously, including scientific researchers, ethicists and the general public.

The working paper has an educational function, and further work may be needed to resolve some of the issues that are discussed here. While an attempt has been made to make the paper accessible to those not trained in science, it necessarily contains scientific material. On the other hand, those who do not find the science difficult may have to work to address the ethical concerns that some individuals and community groups have.

A separate, plain-English, summary of this paper has also been prepared. People who are not familiar with the technical scientific and ethical material included here may prefer to read the summary paper, either before or instead of the more comprehensive working paper.

1.3 Structure

The working paper contains six sections:

- Section 1 (Introduction) outlines the paper's purpose and audience.
- Section 2 (Background) examines the scientific background (including taxonomic definitions, trans-species gene transfer and transgenes) that is directly relevant to the ethical issues associated with trans-species gene transfer.
- Section 3 (Issues and concerns) identifies the public's ethical concerns and potential concerns about trans-species gene transfer, examines how science and ethics are connected, and discusses the relative ethical values and arguments relating to gene transfer and gene technology.
- Section 4 (Resolution of issues and concerns) identifies the public and social roles of science and technology and predicts the course of the trans-species gene transfer debate. This section also includes an overview of the existing regulatory structures that manage the debate about gene technology in Australia.
- Section 5 (Conclusions) contains conclusions drawn from the preceding discussions.
- Section 6 (References) provides a list of further reading.

[1] For more information on the ethics of biotechnology, see http://www.ogtr.gov.au http://www.biotechnology.gov.au www.genetech.csiro.au http://www.ea.gov.au/industry/biotechnology/links.html http://www.bbsrc.ac.uk http://www.usda.gov/agencies/biotech/index.html http://www.i-sis.org.uk

The overall approach of this paper is to use examples, where possible, to illustrate points. However, where there are no examples to illustrate points, the authors use predictions based on theory. For example, the expression of some genes is not affected by other factors such as their genetic neighbours or their position on the chromosome. In contrast, the external environment as well as the internal environment, including the genetic neighbourhood or the gene's position on the chromosome, influence the expression of other genes. It is important to know whether other factors affect the expression of a transgene as this will affect the certainty of the outcome of the genetic manipulation and thus the ethical issues that are raised.

2 Background

This section defines key taxonomic terms and examines the degree to which taxonomic definitions are fixed.

Key definitions

Biological species concept: Species are groups of interbreeding natural populations that are reproductively isolated from other such groups

Class: The next major category of organisms below phylum

Coding DNA: A region of DNA that codes for a protein (sections of coding DNA are also called exons)

Domain: The highest-level grouping of organisms

Eukaryote: Organisms whose genetic material is contained within a distinct nucleus (ie bounded by a nuclear membrane)

Family: The next major category of organisms below order (containing one or more genera)

Genus: The next major category of organisms below family (containing one or more species)

Horizontal gene transfer: Stable transfer of genetic material from one organism to another without reproduction or human intervention

Kingdom: The second-highest level grouping of organisms, after domain

Non-coding DNA: A region of DNA that does not code for a protein

Order: The next grouping of organisms after class

Phylum: The next grouping of organisms after kingdom

Prokaryote: Single-celled organisms whose genetic material is not contained within a distinct nucleus, but is contained within the cytoplasm

Promoter: A segment of DNA that controls gene expression. It marks the site of initiation of gene transcription.

Recognition concept of species: A species is the most inclusive population of individual biparental organisms that share a common fertilisation system.

Species: A loosely defined term commonly used to describe a single, distinct class of living creature with features that distinguish it from others

Transgene: A gene that is intentionally transferred from one species to the genome of another through human intervention

Trans-kingdom gene transfer: The transfer of genes between organisms from different kingdoms

Trans-species gene transfer: The transfer of genes between organisms from different species

Vertical gene transfer: The transfer of genes down through generations through sexual or asexual reproduction

Within this context, horizontal gene transfer and transgenes, both of which involve the movement of genes across taxonomic boundaries, are considered. Where examples exist, they are provided.

2.1 Taxonomic definitions

Scientists organise living things in a hierarchical classification system that usually reflects the evolutionary history of each species. This classification system extends from the specific (species) to progressively broader categories of relatedness, culminating in domains. The amount of similarity in DNA decreases as the degree of relatedness between species (reflected in the hierarchical classification) decreases. Individuals that have the highest degree of similarity in DNA because they share a gene pool are grouped together in the same species. Related species have a high degree of similarity in DNA and are grouped into the same genus. Related genera, which have a lower similarity in DNA than species within a genus, are grouped into the same family. The trend of decreasing similarity between categories of organisms continues, with related families grouped into the same order, related orders grouped into the same class and related classes grouped into the same phylum. Related phyla are grouped into the same kingdom, and they share a greater amount of DNA with one another than they share with phyla from different kingdoms. Kingdoms that share some features are grouped into one of the three domains, which cover all living organisms on earth. Therefore, the hierarchical taxonomic classification reflects the amount of similarity in DNA between organisms.

Defining species

Although most biologists regard them as a fundamental unit of nature there is disagreement as to how to define 'species'. There are more than 20 species concepts that belong to two main schools of thought, either phylogenetic or non-phylogenetic.

Phylogenetic species are based on some form of reconstruction of the evolutionary history, whereas non-phylogenetic species are based on other factors such as morphological similarities.

For the purposes of this paper, the extent of gene flow between different groups is the important issue. How a species is precisely defined is not so important in this context.

2.2 Issues with taxonomic definitions

The definitions of 'kingdom' and 'species' are not fixed, but vary according to different scientific opinions. Some people define a species as a group of organisms capable of sexual reproduction: therefore, if direct gene transfer occurs between two organisms, they belong to the same species. Other people define a species as a group of organisms that are morphologically different from other groups.

Deciding how valid scientific distinctions between kingdoms and species are, and how such distinctions are made and changed, is an important part of the discussion on gene transfer between species. A number of different classification systems are used to define kingdoms and species. This may indicate either a fundamental problem with the whole notion of classification (often associated with the philosophical view that any resistance to trans-species gene transfer is therefore inappropriate), or that, because of new and rapid scientific developments, the current time is one of scientific flux in which the principle of classification remains valid even though its form changes.

2.2.1 Types of classification system

Traditional system

One taxonomic classification system identifies five kingdoms (based on an assessment of cell type, level of organisation and nutrition): Animalia, Plantae, Monera (procaryotae), Protista and Fungi) (Whittaker 1969). Another classification identifies six kingdoms: Bacteria, Chromista, Plantae, Animalia, Fungi and Protozoa (Cavalier-Smith 1998). Others suggest three kingdoms (see Figure 1). Whatever system is followed, 'kingdom' talk implies a reasonably sharp differentiation between groups and is perhaps suggestive of a much earlier stage of biology where distinctions were made based on observable characteristics (including the ability to interbreed). These changes in classification reflect a time of scientific flux as more information becomes available, enabling better distinctions to be made between kingdoms.

The scientific debate about the number of kingdoms is focused on unicellular organisms (prokaryotes). The kingdoms Plantae, Fungi and Animalia are accepted as true kingdoms and are not contested. The debate is primarily about the number of kingdoms in Bacterial and Archaean domains and the number of Protistan kingdoms in the Eukarya domain (see Figure 1). Therefore, the debate does not affect the ethical issues arising from the transfer of genes between kingdoms, because the gene transfers being considered (such as placement of bacterial genes into plants and animals, or animal genes into plants) are agreed upon by scientists as being trans-kingdom gene transfers. The debate does, however, affect the ethical issues arising from gene transfer between species.

