

GENETICS – a background paper

“Introduction

“Genetics is the study of variability caused by inherited characteristics. This paper will describe the history of the study of genetics, its science, and its applications in human beings, animals and plants. A note of warning before we start: the science of genetics is a rapidly moving one, and hard and fast definitions, descriptions and conclusions cannot be guaranteed.

“History

“Babylonian, Assyrian and Egyptian societies attributed malformations to supernatural causes, and viewed birth defects as signs of good or evil for the society itself. Such were also the views of Greek, Roman and European societies. However, naturalistic explanations emerged to explain both malformations and physical differences and similarities between members of the same family. Concepts of inherited differences appear in the Hippocratic texts and in the writings of Anaxagoras (500-428 BC).

“Aristotle based a theory of inheritance on his philosophy of form. The generation of males and females was due to the principles of movement and matter embodied in semen and female secretions. When the male principle was dominant, sons were born who were more like their fathers than their mothers, and *vice versa*. These views were the major source of pre-scientific guidance until the Enlightenment period.

“Part of the Mosaic Code (Lev. 18.6-13: “None of you shall approach to any that is near of kin to him, to uncover their nakedness: I am the Lord...”), which prohibits incest, might also be related to a eugenic concern with avoiding the birth defects which arise from too-close relatives having children together. No biblical texts specifically deal with prevention of birth defects through marital laws, but incest is clearly regarded as a grave moral offence.

“The Talmud rules that a man may not marry into a family afflicted with leprosy, epilepsy or a similar disease, noting that such diseases are more frequently transmitted within families. Manu in his laws seems to warn against marrying certain types, eg women whose hair is red, whose teeth stick out or whose male relations are hirsute. Plato identifies principles for selection of spouses for reproduction in his *Republic*.

“European physicians in the 17th and 18th centuries debated the pre-formationist theory which held that the whole organism was pre-formed in either the ovum or the sperm. The debate foundered on lack of empirical evidence until the experiments of Mendel reported in 1865. Mendel was an Austrian monk and botanist, who experimented with crossing varieties of peas in terms of colour and shape of seed. He counted all types and combinations in the offspring for several generations. From this he deduced the statistical laws that shape the foundations of modern genetics and provided the correct biological theory for the similarities and differences between offspring, namely, that the sex cells, the sperm and eggs, are what give rise to dynamics of inheritance. Interestingly, the work of Mendel remained unused and unappreciated by scientists until 1900.

“Also in 1865, Sir Francis Galton published papers asserting that qualities like social achievement were strongly influenced by heredity. He developed the system of studying variations in whole populations by statistical methods, and was responsible for the term ‘eugenics’, from the Greek meaning well-born. His followers expanded upon the notion that certain behavioural patterns or characteristics of personality could be identified and passed on through a programme of selective mating. They proposed that many negative traits could be traced to a hereditary legacy, hence criminals, paupers, alcoholics, prostitutes, and other “undesirables” had reached their state as a result of heredity.

“In the 20th century such eugenic theories were applied in ethically problematic ways. In the US there was wide-scale sexual sterilisation of epileptics, the mentally ill, and the retarded; restrictions on the immigration of some ethnic groups and prohibition of marriage between people of differing racial backgrounds. So-called scientific criteria derived from eugenic studies were used to argue that parents, ill or handicapped by heredity, always produce defective children, and the peoples of some nations and races were genetically inferior to people of other nations. Mixing the gene pool would dilute the total gene pool to the detriment of all humanity. The most objectionable eugenic practices were seen in Nazi Germany, where attempts to separate and purify the Aryan race were most explicit, consisting of efforts to produce people who did not look like Adolf Hitler.

“Although the word ‘eugenics’ has become a pejorative term, many would argue that selecting embryos which do not have particular heritable conditions as a way of purifying the gene pool is acceptable. Or rather, it is thought that such selective breeding would take place by default because parents would like to avoid their offspring suffering as they or their ancestors did, and the consequence would be a gradual removal of undesirable heritable conditions from the gene pool as technologies such as *in vitro* fertilisation develop to make it possible. However, it should be noted that prenatal selection would have only marginal effects on the gene pool *unless* it was systematically practised by most of the population. Given that most people are unlikely to stop having children by the normal methods, such ‘gene pool cleansing’ is hardly going to happen by default.

