Science & Society

What makes genetically modified organisms so distasteful?

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The debate concerning genetically modified organisms goes on unabated and reflects some genuine concerns. I suggest that a significantly large number of educated people believe that moving genes around between species is intuitively wrong and that this is based on an essentialist view of the world. This essentialist view has a long history that dates back to Plato and Aristotle and was eventually overthrown by the population thinking of Charles Darwin. The essentialist, who is antipathetic to population thinking, will naturally find the transfer of a gene from one organism to another distasteful, and this, I argue, is the result of Platonic thinking, which still remains and casts its spell over us today.

The debate over genetically modified organisms (GMOs) continues and with the destruction of experimental field trials it is now becoming reminiscent of the LUDDITE MOVEMENT (see Glossary) of the 19th century. Many of those involved are salaried middle class professionals[1] and their views appear to reflect a concern for which there is a large sympathy amongst the general public. The arguments for and against GMOs lead to confusion rather than enlightenment and in this article I will try to present what I believe to be a major reason for the reaction against them and that has not yet, I believe, been considered.

Several issues concern the public: (1) the safety issue, human and environmental, and whether or not GMOs are safe in the immediate and long term time-frames; (2) a political issue centring on who will own the technology, how it will be applied, and who will benefit from it; (3) scientific and technical issues associated with transferring genes between one host and another. There is also another issue, antithetical to GMOs and perhaps even science, recently described by Prince Charles in his Reith Lecture as the 'wisdom of the heart' and the need to acknowledge the sacred trust between mankind and our creator[2], which can be broadly thought of as religious. Several reports about public attitudes towards GMOs echo Prince Charles and draw attention to the fact that ethical concerns are widespread (Ref. 3; and the Agriculture and Environment Biology Commission's report entitled 'Development Group on Public Attitudes and Consumer Choice' (2001) at http://www.aebc.gov.uk/aebc/seminarnotes_1601.pdf). Why do some people have such fixed and emotional ideas about GMOs that make them so distasteful? It is this question on which I will focus.

Since the beginnings of agriculture more than 10 000 years ago, humans have been modifying organisms. Agriculture interested Charles Darwin – indeed his argument for natural selection draws analogies from the artificial selection undertaken by farmers and animal breeders. However, he saw a problem when it came to the mechanism by which variation is generated and in a letter, to Dr Asa Grey, he admits, 'The laws governing the incipient or primordial variation I shall discuss under several heads, but I can come … only to very partial and imperfect conclusions'[4]. It was through the rediscovery of Mendel's genetics and its marriage to the origin of species by natural selection that the modern theory of evolution was born. Although the particulate nature of inheritance could be described mathematically, the biochemical or molecular nature of the gene was not understood until later.

The Second World War produced an immigration of scientists from Europe into the UK and the USA. When, the then physicist, Max Delbrück moved to the USA from Neil's Bohr's laboratory in Copenhagen the debate was still raging as to whether the laws of physics and chemistry were capable of explaining biological organisms. This was an old chestnut, and Bohr argued that VITALISM '… scarcely finds its proper expression in the old supposition that a peculiar vital force, quite unknown to physics, governs all organic life. …if we were able to push the analysis of the mechanism of living organisms as far as that of atomic phenomena, we should scarcely expect to find any features differing from those of inorganic matter'[5]. Erwin Schrödinger's book entitled *What is Life?*, speculated about the physical nature of the gene as an 'aperiodic solid'[6]. The book was inspirational to the generation of scientists, many of them trained in physics, who created the molecular revolution in biology. It can be seen as arrogance that they could simply reduce biology to physics but clearly that was a major motivation for the physicists that made the migration into biology.

James Watson had come to Britain as a postdoctoral from America having read Schrödinger's book, and this had motivated him '… towards finding out the secret of the gene'[7]. The drama that ensued was recorded by Watson himself in *The Double Helix*[8] and did not come to fruition without its problems and personality clashes. The book showed science not so much as a SOCRATIC SEARCH for truth, but as much more egotistical and self seeking; indeed there was controversy over certain passages in the manuscript and these were removed before publication was allowed[9]. The structure of DNA proposed by Watson and Crick is regarded as a watershed in molecular biology. The following 10 years and beyond saw the construction of a theoretical model that described the relationship between the information coded in the sequence of bases in DNA and how these build each protein.