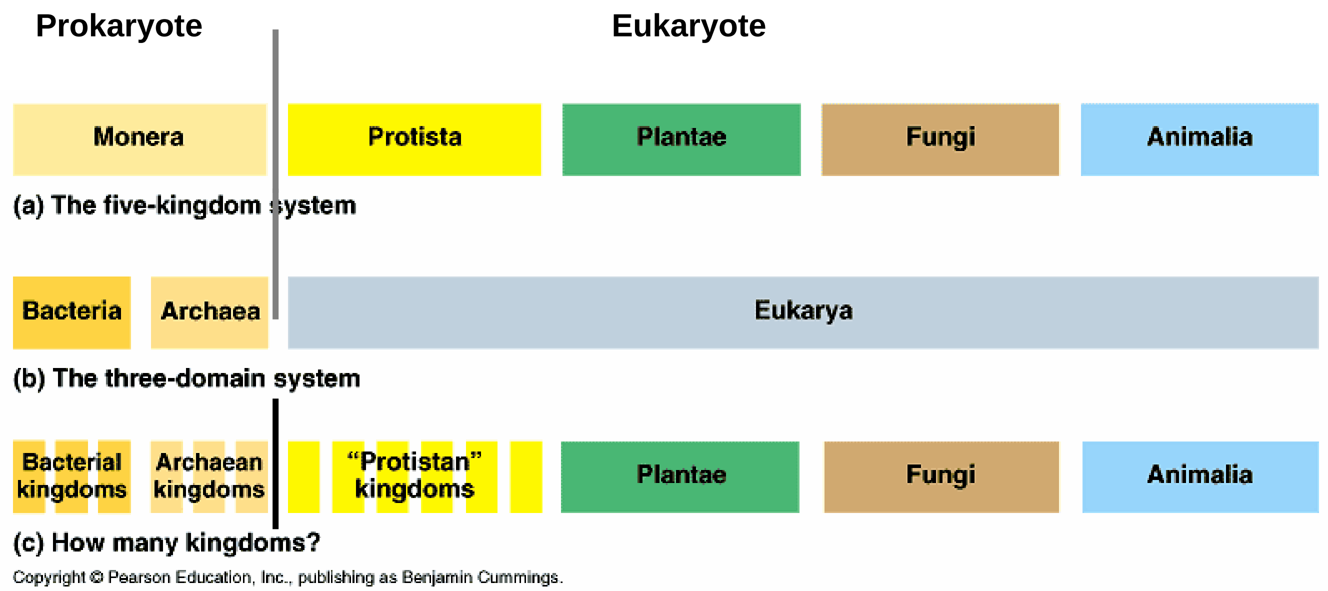

Figure 1 Changing view of the taxonomic world, in terms of the number of kingdoms (from Campbell and Reece 2002, p 523)

DNA-based classification

The actual level of similarity in structural DNA is not a good indicator of differences between species, especially for species between which there is a large difference in phenotypic expression, (eg humans and great apes; humans and cattle). However, the level of similarity in structural DNA indicates the complexity of DNA decoding and the important influence that other factors have on phenotypic expression (eg the number of promoters and enhancers that affect gene expression, the position of a gene on a chromosome and the interaction between a gene and its neighbours). Thus, a small number of genes may be responsible for major differences between closely related species. For example, one gene is thought to be responsible for the decrease in the musculature of the jaws of humans compared with the jaws of other apes. This genetic change, in conjunction with others, is thought to have affected the larynx as well as creating more space, enabling a substantial increase in cranial capacity. These changes facilitated the ability to communicate by speech. However, it may be that the significant differences that exist between some species with significant similarity in structural DNA may be better explained at sociological, environmental or ecological levels rather than solely by reference to the molecular level. The question of the scientific paradigm that is to be used to interpret the situation and make predictions is critically important and currently being debated.

2.2.2 Use of taxonomic classifications

The taxonomic classifications of science are not necessarily used by other disciplines or viewpoints (including ethical and religious ones). This can lead to confusion in communication if the general public does not use scientific taxonomy, while scientists use it when discussing these issues. This has obvious implications for public debate on gene technology, which challenges people's intuitive sense of order. So that the general and scientific communities can properly consider the issues, the following points must be considered:

- the ethical concerns associated with the scientific preference for the distinction of kingdoms and species;
- the scientific preference for discarding these distinctions;
- the validity of the scientific taxonomies of kingdoms and of species; and
- the validity of the use of scientific taxonomies in ethical arguments.

The validity and usefulness of scientific taxonomies depends on how accurately they reflect the evolutionary relationships between organisms. Scientific taxonomies are based on morphological similarities or the amount of similarity in structural DNA in parts of the genome — both of which are supposed to be indicative of evolutionary relationships. Because scientific taxonomies are based on one or both of these two criteria, they more accurately reflect the biological differences between organisms than do the general public's classifications of organisms. However, there are other perspectives that are central to the decision-making process, such as social, cultural, religious, ethical, economic and political perspectives. Therefore, the general public's concerns about trans-species gene transfer are valid, even though they may not be based on a currently accepted scientific taxonomy.

2.2.3 Identifying taxonomic boundaries

The general public is concerned about genes crossing the natural boundaries between species. This concern depends on where the public perceives these natural boundaries to lie; however, its validity does not depend on whether the public's perceptions of species boundaries conform to scientific ones or not.

The general public's use of the term 'kingdom' may differ from the scientific use. For example, people may classify poriferans (sponges), pigs and people as belonging to different kingdoms, but scientifically they all belong to the same kingdom, Animalia. The poriferan belongs to the phylum Porifera, whereas pigs and people belong to the phylum Chordata. However, pigs and people belong in the same class (Mammalia) but are placed in different orders (Cetartiodactyla and Primates, respectively).

Therefore, what the general public considers to be gene transfer between two different kingdoms may actually be gene transfer within the same kingdom. Scientifically speaking, inserting a pig gene into a human would be a trans-order gene transfer, whereas inserting a gene from a chimpanzee into a human would be a trans-genus gene transfer, because chimps and humans belong to the same family but different genera. Nonspecialist terms may mix different levels of classificatory resolution. Therefore, based on the general public's understandings of taxonomic groups, gene transfer may occur between species or between various combinations of taxa groups; however, the ethical issues exist in both situations.

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Key point

The general public's concerns for trans-species gene transfer may not always align with the taxonomic levels of separation between species. This may not be justifiable in scientific terms, but can be understood in terms of the cultural and religious values that people may attribute to different living things.

2.3 Horizontal gene transfer and transgenes

Minor portions of DNA can naturally transfer between living organisms. Horizontal gene transfer involves the transfer of small amounts of DNA between individuals other than by sexual or asexual reproduction (which is 'vertical' gene transfer). This section examines the influence of horizontal gene transfer in debates about trans-kingdom gene transfer.

It should be noted that *Gene Technology Act* 2000 does not include horizontal gene transfer between bacteria in the definition of a genetically modified organism.