“Mendel’s discoveries eventually led to clear and less controversial applications in medical genetics, and to evidence that genes were composed of the content of DNA molecules, the building blocks of protein synthesis common to life in all its forms. Techniques in molecular biology gradually laid a foundation for understanding the basic principles of gene action. **The Human Genome Project** was started to provide a proper grounding for all genetic investigations in humans. Its aim has been to create a generalised map of the genome as an underpinning of all research into human genetics. This has involved determining the sequence of all the 3 billion bases in the human genome, and identifying the number and location of genes. In 2001, draft versions of the human genome were published. Further work is in hand to finalise the map as a complete and authoritative reference. At present, the map is not complete, and contains only small information about variations – different alternative forms (alleles) of particular genes are currently being recorded as annotations to the genome. Many individual genotypes or genomes will need to be sequenced before it is possible to tell what all the variations and commonalities are. Molecular biologists today

routinely recombine particles of DNA to produce new varieties of forms in bacteria, plants and biochemical molecules.

“What is a gene?”

“Each individual (apart from identical twins) has a unique genetic profile – a mixture of the genetic profile of their two parents. This individual genetic profile is, in turn, determined by the unique ordering of just four different molecules (bases), paired together in the famous ‘double helix’ of deoxyribonucleic acid (DNA), a spiral molecule resembling a ladder whose rungs are built of these pairs of bases. The entirety of each individual’s DNA is their genome, rather like a blue print of a person’s genetic makeup. Each of the body’s many cells contains a copy of the genome, mainly in the cell nucleus. The DNA forms chromosomes of which humans have 23 pairs, one half of which comes from their mothers and the other from their fathers. The variation between the genomes of different people is about 0.1% between unrelated individuals. The amount in common is so extensive that it is possible to discuss a general, characteristically human sequence of DNA – the **human genome**. Of course, although inter-individual variation is only 0.1%, that is still about three million differences between people (there are three billion bases to vary).

“DNA controls the operation of the body’s cells by determining the various proteins (molecules which are vital for cell growth and function) produced within them. In this way, DNA influences not only overall physical characteristics but also many of the processes that help determine good health or illness. **Genes** are the part of the DNA sequence which governs protein production. There are thought to be 30,000 to 40,000 genes in the human genome, occupying only about 3% of the total DNA. The role of most of the remaining 97% of the DNA (the so-called ‘junk’ DNA) is not yet understood.

“A small number of genes comprising a small percentage of the DNA are contained in the mitochondria, tiny but important structures in each cell but outside the nucleus which play a major role in energy production. In contrast to other genes, they are inherited only from the mother. One could think of the egg cell providing not only half the genetic makeup of the offspring but also the food needed for its survival and development.

“While an individual’s cells contain full copies of that person’s genome, in different cells different genes are active or expressed. As a result, there will be different products in each cell type, giving them their separate function in the body, such as liver, hair, toenails, retina, etc.

“Variations between individuals’ genomes come in two important types: alterations to the sequence at specific locations along the genome, and variable numbers of repeating base sequences between particular locations on the genome. The sequencing of the human genome conducted over the past few years has resulted in a general map of human DNA. This map is being annotated by adding information about the different variations or alleles that have been observed at certain locations, what function in the body particular regions of the genome influence, and the significance of observed variations.

“Most genetic diseases follow two patterns of inheritance. In some cases a single abnormal gene from one parent is sufficient to cause disease; this sort of gene is said to be dominant. More commonly, a child must inherit a defective gene from both parents before the disorder shows itself; in this case the genes are said to be recessive. Healthy persons who have just one defective recessive gene are called carriers. They do not suffer from the disease but could pass it on to their children if their spouse is also a carrier for the same disease. We all carry a few potentially harmful recessive genes. There are also whole chromosome mutations which give rise to other genetic diseases.

“Different alleles at important locations within the genome, particularly within genes, can change an individual’s susceptibility to various diseases. In some cases, genetic factors make the onset of disease inevitable, in others they merely make it more likely. For many common diseases, environmental and lifestyle factors combine with genetic susceptibility in determining whether symptoms appear, at what age and with what severity.

“Applied genetics

“Physicians and other scientists apply genetic knowledge in numerous ways. These can be considered under the following headings:

- i) genetic screening of new-born babies and carriers;
- ii) genetic counselling;
- iii) prenatal and pre-implantation diagnosis of genetic disorders;
- iv) the treatment of harmful results produced by some genes or the correction of the genes themselves;
- v) stem cell research and cloning;
- vi) animal transgenics;
- vii) plant transgenics.