Holistic idealism versus reductionist research

It is clear that the underlying search and motivation of these scientists was to address the debate around vitalism. François Jacob suggests the answer appears to be subtle: 'What is new in molecular biology is the recognition that the essential properties of living beings could be interpreted in terms of the structures of their macromolecules. This, ... partly contradicts the hope of the physical-chemical school at the beginning of the century. …. if the cell, … really did have at its disposal only direct chemical interactions, … then the overall tendency of the system would be to go to equilibrium. Now chemical equilibrium means death. ... What we now understand is quite the reverse: the cell is entirely a cybernetic feedback system. The regulation is entirely due to a certain kind of circuitry … But it is a chemical circuitry ... and yet it transcends chemistry[7]'.

Isn't this just giving lip service to the vitalist notion that things cannot be reduced to physics and chemistry? No, it is not, because that is not the way science works.

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It is the late philosopher Karl Popper's contention that all our knowledge is based on theories that are guesses, and these are then open to rational analysis: 'There is only one element of rationality in our attempts to know the world: it is the critical examination of our theories. These theories themselves are guesswork. We do not know, we only guess. If you ask me, "How do you know?" my reply would be, "I don't; I only propose a guess. If you are interested in my problem, I shall be most happy if you criticize my guess, and if you offer counterproposals, I in turn will try to criticise them"'[10].

Our theories are therefore mere best guesses that take account of all the relevant information available. Our scientific knowledge at any one moment is always hypothetical, to be tested by experiment and, at the time of undertaking each and every experiment, all judgement has to be suspended, the results must be allowed to speak for themselves and judgements made on the basis of crucial arguments. Scientific theories progress by subsuming more and more empirical evidence in the light of more and more crucial experiments in a manner in which if a given set of circumstances is known, the results become predictable. In terms of the technology surrounding GMOs, we have a theory based on molecular genetics, which today is an amalgamation of Darwin's theory of evolution with Mendel's particulate theory of inheritance subsumed within molecular biology.

What is coded in the chromosomes is a program to build the adult, the instructions of which build the molecular structures required at the correct time and in the correct place. The rapid development of molecular biology is because of the one-dimensional nature of the relationship between nucleic acids and proteins. However, as Jacob pictures the development of an adult from a single egg, '… the world is no longer merely linear. The one-dimensional sequence of bases in the genes determines in some way the production of two-dimensional tissues and organs that give the organism shape … How this occurs, however, is still a mystery'[11].

This might sound like a return to vitalism but it is not. It is merely saying that there is still a lot to know and understand about the development of an organism but the basis of that knowledge will not contradict or invalidate either the laws of physics and chemistry we know today or will know in the future. (Indeed, the roles played by families of *Homeobox* genes in the development of organisms[12,13] continues apace.) However, the claim that REDUCTIONISM is the only alternative to vitalism is also clearly not the case. There are aspects of cellular organization which, 'transcend chemistry' and, therefore, the difference between the living and the non-living does not consist of differences in what they are composed of but in the level of their organization. All life can be seen as an interacting hierarchy of different systems, from cells to complex communities and ecosystems.

I have shown that some of the motives that drove the research behind present day molecular biology were associated with a reaction against vitalism and to push the analysis of the mechanism of living organisms as far as that of atomic phenomena[14]. This approach has been highly successful and gave birth to molecular biology. However, it is clear that we cannot rely on naïve reductionism any more than we can rely on vitalism, and many biologists today are dissatisfied with a purely atomistic–reductionist research paradigm and call for a more HOLISTIC approach. If a non-critical approach is taken to holism this leads to a form of IDEALISM and as such has a long