2.3.1 Natural gene transfer

Horizontal gene transfer is independent, unidirectional, and occurs commonly in bacteria. Scientists have known for more than 60 years that bacteria can acquire naked DNA (DNA that does not have any proteins bound to it) from the environment as genomic or plasmid DNA, or through interaction with bacterial viruses (Avery *et al.*1944). In addition, agrobacteria are able to add genes to the chromosomes of plants and perhaps even to add genes to animals (including, potentially, humans). Horizontal gene transfer is now considered the most important mechanism for the evolution of new traits in bacteria.

Horizontal gene transfer can occur in organisms other than bacteria. In disease initiation in some plants, the bacterium *Agrobacterium tumefaciens* transfers genetic material to the plant, which is incorporated into the chromosome and expresses a range of genes. This process is now commonly used for the artificial transfer of foreign genes expressed in plants. A potential problem is that, although a gene from a eukaryotic cell may be non-coding in a bacterium, it does not mean that it cannot be transferred to other eukaryotic cells where it can code for a protein. This raises ethical questions, because it suggests that there is not complete control over the process.

Some scientists believe that many human genes are the result of horizontal gene transfer from bacteria, while other scientists argue that the putative horizontal gene transfer genes are present in more ancient eukaryotes (nucleated cells) and have been transferred through vertical gene transfer.

Artificially produced transgenes differ from natural genetic variation, because their numbers are increased by humans artifically and transgenes are often modified to allow expression across a broad range of hosts.[2] Inserting a transgene into a chromosome may affect the stability of the genome and thus the probability of horizontal gene transfer. For example, where a transgene decreases the genome's structural stability, it increases the availability of DNA for horizontal gene transfer and recombination. There is less horizontal gene transfer in bacteria with stable genomes than those with less stable ones. This stability can result from the loss of genes responsible for transferring genes (see Silva et al. 2003).

The potential for transgenesis to destabilise the recipient's genome and increase the probability of horizontal gene transfer (Woese 2004) is of concern because of the uncertainty surrounding the spreading of a transgene to nontarget species and causing ecological damage, such as disrupting a

[2] See http://www.icsu-scope.org/downleadpubs/scope44/chapter03.html

biological community. That having been said, it is interesting to note that the human genome has a large amount of DNA of viral origin in the non-coding part of its DNA (see MacPhail 2004). There does not seem to be any evidence as yet about humans being recipients to DNA from prokaryotic and other eukaryotic organisms. The difference in the frequency of HGT by viruses and other organisms is that viruses are parasitic, making use of host replicating and production machinery to produce more viruses, whereas prokaryotic and eukaryotic organisms are not. In summary, gene transfer across kingdoms may be problematic because species from different kingdoms are more distantly related than are species from within the same kingdom. In other words, more distantly related organisms have a shorter shared evolutionary history and therefore the degree and nature of organisation of genome function are very different.

2.3.2 Artificial gene transfer

Gene transfers made by humans using gene technology are not a simple extension of traditional breeding techniques. There is a profound difference in the genetic composition of modified organisms. In traditional breeding, a gene for the desired trait is inherited with 50% of the genome of the parent organism. Thus, the gene remains with other genes that have evolved together in a gene pool, and are more likely to be compatible with one another than they are with genes from a different gene pool. Introducing a foreign gene using gene technology may disrupt the genome’s stability — a stability that has taken many generations to stabilise under specific selection pressures. Increased instability of the genome may cause ecological problems as well as problems for the organism itself (Hulsman 2004). The ethical issues associated with these scientific points relate to ecological integrity, animal welfare and the intrinsic value of the organisms involved.

The cognitive framework used when considering gene transfer affects the predicted outcomes of genetic manipulations, and therefore also affects the ethical issues raised. For example, certainty of the outcome of any genetic manipulation is greatest where the transgene’s expression is independent of other factors. In contrast, certainty of the outcome decreases where other factors, such as the gene’s genetic neighbourhood and external environment, affect the gene’s expression. In other words, the level of uncertainty in outcomes of genetic manipulations depends on whether other factors affect the transgene’s expression (Hulsman 2004). Therefore, one could encounter ‘surprise’ or unexpected outcomes (including no effect), if one were to assume that other factors did not affect the transgene’s expression, when in fact they did. Increased uncertainty about the outcome of any genetic manipulation raises ethical issues that would not be raised, if the outcome were certain.

2.4 Trans-species gene transfer

Fungi, plants or animals may be genetically manipulated to introduce or enhance some characteristic that already exists within a species. In cases where the characteristic is naturally expressed, a natural process could, in the right conditions, transfer the introduced characteristic to another organism. Trans-species gene transfer, however, involves the movement of genes between different species. For example, using gene technology techniques, genes from a bacterium can be inserted into a plant; this is the case with Bt cotton, where the gene is expressed and provides a defence against insect pests.

It is popularly assumed that the various species and kingdoms are distinct and separate, and that under normal circumstances genes cannot be transferred between them. In this sense, gene transfer between kingdoms may introduce new ethical questions beyond those involved in other forms of genetic modification within kingdoms or genera.

Included within the ethical discussion about trans-species gene transfer are gene transfers between higher levels of taxonomic classification (such as families, classes, orders, phyla and kingdoms), and whether these gene transfers lead to ethical issues in addition to those associated with gene transfers between more closely related organisms.

Particular ethical questions arise where, for example, a human gene is inserted into an animal or crop. The effectiveness of the boundary between species for gene transfer increases as more distantly related species are involved, and the associated ethical issues must be identified. Evolutionary history shows that organisation of cells has become increasingly complex with time (Woese 2004). This complexity results from the increased connectivity between different parts of the genome. The shorter that shared evolutionary history of a gene has with the recipient genome, then the more likely that the gene will disrupt the organisational complexity of the genome thereby decreasing the function of genome and thus its survival value. With increasing connectivity between clusters of genes and within a cluster, the placement of a transgene is crucial for the recipient's fitness.

2.5 Summary

A transgene is any gene that is transferred from one species to the genome of another. Most species of multicellular organisms are distinct and do not normally transfer genes to one another, whether they are closely or distantly related. The scientific definitions of taxonomic categories, such as species and kingdom, are not fixed and are still subject to scientific debate. However, the vast majority of gene transfers involve organisms that are clearly of different species, irrespective of how species is defined. Although horizontal gene transfer does occur in eukaryotes, it is negligible compared with the number of gene transfers made using biotechnology. In addition, the quality of natural horizontal gene transfer differs from that of artificial gene transfers. For example, horizontal gene transfer includes the transfer of non-coding DNA, or coding DNA that does not confer a selective advantage and so may be lost through genetic drift. The transfer of genes whose expression is affected by neighbouring genes or by environmental conditions is more problematic than the transfer of genes whose expression is not affected by other factors.

3 Issues and concerns

This section outlines the public's ethical concerns and potential concerns relating to trans-species gene transfer and locates them within the values and principles provided by the *National Framework for the Development of Ethical Principles in Gene Technology*. It considers the connection between science and ethics, and whether kingdoms have relative ethical values. The questions of whether horizontal gene transfer is a natural precedent for trans-kingdom gene transfer, and whether gene transfer is natural or unnatural, are examined. The role that ethical arguments play in decision making is considered in this context.

3.1 The ethical context

In developing the National Framework, GTEC identified the following values and principles as the most relevant for ethics of gene technology. They are presented here only in summary form. For further detail reference should be made to the National Framework document.

The following values are important because they are part of a common currency in discussions about the ethics of gene technology.