“i) Genetic screening

“This is done for three reasons:

- a) “to uncover a disorder that is latent or actual, so that treatment or support can follow;
- b) “to detect persons of reproductive age who are at higher risk of transmitting a genetic disorder, so that information about reproduction can be given to them;
- c) “to answer questions about the natural history of a disorder, how frequently it appears in the population, and how the gene or genes are distributed. Large-scale screening programmes were organised to screen for carriers of Tay-Sachs disease, beta-thalassaemia, and sickle cell disease. Because these conditions are found frequently in those of, respectively, European Jewish, Mediterranean and African ancestry, screening creates occasions for racial and ethnic discrimination.

“There are problems associated with genetic screening even if it is sought by an individual, since very few treatments exist as yet and the implications for a person’s family can be extensive.

“ii) Genetic counselling

“This is, as its name implies, giving advice to parents about genetics. It might involve asking a pregnant mother if she wishes to have an amniocentesis test (see below) for Down’s syndrome, and explaining the options to her if her baby turns out to suffer from Down’s. It might involve explaining to parents that they are both carriers of a particular genetic disorder, and any child they have together may suffer from the disease. For example, if both parents are cystic fibrosis carriers, the chance of their children being sufferers is one in four. Counselling might, finally, involve explaining to someone that the disease from which he or she is suffering is inherited, eg some forms of breast cancer. This has implications for the rest of the family of such a person, since they too might be susceptible. In some cases advising a woman that she has the defective gene that may lead to her developing breast cancer at some future date has resulted in her having both breasts removed prophylactically.

“It can be seen that in genetic counselling the way information is given and the advice that follows from the information can be enormously influential on the subsequent actions of the people involved.

“iii) Prenatal and pre-implantation genetic diagnosis

“**Prenatal** diagnosis is conducted in the following ways:

- a) *amniocentesis* extracting amniotic fluid by needle puncture between weeks 16-18 of a pregnancy, from which fetal cells can be obtained and cultured in the laboratory for diagnosis for Down’s syndrome;
- b) *fetoscopy* the insertion of a small-gauge endoscope into the abdomen of the pregnant woman to remove fetal blood or tissue;
- c) *ultrasound* the transmission of the fetal image on to a screen by high frequency, low intensity sound waves;
- d) *chorionic villus sampling* in the late first trimester (three months of pregnancy) by ultrasound-guided catheter (very thin tube which can take samples).

“The purpose of prenatal diagnosis is to generate information about the presence and severity of a genetic disorder. The mother is given the option of abortion or bringing the child to term, making appropriate arrangements for the special care it will need. The moral problem with prenatal diagnosis is not in the action itself, though some of the techniques are associated with a significant risk of miscarriage. The moral problem is rather that the purpose of the diagnosis is not, at this stage, to offer treatment, because none yet exists for these genetic conditions, but to open up the possibility of aborting the malformed child. Some physicians and geneticists offer justifications for such abortions (apart from the individualistic one of preventing the suffering of parents from having to care for a sick child), namely, to prevent genetic disorders in future generations. Hence, abortion of such genetically disordered people is seen as a means of eliminating the disease altogether (eugenics).

“Pre-implantation diagnosis involves genetically testing an embryo (fertilised egg) to discover whether it contains a faulty gene likely to give rise to a genetic disorder. Such testing happens when the method by which a couple is having a child is *in vitro* fertilisation (IVF) – fertilisation outside the body, literally ‘in glass’. The woman is given drugs to super-ovulate, and her eggs will be fertilised by the father’s sperm, and then two embryos (the law allows no more than that) will be re-implanted. The question is, which two? Once conception has taken place, the complete genetic makeup of the future person is in place. Hence genetic tests can be done to discover increasing numbers of characteristics, from some genetic disorders to social traits such as sex and hair colour (though tests for the latter are far from straightforward, rather surprisingly). In theory, and increasingly in practice, defective embryos are isolated from the others and not implanted.