Glossary

Luddite movement: The Industrial Revolution saw a massive change in working practices and people who had worked from homes in villages migrated to the towns to work in factories. Between 1811 and 1817 bands of weavers and artisans aggrieved at this mechanization rioted and destroyed machinery.
Vitalism: a doctrine that life contains some vital principle that is distinct from physical and other chemical forces. It has been claimed that reductionism (see below) is the only alternative to vitalism, however, although some anti-reductionists are vitalists there are anti-reductionists that reject vitalism.
Socratic search: Socrates (d. 399 BC) was one of a group of philosophers whose teaching comes down to us through the writings of Plato (d 347 BC). According to the oracle at Delphi, Socrates was the wisest man in Athens and this was because his wisdom was based on not knowing anything. Therefore his discussions all proceeded from a starting point of ignorance.
Reductionism: the principle of analysing complex interactions in terms of their isolated constituent parts. For example, it would be reductionist to suggest that living organisms are nothing other than physico-chemical systems (compare with vitalism and holistic).
Holistic: the principle that whole organisms are to be regarded as greater than the sum of their parts (compare with reductionism). When the term was first introduced by Smuts in 1926 he unfortunately combined it with various vitalistic ideas (see Ref. 26).
Idealism: the philosophical doctrine that ideas are mental constructs of the mind. Pushed to its extreme leads to the primacy of mind and that the self is all that exists.
Telos: the concept developed by Aristotle (d. 322 BC) of a final stage towards which all organisms are ultimately developing; it is the material manifestation of his idea of essence (see below).
Essences: are a limited number of fixed unchanging forms that could be applied to plants and animals based on Plato's concept of ideal forms (see below).
Neoplatonist: Neoplatonism is considered to be founded by Plotinus (*c.* 204–277 AD) taking his lead from his reading of Plato, Plotinus developed a complex spiritual cosmology, which became integrated into Christianity.
Typological thinking: the types are ideal forms that can exist independent of any objects and the variation that are perceived in these objects is owing to the imperfect manifestation of the underlying types or essences.
Ideal form or eidos: Plato's thinking was that as a student of Pythagoras (6th C. BC) a triangle always has the form of a triangle and this is discontinuous with any other polygon. Plato thought the variable world of phenomena was nothing more than a reflection of a limited number of fixed unchanging ideal forms or essences (see above) that are not perceived through the senses.
Two cultures debate: Charles P. Snow, in his book '*Two Cultures*', eloquently expressed concern about what he saw as a widening and worrisome gap of misunderstanding and mistrust between people involved in science and those in the arts and humanities.

Fig. 1. Aristotle, a student of Plato, believed that although each individual died and perished, its 'Ideal Form' was eternal and fixed as a species. (Detail of the fresco 'School of Athens' by Raphael (1483-1520), depicting Plato and Aristotle; Vatican Museums and Galleries, Vatican City, Italy/Bridgeman Art Library)

history dating all the way back to Plato and Aristotle (Fig. 1).

Influence of Plato and Aristotle

Plato became the major exponent of teachings, which included the mystery of numbers, the transmigration of souls and the substitution of experiential knowledge for reasoned *a priori* knowledge. This grew into a world of 'ideals' that were fixed, totally independent of experience, universal and eternal[15]. The material physical world of sense perception is to be regarded as nothing more than flickering shadows on the walls of the cave in which we are all imprisoned[16]. Aristotle was a student of Plato and the study of plants and animals, with their purposeful behaviour, was incisive in his development of the concept of 'TELOS' or final cause, and the idea of 'ESSENCE'. He says, 'Since it is impossible that creatures should be eternal, these things which are generated are not eternal as individuals (though the essence is in the individual) but as species'[17]. According to Karl Popper, Aristotle and Plato both held to the view that, as humans, we possess a faculty of 'intellectual intuition' by which we can visualize essences and discriminate between them[18]. Aristotle's view of this 'essence' is that it is a metaphysical character by which a thing is itself and no other. It is therefore fixed typologically and for eternity. These ideas were taken up by Plotinus and incorporated into Christian dogma, which then, via St Augustine and St Thomas Aquinas, have exerted their influence down until the present day. Today's 'New Age' movement, can be traced back to the artist and poet William Blake and his NEOPLATONIST views, for example 'Whatever can be Created can be Annihilated: Forms cannot: The Oak is cut down by the Ax, the Lamb Falls by the Knife, But their Forms Eternal Exist For-ever.'[19]