- Respect for human life
- Respect for animals
- Respect for the environment
- Freedom of choice
- Acquiring and applying knowledge
- Reasoned argument and decision making
- Trust

GTEC has developed the following nine principles that should guide researchers and all others involved with gene technology. They help to ensure that the values identified above shape policies and actions that arise when dealing with gene technology, GMOs and GM products.

Researchers and all others involved in gene technology should:

- treat integrity as the guiding value in the search for and application of knowledge and benefits and in regard to the obligations of, and intentions underlying, the national regulatory system and other relevant guidelines and regulations (Principle 1)
- take responsibility for ensuring that activities within their control do not cause damage to the Australian environment or to areas beyond the limits of the national jurisdiction; to achieve this, there must be a thorough assessment of the long-term side effects of applications of gene technology (Principle 2)
- minimise risks of harm or discomfort to humans and animals likely to be adversely affected by gene technology (Principle 3)
- assess and respect the environmental and health needs of present and future generations (Principle 4)
- conduct research in a manner that protects the environment, including protection of genetic diversity, organisms, species, natural ecosystems, and natural and physical resources (Principle 5)
- act justly towards others, and demonstrate respect for human beings (as individuals and group members) in all activities associated with gene technology, including obtaining proper consent (Principle 6)

- promote equitable access to scientific developments and sharing knowledge, and recognise the value of benefit sharing (Principle 7)
- conduct research in a manner that promotes the benevolent and avoids the malevolent uses of gene technology (Principle 8)
- conduct gene technology research after appropriate consultation and ensuring transparency and public scrutiny of the processes (Principle 9)

These values and principles provide a background against which the ethical issues related specifically to trans-species gene transfer can be assessed.

3.2 Ethical concerns of the public

GTEC addressed the ethics of trans-species gene transfer because the matter was raised in the following contexts:

- with OGTR in written submissions on the discussion paper *Proposed National Regulatory System for Genetically Modified Organisms: How Should it Work?*;
- in submissions to the Senate Community Affairs Reference Committee *Inquiry into the Gene Technology Bill 2000* in August 2000; and
- in public consultations.

Clearly, the ethics relating to trans-species gene transfer are of public concern. It is notable that the final Senate report published in November 2000 is titled *A Cautionary Tale: Fish Don't Lay Tomatoes*. The preface to the Senate report states:

> One major area of concern was the gene crossover, sometimes described as transgenic, from one species to another. There was much less concern about wheat genes being used in wheat than bacterial genes being used in wheat, for example .… While there may be genetic exchange between species occurring in nature, genes from fish do not get into tomatoes under normal circumstances (Parliament of Australia 2000, page xii)

The variety of ethical concerns about trans-species gene transfer is also seen in *Reflections on the Use of Human Genes in Other Organisms: Ethical, Spiritual and Cultural Dimensions*. This report comprises 15 papers covering a variety of views, including religious, Maori, scientific, community, agricultural, medical and business views. The benefits of trans-species gene transfer to health and the community are recognised; however, at the same time there is a desire to keep important community values connected to science, and it is recognised that innovations aimed at benefiting the community must be weighed with ethical, spiritual and cultural issues (Forman 2004).

Threats to the integrity of organisms

In the report, most authors are concerned that trans-species manipulation has the potential to threaten deeply held values. For some community groups, transgenic manipulation is a threat to the integrity of the organisms involved, because it 'blurs the necessary distinctions' of organisms (Moxon 2004). Some groups have a religious basis for maintaining the distinction between species (Jarvis et al 2004). For other groups, the most problematic issue is respect for the uniqueness of people when they are involved in trans-species gene transfer. They argue that 'the transfer of genes that cause phenotypic (observable) changes so that the organism shows human characteristics is completely unacceptable to many people and is against Christian and Maori spirituality' (Jarvis et al 2004). This concern does not always apply to every possible situation. One paper argues that many aspects of gene manipulation involving people are positive and to be celebrated, and that it is only the manipulation of some genes — master regulatory genes — that should be treated with great caution. Only some manipulations are 'outside the limits of what is acceptable' (The Nathaniel Centre 2004).

Threats to the intrinsic value of the natural world

Other groups identified in the report are concerned about the intrinsic value of the natural world and what is seen as the 'growing contempt of nature … using creatures simply as tools' (Moxon 2004). Some people suggest that the value of organisms should be judged by their closeness to people, and whether there is 'a right not to be genetically engineered' for 'the species with which we have close genetic and social relationships' (Wills 2004).

Threats to cultural and social identity

For other groups, the appropriateness of trans-species gene transfer must be related to indigenous knowledge (matauranga Maori) concerning the relationships between people and other forms of life (Durie 2004). At this point, the rights of people become involved. Other groups are also concerned about human rights but in a different way. Some argue that people have a right not to have to eat food that has been genetically modified with genes from another species. This may occur in situations in which a certain proportion of food can be genetically modified without notification being required on the packaging (Carapiet 2004).

Threats to specific communities

The rights and values of specific communities are also a concern. Cultural, religious and ethical views should be included when considering trans-species gene transfer, and an exclusively scientific assessment of the risks, benefits and ethics associated with gene transfer should be avoided (Moxon 2004). The Royal Society of New Zealand notes that its code of ethics says that members 'have a duty to respect the values of communities which may be affected by their work' (Gunn and Tudhope 2004, p 31). Maori contributions suggest that transgenic manipulation could constitute a risk to indigenous culture because of indigenous beliefs about the natural world (Durie 2004). In addition, the methodologies usually associated with decision-making processes concerning gene transfer are based on scientific analysis and do not allow other factors, such as cultural and religious beliefs, to be included (Durie 2004).

Consequently, this working paper deals with the potential benefits and dangers associated with trans-species gene transfer in both social and environmental contexts. It also deals with questions related to the appropriate decision-making processes for this, such as how utilitarian arguments should be weighted and the differences in the approaches of environmental ethics and bioethics.

Key point

The general public has various ethical concerns about trans-species gene transfer, including:

- threats to the integrity of organisms;
- threats to the intrinsic value of the natural world;
- threats to cultural and social identity; and
- threats to specific communities.

3.3 Potential concerns relating to trans-species gene transfer

Qualitative research on attitudes to gene technology shows that public concerns relate not only to the physical risk and health matters associated with gene technology, but also exist at an existential level concerning ontology (the nature of things), including the meaning of human nature and the presence of some fundamental order in the natural world. The argument has been expressed in the following way:

- People often have a sense of given order that is radically challenged by the possibilities inherent in gene technology and, especially, by the novelty of trans-kingdom gene transfer.
- Despite this, there is also a feeling that, in certain circumstances, some artificial modifications to genes may be justified, provided the purposes are the right ones.
- There is also a fair degree of cynicism and fatalism that such conditions are unlikely to be met and that more dramatic and less justifiable genetic changes will occur (Deane-Drummond et al 2002).

The general public is most concerned about the animal–human boundary. Historically, anxiety about maintaining the animal–human boundary was a major source of opposition to Darwin's theory of evolution. The same anxiety was evident in the 1890s in the debate over cowpox vaccination, when Edward Jenner's discovery was opposed because it introduced something from a cow into people — despite its potential to save millions of lives. Similarly, there is currently some opposition to xenotransplantation (transplanting a foreign tissue into another species), as well as to patenting life forms. Section 3.4 provides more information about this issue by examining whether different kingdoms are assigned different ethical values.