“There are a number of interesting moral concerns with IVF; here we should consider in particular the status of the embryo and the moral acceptability of different genetic tests:

- a) “Is the embryo something towards which we have moral duties, given that its genetic makeup is already in place, or is it expendable? The reason some find embryo testing and disposal acceptable is that for the first 14 days of an embryo’s life, if it were created in the ordinary way, it would not have settled in the wall of the mother’s womb, but would be making its way there. During this time the embryo might be washed out, or it might divide and become identical twins, or even triplets. The Warnock Commission, which gave rise to the Human Fertilisation and Embryology Act 1990, took this view, that for 14 days the embryo could be treated as a non-person, though with respect for the person it could become. Thus, by law, for the first 14 days of its life an embryo can be used as a means to others’ ends: researched upon, frozen for future use, or discarded; but with due regard to its status. Normally a woman seeking IVF treatment would have several eggs fertilised, but by law she can only have two implanted for pregnancy. Hence there will typically be ‘spare embryos’ in IVF treatment. (In other countries where the embryo is accorded higher status only the number of embryos that are to be implanted may be fertilised.)

- b) “If we accept that pre-implantation genetic testing, with a view to choosing the ‘best’ two embryos, is permissible, what might we test for? Is it only medical concerns that should govern our testing or are there some social characteristics which it is morally acceptable to test for as well? Some couples are very concerned to have either a boy or a girl. Should they be so permitted? What about hair colour and levels of intelligence? The Human Fertilisation and Embryology Authority, the body created by the Human Fertilisation and Embryology Act of 1990 to regulate IVF practices, permits pre-implantation diagnosis and selection for medical reasons only. This might include selecting for sex. For example, haemophilia is only suffered by male offspring and a couple may, therefore, choose only to have female embryos implanted.

“An interesting case gained publicity in January 2002, namely the Human Fertilisation and Embryology Authority’s granting of permission to use pre-implantation genetic diagnosis to ensure that the future child was a genetic match to his/her brother, who needed a blood transfusion to save his life. No match had

been found among the living. The family had been trying for another child in any case. Now they sought to use IVF and pre-implantation diagnosis to form a child that could save his/her brother's life. Thus a child is to be created not as an end in itself but as a means to another's end – breaking Kant's categorical imperative and arguably undermining the Christian belief that each child is individually loved by God for him/her own self and not because of his/her utility.

“iv) Genetic treatment

“Treatment for genetic disorders after birth span a gamut from transplantation of organs to alteration of diet. That is, most of the treatments are for alleviating symptoms rather than for cures. Many children with cystic fibrosis, for example, need heart-lung transplants because these are the organs most affected. Some transplant surgeons balk at offering surgery to genetically disordered patients since they are likely to die early, and there is a great shortage of organs. One surgeon refused to transplant patients with Down's syndrome for this reason.

“Gene therapy proper seeks to treat the underlying genetic cause of disease. Prospects for human gene therapy involve three levels of potential intervention:

- a) somatic cell therapy;
- b) prevention of genetic disorders by germ line (sex cells) therapy;
- c) enhancement genetic engineering: deliberate attempts to alter human traits like height, longevity and intelligence by alteration of either somatic or germ line cells.

a) Somatic gene therapy

“This involves the correction of gene defects in patients' own somatic cells, ie ordinary body cells. The strategy involves gene replacement, gene correction or gene augmentation, the genes being introduced via DNA-carrying agents such as retroviral vectors (DNA-producing RNA which act against the disease in question by changing the DNA in the cell). The aim, then, is to modify a particular cell population and so rectify a particular disease in a particular patient. Success remains elusive for this form of therapy though trials continue. There has been one possible breakthrough, in reversing immune system failure in some babies in France, and most recently in this country. The results are very encouraging, but so far show only a short term effect.

“There are few ethical concerns with such treatment. Its aim is uncontroversial: the alleviation of disease rather than the improvement of the human species. It seeks to treat only the single patient and has no effect on his or her future offspring. The danger may be that it is the start of a slippery slope and opens the way to germ line therapy and attempts pre-emptively to improve individuals. There is also a small risk that such treatment could spread to the gonads thus affecting the germ line cells as well.

“b) Germ line therapy

“This involves “correcting” a gene in the germ line (the cells that become gametes or sperm/eggs and early embryos) so that when the modified individual reproduces, offspring will inherit the “normal” gene. It would most easily be attempted by manipulating the early embryo. Any attempt to “treat” an early embryo, so that the

individual it will become is not affected by the disease, is at risk of incidentally producing genetic modification of the germ cell line. This sort of therapy is illegal to perform on humans (Human Fertilisation and Embryology Act 1990). Animal experiments have shown that the method is associated with some risk, since gene expression may occur in inappropriate tissues. Any damage to the DNA caused by this procedure will stay in the germ line and be passed on to subsequent generations. Such therapy holds out hope for some genetic conditions which may only be amenable to treatment in this way, for example brain cells in hereditary central nervous system disorders, which are not open to genetic repair after birth. It would also dispense with the need to repeat somatic cell gene therapy in future generations of a family with a genetic disorder. The gene can be eliminated from the population (eugenics) and hence improve the efficiency of gene therapy.