It has been argued by the population and evolutionary biologist Ernst Mayr that what has been called the Darwinian Revolution was brought about as a consequence of three elements. The first two, Darwin's overwhelming mass of evidence and the mechanism of the preservation of favoured races by natural selection, are generally well known, but Mayr proposes a third contribution and suggests that Darwin replaced TYPOLOGICAL THINKING by population thinking[20]. Darwin's population thinking stresses the uniqueness of everything in the organic world and the species (type) is a statistical abstraction as only unique individuals have a reality. Therefore, 'For the typologist, the type, Plato's IDEAL FORM or *eidos*, is real and the variation an illusion, while for the populationist, the type (average) is an abstraction and only variation is real. No two ways of looking at nature could be more different.'[20] The metaphysical view of the world in which plants and animals had fixed and unchangeable essences was to hold sway in establishment circles until 1859 and the publication of the 'Origin of Species'[21]. It is therefore not surprising that to a typological thinker the mere thought of taking a gene from one organism and placing it in another is totally abhorrent, it flies in the face of more than 2000 years of the teachings of Plato and Aristotle. We have come in fact to a form of the 'TWO CULTURES DEBATE'[22] and the inability for the empirical biologist, undertaking reductionist experiments, to converse with the holistic thinking of the essentialist. More recently, the split has been articulated by Gould[23] with respect to science and religion, when he proposed the term NOMA or Non-Overlapping Magisteria. A magistertium is a domain of learning within which meaningful discourse can take place and Gould argues that science and religion have no overlapping ground on which discussion can be built. This approach naturally leads to the impasse regarding decisions about the rights or wrongs of undertaking genetic engineering.

Natural versus unnatural

In the minds of many people who are critical of genetic engineering, is the intuition that

it is in some way not natural – they have a concept of species that genetic engineering violates. In this article, I do not want to enter a debate about the biological nature of species but in some fashion for many people the idea of 'species' is equated with the Plato's ideal form and it is this which is violated in the production of GMOs. (This is a huge topic and the literature immense as the concept of species changes depending on which group of organisms are being classified: as might be expected from the approach here involving population thinking the biologist has a fairly flexible notion, but those interested are referred to Section VII of The Nature of Species in Elliot Sober's Anthology of key papers[24].)

It is interesting that the use of mutagenesis by plant breeders has not met with any strong opposition. This technique is based on plants being exposed to mutagens, such as gamma radiation, which cause mutations in the genomes of the plants and give rise to new heritable characteristics. The new characters brought about by this technique can be selected and then integrated into new cultivars using standard plant-breeding techniques. Such approaches, I would claim, do not violate any species barriers and therefore are not of great public concern. On this note I would therefore suggest the thought described in Box 1.

At present, the technologies used for undertaking the type of research described in Box 1 are all relatively crude. When a gene is transferred, the actual location where it eventually resides in the recipient genome is a matter of chance and the selection of a particular transgene (i.e. an organism having had a gene incorporated into it by genetic engineering) is done purely on an empirical basis. However, in the next 10 to 15 years the genomes of all the major crops will have been sequenced and mapped and our understanding of the way genomes function will be much greater. The insertion of an immigrant gene will be much more precise (i.e. the gene will be placed in the genomic environment we choose) and the results and consequences of our manipulations more certain. To argue that one approach is acceptable and the other not is clearly untenable without being totally anti-technology in particular and perhaps anti-science in general.

A healthy future for biology can only be guaranteed if a balance can be struck between the reductionist and holistic approaches; in fact, the tension between them is creative and necessary for scientific progress to continue[25]. However, the essentialist who is antipathetic to population thinking, will find the production of GMOs distasteful and this, I have argued, is the result of Platonic thinking, which still remains and casts its spell over us today.

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Box 1. Thought experiment regarding gene transfer

Imagine removing a gene from one so called 'species' and using genetic engineering to place it back into the same 'species'. To most people this would not present a problem, the so called 'species barrier' has not been violated. The recipient host would have an extra copy of the gene somewhere in the genome (gene duplication is a common occurrence in nature). However, from a technical perspective, where the inserted gene eventually resides within the genomic environment is very important and could result in a range of different outcomes. One possibility is that it would be fatal, it would disrupt some vital component of the recipient's functioning, or cause some fatal mutation. Another scenario is that it would simply have no effect. Between these extremes, even for a gene extracted and being replaced into the same 'species', it could increase or decrease fitness depending on its spatial and temporal expression. Empirical testing would be the only way to see the eventual outcome. This same argument, I would claim, would hold true for the insertion of a gene from another species. It might be argued that this is just the old reductionist approach. But I would say that it isn't. Because the key to the successful transfer of the gene is my claim that the genomic environment into which the recipient gene placed is all-important. It is not where the gene comes from but where it ends up.

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