Overall, some of the issues in trans-species gene transfer may be the concern of the Gene Technology Community Consultative Committee, because concerns about animal–human boundaries extend beyond the scientific community into the wider community. GTEC's role may be seen as clarifying the ethical validity (or otherwise) of these concerns, as well as expressing its own view on them.

3.4 The connection between science and ethics

Scientific and ethical views are strongly connected; however, at times it may be preferable to work with social, cultural, ethical, philosophical and religious categories as well as scientific ones. Some scientists may find this difficult, but it reflects the social context more adequately.

3.4.1 Levels of viewing organisms

One reason for the different approaches (scientific versus cultural or religious) is that the way in which organisms are viewed can affect how they are understood. Acceptance or rejection of the scientific assessment of trans-species gene transfer may depend on whether an organism is viewed from a molecular or an organism level. Woese (2004) distinguished the two different meanings of reductionism as used by biologists. There is methodological reductionism and fundamental (conceptual) reductionism. Significant problems arise in any discipline when conceptual reductionism dominates the thinking because the object of investigation is removed from the context in which it has meaning.

Molecular level

At the molecular level, there can be a tendency to operate in a conceptually reductionist way, with equal value for all. For example, DNA is DNA irrespective of its origin, and its origin makes no difference as long as it does what is required. At the molecular level, the genes we possess are not marked 'human gene' in any way. Consequently, the assumption is that there are really no such things as human genes, only genes that are found in humans. However, to say that a gene is just another sequence of nucleotides can be conceptually reductionist, if it does not consider the role of the gene in a wider context, which includes social and cultural issues as well as scientific ones.

Scientists operating at the molecular level (the most fundamental scientific level) can be led into an ethically reductionist perspective. For example, take the following statement:

> … in fact, species now appear to be messy, plastic and mutable. To proscribe the crossing of species borders on the grounds that it is unnatural seems scientifically indefensible (Comstock 2000).[3]

In this kind of statement, ethical conclusions are made by referring to scientific arguments. That there is a connection between ethics and science is not questioned (except by a few), because many would argue that ethics should determine what is done in science.

Organism level

At the level of complete and complex organisms (eg plants, animals and people), the tendency is to operate in a holistic and hierarchical way, using definite boundaries and recognising the significance of higher-level functions. Genes are components in a hierarchical biological system, in which they perform very important functions that have social, moral, political, religious and economic implications. In isolation, genes are simply complex chemicals; however, when operating in the context of a living cell (and perhaps as part of a complex entity such as a person), the genetic code takes on a different significance that cannot be understood by reducing it to a sequence of chemicals. Neither individual organisms nor humanity can be reduced to a definition that only involves a description of structural DNA, because this does not capture the essence of the organism.

The fact that it is impossible to draw a scientific boundary to define species does not mean that a boundary cannot be drawn in another way. In fact, the general public does so consistently and has largely declined to accept the argument that the treatment of animals and human neonates is inconsistent and 'species-ist' on the basis that the species cannot be unambiguously differentiated using a scientific viewpoint. However, the public must consider whether technical, scientific categories should be the only categories used for defining species. In addition, although science has uncovered some limitations with the concept of species at the genetic level, this does not necessarily mean that defining species using cultural categories is no longer important (Nicholas 2000).

Key point

Science and ethics are connected, and both views can contribute valid criteria to determine what is ethically acceptable in trans-species gene transfer. Effort is required to establish an understanding between the different views before trans-species gene transfer can be discussed effectively.

3.5 Relative ethical values of kingdoms

If kingdoms can be scientifically defined, the question can be asked whether some kingdoms have higher ethical value than others. Attributing relative ethical value to different kingdoms may affect whether or not gene transfer is used.

At certain levels, the distinctions between kingdoms are clear and generally accepted. For example, in ethics, science and law, clear distinctions of treatment are made between bacteria, pineapples, and humans, with increasing value attributed to them respectively. However, these distinctions are grounded more in social, cultural and religious factors than in scientific ones. This is apparent in the fact that the term 'kingdom' does not distinguish between people and great apes in a scientific context, yet they are treated differently in law. Inconsistencies between cultural and scientific

[3] See http://www.agbioworld.org/biotech-info/religion/nzbrief.html

classification systems may well result from mixing different scales of resolution. These inconsistencies will be eliminated by the use of classifications at the appropriate level of resolution, for example, at the level of genus to distinguish between great apes and humans.

Key point

A system of cultural classification exists in which there is scientific distinction at the genus level, but not at the kingdom level.

Classification systems are human constructs imposed on nature to help us to understand it. Scientific classification systems are usually designed to show degrees of evolutionary relatedness. Thus, when considering ethical issues associated with gene transfer, it is important to choose the most appropriate classification system. Gene transfers between more distantly related organisms may indicate a greater ethical problem than transfer between closely related organisms, and, therefore, the transfer of genes between kingdoms may produce different ethical issues from the transfer of genes within kingdoms. However, when using a non-specialist definition of kingdom that places, for example, pigs and people in different kingdoms, the resulting ethical issues would encompass what scientists would call within-kingdom gene transfers. Therefore, ethical issues arising from trans-kingdom gene transfer for the general public may encompass both between-kingdom and within-kingdom gene transfers. Thus, it is essential in this debate to state explicitly which taxonomic classification system is being used to identify trans-kingdom gene transfer. Once the classification system is identified, the following questions may be considered:

- Do the various kingdoms have different ethical values?
- Does the fact that organisms can be put in taxonomic kingdoms mean that these organisms can and should be compared or treated as equal in value?
- Are there, for example, fewer concerns about trans-kingdom gene transfer between bacteria and protozoa than between plants and animals? And if so, why?
- Is crossing boundaries at a ‘higher’ level more problematic than at ‘lower’ levels?
- What are the implications of abandoning the concept of kingdoms?

Whether different kingdoms have different ethical values depends on the ethical position adopted. If, for example, humans are considered to be the only organisms that have intrinsic value, then the animal kingdom, of which humans are part, may have greater ethical value than other kingdoms. With an anthropocentric (human-centred) approach, the ethical value of a kingdom would depend on how useful it was to humans. Kingdoms such as Bacteria, Fungi, Plantae and Animalia could then be assigned ethical value either because they are important for humans’ survival or because they have an intrinsic, though lesser, value of their own. For example, Bacteria and Fungi are important because of their roles in decomposition and making nutrients available for the growth of plants and animals. Plants and animals are important as food sources for humans, and both algae and plants replenish atmospheric oxygen, which many organisms (including humans) need to live. If all organisms are considered to have an intrinsic value, and these intrinsic values differ, then it would be possible to distinguish kingdoms using ethical values.

There may be fewer concerns about gene transfer between the kingdoms of Eubacteria and Protozoa than between Plantae and Animalia because the impact on an ecosystem caused by genetic changes to microorganisms (eg bacteria and protozoans) is less observable than genetic changes to macroorganisms (eg plants and animals). However, humans may need to be very concerned about genetic changes to microorganisms because of their importance in ecological processes that create, maintain and destroy ecosystem structure and function.

Differences in the amount of similarity of DNA between organisms that exchange genes do not change the ethical issues raised; however, these differences do change the focus on the ethical issues. For example, gene transfers between different kingdoms and species raise the same four ethical issues:

- the integrity and the intrinsic value of the organisms involved;
- the concept of natural order and the integrity of species;
- the integrity of the ecosystems in which the genetically modified organism occurs; and
- the different ethical values to be attributed to different species and kingdoms, especially as this affects specific people.