“This kind of gene therapy necessitates IVF treatment, as the treatment can only be given to sperm/eggs/embryos. Since IVF has to be undertaken anyway, the simplest solution would not be gene therapy but simply to destroy the embryos with the genetic abnormality, which is lawful, unlike germ line therapy. There would then not be a person with the faulty gene to reproduce at all.

“b) Enhancement genetic engineering

“This involves the insertion of a gene in an attempt to alter a particular trait of an individual. It is similar to providing growth hormone to normal individuals to enhance their sporting prowess. The extra gene may have adverse consequences resulting from protein imbalance. However, an alternative preventive use of enhancement genetic engineering can be imagined, such as altering the concentration of the protein that leads to heart disease.

“v) Stem cell research and cloning

“**Stem cell** is the name given to the cells that become the more than 200 different types of cell in the human body. They exist in the early embryo, in the fetus, in the placenta and umbilical cord, and in many, possibly most, tissues of the body. Because of their ability to reproduce themselves, and to differentiate into other cell types, stem cells offer the prospect of developing cell-based treatments, both to repair or replace tissues damaged by fractures, burns and other injuries, and to treat a wide range of very common degenerative diseases, such as Alzheimer’s disease, cardiac failure, diabetes, and Parkinson’s disease. These are some of the most common serious disorders, which affect millions of people in the UK alone, and for which there is at present no effective cure. Stem cell treatments, unlike most conventional drugs treatments, have the potential to become a life-long cure.

“Most scientists believe that in order to harvest stem cells and do the necessary research to make treatment of such conditions possible, early embryos have to be used. This is controversial for the same reason that IVF is controversial: it raises the question of the status of the embryo, and whether it should be used as a means to others’ ends.

“Cell transplantation is best done, like organ transplantation, from genetic matches so that the recipient of the transplanted organ does not reject it. One way of ensuring a genetic match in stem cell treatment is to create an embryo which is a **clone** of the person who needs the treatment. The technique of cloning, practised in animals (see

below) can be used for the purpose of creating an embryo specifically to harvest stem cells and then to be destroyed before the 14 day deadline. The cloned embryo in this context consists of an enucleated egg which has been given a nucleus from a cell of the person who needs the treatment, tricked into thinking it is fertilised and producing stem cells for harvesting.

“A law was passed in 2001 specifically criminalising the implantation of such cloned embryos into a woman. Hence cloning, or cell nuclear transfer as it is usually called, would only take place (in the UK) in the context of stem cell research and treatment.

“vi) Animal transgenics

“Because of the low success rate in animal germ line therapy, the technique has been transferred to cells grown in culture rather than in the animal. Embryo stem cells from mice are grown in laboratories in culture, and genes are targeted very precisely into the embryo stem cells, which then grow well in culture. These modified cells are then injected into an embryo, placed in a surrogate mouse mother, and after one generation of breeding, a transgenic mouse is produced. This technique thus produces 100% transgenic animals with precisely engineered modifications. Such transgenic mice are widely used in medical research (eg the oncomouse).

“Visions of transgenic farm animals with desirable traits such as protein-enhanced milk or low fat meat have failed to materialise as scientist have been unable to produce embryo stem cells in farm animals. Scientists at the Roslin Institute famously overcame this problem by using sheep cells that were at later stages of development than the embryo stem cells of the mice. In culture, the scientists were able to control the conditions of growth of these more mature cells and reprogramme their nuclei so they would function against an early embryo stage. The nuclei could then be transferred into an unfertilised egg, placed in a surrogate mother who would then give birth to a live lamb. It was the fact that this process of nuclear transfer could be done with adult cells that gave rise to the possibility of successful cloning.

“vii) Plant transgenics

“During the last 20 years or so there has been a revolution in plant science which has allowed the skills of the plant breeder to be supplemented by the application of plant biotechnology. This revolution has resulted from an increased understanding of how cells and organisms work at the molecular, biochemical and physiological level and also from the development of techniques which allow the transfer of genes from one plant species to another, or from other organisms such as bacteria. In the last year the availability of the complete sequence of the three genomes (nuclear, chloroplast and mitochondrial) found in the model plant *Arabidopsis thaliana*, and the first draft of the nuclear genome sequence from rice, has opened up even further possibilities for the manipulation of plant genomes. This knowledge is of use not only in marker-assisted plant breeding programmes but also has the potential, combined with transgenic techniques, of modifying plant metabolism for a wide variety of purposes. These include:

- a) “improvement of the efficiency of specific metabolic pathways so as to improve the plant as a whole in respect of, for example, its yield, nutritional quality, agronomic characteristics, and its ability to take up and utilise soil nutrients;

- b) “increased resistance to abiotic stresses such as heat, cold, drought or saline conditions and biotic stress caused by pests and pathogens;
- c) “engineering of metabolism to change the nature of the harvested product so it can be used as an industrial feedstock or to provide a product of therapeutic value.

Concluding remarks

“In this paper I have described the history of genetics, its nature, and its applications in the human, animal and plant worlds. Generally, the study and application of genetics has the potential for very great benefit, and also harm, depending upon how and for what motives the knowledge is used. In human genetics, the possibility of treatments for innumerable hitherto incurable conditions is there. I mentioned the moral issues that are raised by genetic screening, counselling, prenatal and pre-implantation diagnosis, and transgenics. In all of these the spectres of discrimination on the grounds of physical or mental disability, race, ethnicity and sex are raised. So too is the possibility of attempts to modify and ‘improve’ the human species.

“In animal genetics I touched briefly on attempts to modify animals for human benefits. So far, the only benefits actually experienced are those in medical research on GM mice. Here the moral concern may be that animals are being made to suffer for the sake of human beings. In plant genetics I looked at the possible applications of GM. In both animal and plant genetics there is a general concern that GM constitutes a step too far in modifying and altering nature.”

Human genetics

There have been several enquiries during the 1990s into genetic screening and diagnosis generally, to which the Board has responded. In 1992 the Board sent observations to the Nuffield Council on Bioethics’ Working Party on genetic screening. In 1995 the House of Commons’ Science and Technology Committee conducted an inquiry into human genetics, to which the Board contributed. In 1997 the Department of Health’s Advisory Committee on Genetic Testing received a submission from the Board.

In 2000, the Board responded to a Government consultation on the ethics of pre-implantation genetic diagnosis. This is a technique which involves finding out the genetic traits of embryos before they are implanted in the womb.

Paper copies of all these submissions can be obtained from the Community and Public Affairs Unit, via Alison.cundiff@c-of-e.org.uk.

Genetically Modified Organisms

In 1999 the Church Commissioners, who are responsible for the Church’s land, were asked if they would consider leasing farmland for scientific crop trials, which might include genetically modified (GM) crop trials. The Ethical Investment Advisory Group (EIAG) of the Commissioners undertook a detailed study of the theology, ethics and science of GM crop trials undertaken in open fields. The EIAG produced a report with recommendations, which were accepted by the Church Commissioners in April, 2000. The EIAG recommended that

future tenants of the Church Commissioners should not be permitted to conduct GM crop trials without prior permission, which would be granted on a case by case basis. The report includes guidelines on how such trials should be conducted ethically. The report is available as an [RTF download](#).

The EIAG were assisted in their research by the Board, which had produced a briefing paper on GM organisms in April, 1999. Briefing Papers of the Board do not give the policy position of the Church but seek to provide factual information and theological arguments to assist Christians and others in their thinking. The Briefing Paper is reproduced in full here:

GENETICALLY MODIFIED ORGANISMS

A BRIEFING PAPER

1. Introduction

“The Church of England encourages its members to think through issues themselves in the light of the Christian faith and in dialogue with the wider Christian tradition. Nationally and locally, the Church of England seeks to support its members in their explorations in discipleship through encouraging participation in social institutions where moral and ethical issues arise. As an established Church, the Church of England seeks to develop debate and dialogue with a wide range of social institutions in order to explore the contribution which Christian ethics can make to the life of the nation. This paper is offered as a resource for these purposes.

“The public has expressed enormous concern at the prospect of genetically modified organisms, and this needs to be taken seriously. Much of this concern, more or less well articulated, arises from a sense that genetically modified foods are radically unnatural. This paper attempts to clarify the scientific facts and the theological and ethical issues arising from them in order to assist clear thinking in this area.