However, gene transfer between kingdoms poses a greater threat to these four listed ethical values than does gene transfer between species, because trans-kingdom gene transfer is more likely to introduce a novel gene that increases the likelihood of an unexpected outcome, which is, in turn, more likely to change the organism's chances of survival and reproduction. This is based on predictions of the dynamic genome model and the idea that the amount of similarity in DNA decreases as the evolutionary distance between species increases (see Section 2.3). If the organism's chances of survival and reproduction are increased, it may negatively affect other species by disrupting population dynamics, community structure and ecosystem function. Using the same argument, gene transfers between species that are more distantly related impinge on the ethical value of respect for life.

Abandoning the concept of kingdoms

One implication of abandoning the concept of kingdoms is the loss of a short-hand means of indicating the extent of DNA similarity between species, and therefore losing a useful classification system that provides indications of the ethical issues that arise from trans-species gene transfers. The degree of threat to ethical values depends on the degree of similarity in functional DNA between the species involved in the gene transfer.

3.6 Arguments associated with horizontal and trans-kingdom gene transfer

There is a tendency for public ethical debate to be primarily consequentialist in focus (that is, the ethical value of an action is judged solely on the action's outcomes). However, in the case of gene transfer between kingdoms, the real arguments deal with intrinsic (naturalist) issues, as well as extrinsic (consequentialist) issues. This is evident in the way that some people refer to the 'nature of things' as an argument for caution (or even prohibition) in trans-kingdom gene transfer. The argument is that there is a natural order with species and kingdom differences that should be respected.

However, those advocating trans-kingdom gene transfer also make use of naturalistic arguments, arguing that horizontal gene transfer exists naturally and is a justification for artificial trans-kingdom gene transfer. For example, many human genes are thought to be the result of horizontal gene transfer from bacteria, although this is disputed — some scientists argue that the putative horizontal gene transfer genes are present in more ancient eukaryotes (nucleated cells) and have transferred to humans through vertical gene transfer. The reasons supporting the latter position have already been put forward in Section 2.4.

3.6.1 Arguments for trans-kingdom gene transfer

Perhaps it is necessary to recognise that genomes are designed to balance horizontal gene transfer and the stability of the species. Speciation into groups of organisms that are not crossfertile would allow them to exploit different ecological niches across generations with only minimal random DNA mutations. Horizontal gene transfer, however, would make it easier for one species to incorporate 'working' DNA from another species. This process might be more effective for the species than relying on random mutations for evolution, making horizontal gene transfer a beneficial design feature, rather than just an accidental phenomenon (Livingstone 2002).[4] However, recognising the benefits of relatively rare acts of horizontal gene transfer may not justify artificially induced, large-scale trans-kingdom gene transfer.

3.6.2 Arguments against trans-kingdom gene transfer

The use of horizontal gene transfer as a 'naturalist' argument supporting trans-kingdom gene transfer, to the point that it becomes difficult to regard various divisions of organisms as separate, is countered by the following factors:

- Anyone who uses a naturalistic argument to justify artificial trans-kingdom gene transfer should, logically, pay even more attention to corresponding naturalistic arguments concerning the natural order of things that are used in an attempt to restrict trans-kingdom gene transfer.

- If horizontal gene transfer is used as an argument for artificial trans-kingdom gene transfer, certain factors limit its value as a precedent. The increasingly complex organisation of genome function of modern day prokaryotic and eukaryotic organisms is a major factor in decreasing the frequency of HGT. For example, the gene-transferring action of agrobacteria demonstrates how rarely trans-kingdom gene transfer occurs. When trans-kingdom gene transfer does occur, it shows that the overall level of DNA movement between kingdoms is miniscule compared with the potentially large number of transfers that could take place through artificial trans-kingdom gene transfer. It is unknown whether this will change the rate and direction of evolution, or whether it is ethical to do so.

Associated with the argument against trans-kingdom gene transfer is the fact that, if evolutionary mutations demonstrate anything, it is the incredible slowness of genetic changes — comparatively tiny changes spread over significantly long periods of time. This is quite different from the effects of gene technology, especially in terms of the timeframe involved.

Finally, the argument that horizontal gene transfer is a precedent for artificial trans-kingdom gene transfer, and the argument that the existence of species is a reason to prohibit trans-kingdom gene transfer, are examples of a naturalistic fallacy — in which something that exists in the natural world is seen as ethically desirable.

Despite these arguments, substantial interspecies mingling would create difficult ethical issues for many people. Therefore, it is appropriate to address the nature of order in the natural world and the public concerns that arise from the use of gene technology. These concerns appear to threaten the natural order and humanity's place in it.

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[4] See http://www.agbioworld.org/newsletter_wm/index.php?caseid=archive&newsid=1056

Key point

Horizontal gene transfer is considered the most important mechanism for the evolution of new traits in bacteria. However, its use as a precedent for trans-kingdom gene transfer is limited, because it is a relatively rare and slow process in which only small amounts of DNA move between kingdoms.

3.7 Arguments for and against gene technology

When considering gene technology and its associated ethical concerns, the more general question of 'How natural is gene technology?' must be addressed.

On one hand, gene technology can be viewed as completely artificial. The religious version of this argument often includes reference to the proposition that humans should not be 'playing God'. On the other hand, this argument can be dismissed by reference to many other things that were once considered unnatural, such as surgery and vaccinations. The Judeo-Christian view states that humanity is actually required to fulfil the will of God, which is for the best that can be done in the world. However, even this argument does not completely counter the more fundamental issues of the apparent order of the world and the existential convictions that people hold. Many people consider that altering an individual's genetic structure or changing the boundaries of the natural order is a great responsibility that should not be undertaken lightly.

The distinction between natural and unnatural is also accounted for in moral terms. That is, an act (such as killing an innocent human being) may be unnatural because it is contrary to the natural moral law and is therefore something that human beings should not do, rather than something that human beings do not do. On this account, natural and unnatural acts are not necessarily those in which one acts to overcome restrictions in the laws of nature (eg flying in an aeroplane, with which the laws of nature are used to overcome an otherwise natural restriction), but acts that are unnatural in a moral sense.

Key point

Trans-species gene transfer should not be rejected purely on the grounds of it being unnatural. Humans engage in other activities (such as flying or scuba diving) that are unnatural but ethically acceptable.

3.8 Approaches to assessing gene technology

This section outlines the potential risks and benefits of gene technology. The different ethical arguments that can be used to assess these risks and benefits are introduced, as well as the problems that arise when proponents of these arguments fail to understand alternative views on gene technology.

Despite the public's general concerns about gene technology, some potential benefits have been viewed positively. Obvious examples include the benefit to agriculture through crops that have been immunised against pests or herbicides, enhanced for increased growth, or both. Transgenic animals, such as pigs, are being used to developed organs less likely to be rejected in xenotransplantation, and research continues on animals used for human benefit, particularly in the development and testing of new pharmaceuticals. For some people, the potential benefits of gene technology provide an unassailable ethical argument for its development. These people argue that there is a moral duty to use the technology to feed the expanding world population and develop new medicines.

Even people who argue that a purely utilitarian approach to trans-species gene transfer is inadequate may recognise the overall benefits of genetic manipulation and, in this specific context, the benefits of trans-species gene transfer in particular. However, any utilitarian evaluation of the issues should also take into account any negative consequences of gene technology.

3.8.1 Ethical approaches

Despite these qualifications, public debate on gene technology, as well as on many other ethical issues, has frequently reduced ethical debate to a discussion of consequences, where the action that produces the greatest overall benefit is the action that should be taken. This purely utilitarian ethics approach is concerning because there are other valid approaches that can be used.

In classical ethical terms, there are four common approaches, but rarely are all used in public debate.

Utilitarian ethics

In utilitarian or consequentialist ethics, the focus is on the consequences of the act. There are various forms of utilitarian ethics (eg act and rule, individual and corporate) but they all define the appropriateness of an action by weighing up the positive and negative consequences of all possible actions. The action that has the greatest overall benefit is the course of action that should be taken.

However, a consequentialist approach may include one or more of the following:

- overly individualistic (eg there is benefit for me or my family and therefore it should happen), rather than community-oriented (taking into account benefits and disadvantages that accrue to society as a whole)
- too focused on the short-term rather than taking into account the more imponderable long-term consequences
- too sensitive to economic factors (eg gene technology must be used if business is at stake).

Deontological ethics

In deontological ethics, the focus is on the nature of the act. The appropriateness of a course of action is determined by reference to a standard involving specific rules or principles. Deontological ethics involves the conviction that people have a responsibility to act correctly, irrespective of the consequences.

Virtue ethics

In virtue ethics, the focus is on the character of the person involved and whether they have inculcated appropriate virtues, such as compassion and love, which would provide built-in ethical guidance.

Natural law ethics

In traditional natural law ethics, appeal is first made to basic human values that are recognised as goods for which human beings can choose to act, if they wish to flourish as people. These human values are basic in the sense of being self-evident to human beings, and may be referred to as pre-moral goods because they exist before moral decisions are made on whether or not we will participate in them. One of these pre-moral goods is reason. By using reason, we can identify the principles of practicable reasonableness that, if we obey them, allow us to participate in the other goods in a rational matter. Natural law can thus be related to basic human goods (such as life, aesthetics, friendship and so on), reason, choice, act, consequences and character.

Key point

Ethical approaches to trans-species gene transfer may be based on utilitarian, deontological, virtue, or natural law approaches.

3.8.2 Use of ethical approaches

In public ethical debate, deontological ethics suffer because there is no common acceptance of the authority possessed by the governing source. Although virtue ethics significantly influence decision making, they have a less formal and measurable role, because virtues cannot be enforced by law and are not easily calculated. In contrast, utilitarian ethics appear to be reasonable, measurable and objective, and therefore dominate public debate. Utilitarian ethics can, however, be considered subjective, because one person's preferred consequence may be someone else's problem. In some accounts of utilitarianism, every preference is equal, but in other versions that is not so. Utilitarians and deontologists sometimes fail to understand the value of the other's argument.

Some people argue that ethical problems emerge when utilitarian arguments are allowed to operate in a totally independent or uncontrolled manner. In the context of the present debate on gene transfer, a utilitarian argument based on the consequences of trans-species gene transfer should be related to the more deontologically oriented responsibility felt by some people that it is inherently wrong to cross boundaries established in the natural world.

One expression of these different approaches may be found in the way that trans-species gene transfer combines environmental ethics with bioethics. Through the focus of DNA, gene technology combines a number of previously separated issues. The *Gene Technology Act 2000* refers to 'the environment' to describe what might be affected by genetic modification in addition to humans and other animals. Some would suggest that this falsely separates humanity and nature by treating the natural world as the environment in which humans live. Ecological ethics tries to be more holistic in focus, integrating human interests with those of the natural world. Both environmental and ecological ethics attribute significant value to the natural world, but in different ways. In common usage, the terms 'ecological' and 'environmental' are not used consistently or even differentiated. Environmental ethics (emerging out of broad environmental concerns) is more likely to focus on deontology, rely on the significance of an understanding of nature and have significant concerns about the commodification, subjugation or objectification of nature. This approach is more likely to be critical of any approach that focuses narrowly on benefits to individuals or corporations that occur at the expense of nature.

The importance of developing an environmental or ecological approach to bioethics should not be underestimated. It should not be assumed that a medical model (stressing, for example, individual autonomy) is the best or most appropriate approach. It may be that the term 'bioethics' itself is too heavily identified with medical procedures to be helpful in the current discussion. Further consideration should be given to the broad and significant issues raised by environmental–ecological ethics. Environmental ethics treat humans as one of many species and yet still recognise the uniqueness of humans.

Key point

Proponents of the different ethical arguments about gene transfer often fail to understand the value of alternative arguments. This problem must be overcome before the ethical issues can be effectively debated.

3.9 Summary

There is a connection between scientific and ethical determinations. Species from different kingdoms are less likely to transfer genes to one another than are species from the same kingdom. Thus, trans-kingdom gene transfer does not raise new ethical issues in addition to those already raised by trans-species gene transfer. However, trans-kingdom gene transfer does change the emphasis placed on the ethical issues raised by gene technology. In addition, the cultural importance of a concept may be independent of its scientific importance. Therefore, the scientific debate about the appropriateness of taxonomic definitions, such as species and kingdoms, may not be relevant to public concerns about trans-species gene transfer. What is certain is that gene transfers across the human–nonhuman boundary are of greatest public concern, and defining gene technology as natural or unnatural does not necessarily make its use ethically desirable. The values and principles established in the National Framework, such as the values of respect for organisms and species as well as for human life and the environment provide some guidance for making ethical determinations about trans-species gene transfer, but a number of ethical approaches can still be used, each based on a different premise. In the current public debate, the utilitarian approach tends to dominate because of its apparent reasonableness, measurability and objectivity. Despite this, it is desirable to develop an ecological ethics model in preference to the currently used medical one.

4 Resolution of issues and concerns

This section addresses the public and social roles of science and technology, and predicts the course of the trans-species gene transfer debate. Existing regulatory structures for decision-making in gene technology are also explained.

4.1 Public and social roles of science and technology

Within gene technology, there is a broader question of the public and social role of science and technology, as well as the public role of scientists and technicians.

On one hand, if scientific categories and concerns dominate public debate, then, inevitably, the scientific ‘experts’ reign. The responses of those who have less knowledge may very easily be seen as emotional and subjective, using personal and inappropriate foundations for controls on trans-species gene transfer.

On the other hand, there is increasing public scepticism about scientific claims. In particular, as indicated in Section 3.1, there is evidence of significant public concern about trans-species gene transfer, leading to a gap between the focused, single-issue, scientific assessment and the public’s generalised, holistic concerns about gene technology.

4.2 Predicting the course of the trans-species gene transfer debate

The following sections outline a potential course of the trans-species gene transfer debate.

4.2.1 The argument for trans-species gene transfer

The argument for trans-species gene transfer will undoubtedly be primarily utilitarian. A significant number of people, most likely including scientists and medical practitioners, will support a purely utilitarian argument that weighs up the benefits of trans-species gene transfer (for example, in terms of advantages to crops or efficiency of production) and balances this against the short-term dangers inherent in any new technology. Some people may also weigh up the long-term dangers. The naturalistic argument, using horizontal gene transfer as a justification for trans-species gene transfer, may be used as a secondary argument.