2. Genetic Modification

“Foodstuffs have been derived from genetically modified plants and animals ever since the time when agriculture began and selective breeding turned wild cereals into cultivated crops and wild animals into domesticated herds. However, the use of the phrase ‘Genetically Modified Organisms’ (GMOs) is usually reserved for plants, animals and micro-organisms that have been modified by genetic engineering in ways that could never be achieved by natural breeding. For example, a gene from a fish could be inserted into a tomato. Present and foreseeable uses of these techniques are limited, in that:

- a) “they involve only small transfers of genetic material, often just a single gene which is correlated with the production of a specific protein;
- b) “for the purposes connected with foods, the transfers envisaged are principally into plants. GM of animals is a more difficult procedure and current uses concentrate on medical applications, employed for the production of therapeutically valuable proteins. However, in due course GM animals may be introduced into the human food chain.

3. The Nature of Genes

“Although it is common parlance to talk of genes as carrying ‘information’, it is important to recognise that the genetic code is only meaningful in the context of the whole cell within which a gene is operating. Some have, therefore, suggested that genes in themselves are simply complex chemicals and that their biological significance derives from their cellular host. On this view, a gene derived from a human being but transferred to a plant would be a ‘gene of human origin’ but functionally, and ethically, a gene of the plant that contained it.

“A MAFF Committee that considered ethical issues arising from GM foods took this view, though it recognised that it would not be shared by everyone. Some perceive genes as still being endowed with an ethical significance derived from the organism of origin, so that for them genes of human origin are still ‘human genes’, and genes of porcine origin are still pig genes (a worry to Moslems but not to Jews, according to evidence given to the Committee).

4. Purposes Served by GM Foods

“A number of different purposes might be served by introducing GM organisms into food use:

- a) “Marketing convenience and consumer preference. One of the first GM products marketed in the UK was a tomato modified to prolong its shelf life. This brought some benefit to the consumer in a reduced price of tomato paste because of reduction of losses in transportation of the raw material.
- b) “Improving fertility and viability in hostile environments, such as very arid or salty domains. The world population is predicted to rise from its present 6 billion to 8 billion by 2020. Present resources, even if evenly distributed, could provide an adequate diet for only about 6.4 billion people. There is, therefore, a clear need to improve agricultural productivity. GM offers one promising way of achieving this end, though coping with drought and salty conditions will probably require the transfer of small gene clusters, rather than single genes.
- c) “Conferring herbicide resistance, so that crops could be sprayed against weeds without being themselves destroyed.
- d) “Improving the resistance of crops to virus and insect predators. For example, a GM plant might produce a specific toxin hostile to its principal insect predator. Not only would this be valuable protection, but it would also be expected to reduce the use of general insecticide sprays, an environmentally friendly outcome.

5. Theological Issues

“Perhaps the most widely articulated opposition to GM foods is based on the belief that they are radically unnatural and that to produce them is for human beings to be guilty of the hubris of ‘Playing God’. Certainly, they represent possibilities that could not come about without direct human action upon nature. However, much technology and most medicine is based on human intervention into natural processes. Human beings are themselves part of nature, creatures within creation. Human discovery and

invention can be thought of as resulting from the exercise of God-given powers of mind and reason. Many have thought that the possession of these powers is part of what it means for humans to be 'in the image of God'.

“It does not seem that radical ‘unnaturalness’ can of itself be the source of an ethical prohibition. It by no means follows, however, that everything that can be done, should be done. There is a reverence due to the goodness of nature, seen as being God’s creation. Major scientific discoveries confer knowledge, and the power that comes from knowledge, but if we are to choose the right and refuse the bad, we shall have to add wisdom to knowledge in order to make that discrimination. Here the religious traditions, which are reservoirs of wisdom accumulated and sifted over the centuries, have a vital role to play in helping society to reach the right conclusions. Wisdom is unlikely to lie either in an unrestricted exploitation or in a total prohibition, but in a careful consideration of individual proposals. In this respect, genetic engineering does not seem very different from other forms of scientific advance.

6. Labelling

“The MAFF Committee referred to in section 3 concluded that foods containing ethically sensitive genes (eg of human origin) should be labelled in the interests of affording consumers a legitimate degree of informed choice. The present public mood in the UK seems to be supportive of the labelling of **all** GM foods, on the grounds that people may have ethical or safety concerns about them.