4.2.2 The argument against trans-species gene transfer

The argument against trans-species gene transfer will involve a coalition of the minority of utilitarians (including conservationists) who think that the dangers of the technology outweigh the benefits, as well as people from various other approaches (such as religious approaches). These approaches either suggest that there is something intrinsically wrong with crossing traditional or natural boundaries, or that the whole process is species-ist and anthropocentric, to the detriment of other species that are in danger of becoming another resource for human benefit. People arguing from a religious point of view are more likely to be concerned about the identification of boundaries between species and how these boundaries relate to humans, as well as wanting to preserve the integrity of the human person.

Key point

Many of the issues associated with trans-species gene transfer are not solely scientific and technical, but also ethical, medical, legal, social and cultural. If the scientific argument dominates the public debate, the input of those who are not scientific experts may be seen as subjective and personal. A coordinated approach is required so that the various arguments can be considered on their respective merits.

4.3 Existing regulatory structures

In medical research, there is a well-developed system with responsibility for addressing ethical debates that arise and for issuing advice.

The Australian Health Ethics Committee (AHEC) is established as a multidisciplinary committee under the *National Health and Medical Research Council Act 1992* with power to develop and issue guidelines for the ethical conduct of research involving humans. The minister for health has conferred further functions on AHEC in relation to monitoring institutional ethics committees, promoting public debate and issuing health ethics guidelines. The *National Statement on Ethical Conduct in Research involving Humans* (the National Statement) was developed by AHEC following the required two stages of public consultation and then endorsed by all universities, national funding agencies and research institutions. Special sections of the National Statement deal with human genetic research. The National Statement was intended to cover situations in which plant or animal genes are used in research involving humans.

In Australia, there is a new system with responsibility for giving ethical advice in relation to genetic modification involving plants and animals. The *Gene Technology Act 2000* established the Gene Technology Ethics Committee (GTEC) and the Gene Technology Community Consultative Committee (GTCCC). GTEC can be requested to develop guidelines and determinations embodying its advice, and GTCCC can conduct public consultation on specific issues.

One of the intentions of the *National Health and Medical Research Council Act 1992* and the *Gene Technology Act 2000* was that AHEC, GTEC and GTCCC would facilitate the involvement of the general public. The acts recognise that many of the issues in gene modification or transfer involve considerations that are not solely scientific and technical, but also ethical, legal, social and cultural.

These issues are the responsibility of GTEC and GTCCC. Although this paper focuses specifically on trans-species gene transfer (as opposed to gene technology more generally), artificial transfer of genes between species crosses new ethical boundaries and therefore challenges people's sense of existential order.

4.4 Summary

A purely utilitarian approach to trans-species gene transfer may result in use of the technology, because a majority of people tend to be either optimistic (and assume that the dangers can be handled) or fatalistic (and assume that the dangers cannot be avoided). The most significant danger associated with the different cases for and against trans-species gene transfer is that arguments will be presented in such a way that they do not relate to each other. A satisfactory resolution will only be achieved when the different arguments on both sides of the trans-species gene transfer debate are all addressed.

In summary, scientific reductionism is a poor basis for ethical decision making. The whole organism and its context should be considered. Similarly, a gene cannot be realistically separated from the context in which it functions. There is a problem of incommensurability of arguments when different approaches are used. A coordinated approach to decision making is required so that the various arguments can be considered on their respective merits.

5 Conclusions

This working paper has been prepared as a result of significant public ethical concerns about the movement of genes between species, including the transfer of genes between kingdoms. These concerns are in addition to the public's general concerns about gene technology.

The ethical values particularly in contention when trans-species transfer is considered include:

- the integrity and the intrinsic value of the organisms involved;
- the concept of natural order and the integrity of species;
- the integrity of the ecosystems in which the GMO occurs; and
- the different ethical values to be attributed to different species and kingdoms, especially because this affects individual people and perceptions of human nature.

These relate to all of the National Framework's values and principles, but particularly to the values of respect for human life; animals; and the environment, including organisms, species and natural ecosystems, and the Principles of -

- taking responsibility for ensuring that activities do not cause damage to the environment;
- conducting research in a manner that includes the protection of genetic diversity, organisms, species, natural ecosystems, and natural and physical resources;

- minimising the risks of harm or discomfort to humans and animals;
- assessing and respecting the environmental and health needs of present and future generations; and
- acting justly towards others, and demonstrating respect to human beings (as individuals and group members).

Distinctions of species based on cultural, social and religious conviction are as important as scientific distinctions in any discussion of the ethics of trans-species gene transfer.

The degree of similarity in genome organisation affects the expression of DNA and the amount of gene flow between species is an important point, when considering the ethical issues raised by trans-species gene transfer. Therefore, a classification system that reflects genomic organisation is a useful model for the concept of shared DNA and gene flow between taxa. A scientific classification system based on both morphological and genetic similarities may provide the best model of phylogenetic relationships and therefore could be used a general rule of thumb to indicate levels of similarity in both DNA and its expression. However, at present, even the best classification system available provides only a general indication of the degree of uncertainty associated with trans-species gene transfer.

The ethical issues raised by trans-species gene transfers are the same irrespective of the extent of the similarity in DNA between the species concerned, although the degree of concern may reflect the degree of similarity. In addition, the risks are increased as the degree of similarity decreases, because of the greater number of unexpected outcomes.

As a result, this working paper affirms the need for an ongoing discussion of the ethical concerns regarding trans-species gene transfer. However, it is necessary for people to use commensurate arguments, otherwise they will continue to talk past one another and conflicts associated with ethical issues will remain unresolved. If issues can be resolved, there is a potential for them to become a part of the regulatory framework.

There is an overlapping jurisdiction between GTEC and medical agencies, such as the National Health and Medical Research Council, and this requires further consultation and exploration of a cooperative approach between various committees to prevent unnecessary duplication. GTEC has statutory responsibility for many of the matters referred to in this working paper; however, many other bodies also have interests and expertise in these areas. As part of the ongoing process of formulating a position, it would be helpful to identify those bodies that have an interest in trans-species gene transfer in order to encourage a common approach.

Ethical issues should continue to be a part of the general, public discussion about gene technology and would benefit from further consideration by GTEC and the other advisory committees (the Gene Technology Technical Advisory Committee and the Gene Technology Community Consultative Committee).

Summary of conclusions

- The general public has a variety of ethical concerns about trans-species gene transfer, including:
  - threats to the integrity of organisms;
  - threats to the intrinsic value of the natural world;
  - threats to cultural and social identity; and
  - threats to specific communities.

- The general public's definition of species may be related to but not the same as the scientific definition.
- Science and ethics are connected, and distinctions between organisms based on cultural, social and religious convictions are as valid as scientific distinctions. Both views can contribute valid criteria to determine what is ethically acceptable in trans-species gene transfer.
- The general public's concerns about trans-species gene transfer may not always align with the taxonomic levels of separation between species; however, it is important to consider these different ways of understanding organisms when engaging in debate about the ethics of trans-species gene transfer.
- Many of the issues associated with trans-species gene transfer are not solely scientific and technical, but also ethical, medical, legal, social and cultural. If the scientific argument dominates the public debate, the input of those who are not scientific experts may be seen as subjective and personal. A coordinated approach is required so that the various arguments can be considered on their respective merits.
- Proponents of the different ethical arguments about gene transfer often fail to understand the value of alternative arguments. This problem must be overcome before the ethical issues can be effectively debated.

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