“In terms of primary foodstuff (such as GM tomato) this might seem reasonably straightforward. However, there are greater difficulties in relation to crops that are shipped around the world in huge amounts. In the United States, Monsanto has declined to segregate GM and unmodified soya beans, an action that has given rise to protest in Europe, not least because of the considerable power and influence multi-national companies such as Monsanto appear to be able to wield. Brazil is still a source of unmodified soya but it is uncertain how long this will continue to be so.

“Processed foods present greater difficulties. As some stage a *de minimis* principle must surely operate for products with long lists of ingredients, some at the trace level. It must also be remembered that processing in general breaks down the DNA in the raw materials, so that the genes themselves are unlikely to be present in the final product.

“Refined products derived from GM plants will be identical to those of unmodified origin. For example, sugar will be the same whether it comes from a GM or an unmodified sugar beet. There seems to be no scientific case for labelling such products.

7. Possible Problems with GM Food

- a) “Safety It is clear that currently GM foods are perceived by many of the public as posing serious safety problems. All novel foods and processes are subject to a well-established and respected system of independent assessment

by the Advisory Committee on Novel Foods and Processes. This ensures that issues such as toxicity and allergenic properties are carefully investigated for all new entries into the human food chain in the UK. Complex chemicals, such as genes, are broken up in the digestive system and there is no evidence to suggest transfers of any genes from GMOs into the human body. After all, we have been ingesting 'foreign' genes for millennia in our food, without take-up from ordinary plants and animals.

"There is, however, one matter for concern about which ACNFP, the Royal Society, and other bodies have spoken. It relates to the *antibiotic resistance markers* in genetic engineering. These are genes conferring resistance to a specific antibiotic which are linked to the gene that it is wished to implant. The process of transfer is relatively inefficient and subsequent treatment with the specified antibiotic can then be used to eliminate the majority of cells in which it has not taken place. If these resistance genes were to transfer into the bacteria in the human gut there might be health implications, though the antibiotics employed are not those commonly used in contemporary medical practice. There is a widely supported view that antibiotic resistance genes should not be allowed to remain present in GM crops.

- b) "Gene transfers to other species Concern has been expressed particularly at the possibility of genetic transfers from GM crops into other crops or wild species. One way in which this might happen would be through the carrying of transgenic pollen by the wind, bees or other insects. The spectre has been raised of the development of a 'superweed', incorporating genes that gave it resistance to a variety of herbicides. Not enough is currently known to enable full evaluation of the risks that might arise in this way, but an appropriate degree of isolation of GM crops from possible unintended recipients, and a careful monitoring of such crops and their effects over several years, are clearly important measures that should be undertaken.
- c) "Environmental Consequences Some of these were dealt with in (b). Others could result from effects arising from the toxins that generate insect resistance, since they could affect non-targeted species and also upset natural balances. These are considerations that need careful evaluation but they are not unique to GMO but may arise with any new form of pest control. We have already noted that herbicide resistant genes might have beneficial environmental effects in reducing the use of general herbicides, but some take the view that overall their effects may be detrimental. If a moratorium were to be imposed on the commercial-scale growing of GM crops, it would be essential to use the pause induced to mount a carefully thought out programme of research to evaluate these issues..
- d) "International Issues While GM developments may be of particular value for developing two-thirds world countries, through enabling the productive use of currently marginal land, there are concerns that this technology should be made available to them in a way that does not increase their dependence and indebtedness to the technologically advanced countries, nor to the powerful multi-national companies on whose products they will have to come to depend. Some imaginative generosity from governments and multinational

corporations will be needed to achieve this. Here is an issue on which the Church might well wish to exert influence.

8. Postscript

“From time to time, public thinking about the use of new scientific techniques can be unduly influenced by slogan words that are unreflectively taken to carry sinister meanings. A striking example of this happening has been with irradiated food. This carefully controlled process is effective in making food safer by killing harmful bacteria. However, public fear inspired by the word ‘radiation’ (perceived as invariably signifying an invisible menace) led to demands for labelling, which in turn proved to be the kiss of death for this food safety measure because of unjustified public fear. It would be regrettable if a similar story repeated itself in relation to GM foods.

“As with almost all scientific and technical developments, GMOs offer opportunities for good use and for bad use. As with almost all scientific and technical developments, careful review and monitoring of their use is important, particularly in the early years of development. It would be unwise, either to ban GMOs from foods, or to fail to keep their use under scrutiny.”

At the time of preparing these pages, the implications of the farmscale evaluations are still to be clarified.