

The Summer Meeting of the Nutrition Society was held at King's College, London on 7–10 July 2003

Plenary Lecture

Nutrigenomics, individualism and public health

Ruth Chadwick

*Centre for Economic and Social Aspects of Genomics, Lancaster University, Bailrigg, Lancaster,
Lancashire LA1 4SH, UK*

Issues arising in connection with genes and nutrition policy include both nutrigenomics and nutrigenetics. Nutrigenomics considers the relationship between specific nutrients or diet and gene expression and, it is envisaged, will facilitate prevention of diet-related common diseases. Nutrigenetics is concerned with the effects of individual genetic variation (single nucleotide polymorphisms) on response to diet, and in the longer term may lead to personalised dietary recommendations. It is important also to consider the surrounding context of other issues such as novel and functional foods in so far as they are related to genetic modification. Ethical issues fall into a number of categories: (1) why nutrigenomics? Will it have important public health benefits? (2) questions about research, e.g. concerning the acquisition of information about individual genetic variation; (3) questions about who has access to this information, and its possible misuse; (4) the applications of this information in terms of public health policy, and the negotiation of the potential tension between the interests of the individual in relation to, for example, prevention of conditions such as obesity and allergy; (5) the appropriate ethical approach to the issues, e.g. the moral difference, if any, between therapy and enhancement in relation to individualised diets; whether the 'technological fix' is always appropriate, especially in the wider context of the purported lack of public confidence in science, which has special resonance in the sphere of nutrition.

Nutrigenomics: Ethical issues: Individualism: Public health

As society goes further down the path of grappling with the issues of the post-genome era, the relationship between genetics and diet is becoming increasingly central. The Department of Health (2003) White Paper, *Our Inheritance, Our Future: Realising the Potential of Genetics in the NHS*, states that: 'We will learn more about the genetic features of common diseases such as heart disease and diabetes and the way external factors such as diet and smoking interact with our genes to increase the likelihood of developing a given disease ... There will then be the option to test people for a predisposition to disease, or a higher than normal risk. Treatment, lifestyle advice and monitoring aimed at disease prevention could then be tailored appropriately to suit each individual'.

The particular concern considered in the present paper relates to the interaction between diet and genes. Here the issues of nutrigenomics and nutrigenetics arise.

Nutrigenomics refers to the application of genomics in nutrition research, enabling associations to be made between specific nutrients and genetic factors, e.g. the way in which foods or food ingredients influence gene expression. Nutrigenetics is the study of individual differences at the genetic level influencing response to diet. These individual differences may be at the level of single nucleotide polymorphisms (variations in a single base pair) rather than at the gene level. Nutrigenomics should facilitate greater understanding of how nutrition affects metabolic pathways and how this process goes awry in diet-related diseases. It is envisaged that nutrigenetics may lead to individualised dietary advice (Müller & Kersten, 2003).

It is important to consider the context in which the discussion takes place. First, it is by now commonplace to refer to the anxiety attached to public perceptions of genetics, which has been particularly prominent in the food

arena, as opposed to the medical arena. Indeed, it was public response to GM food that was at least partly responsible for the attention now paid to public engagement and participation. Second, the issues have to be considered not only in relation to contemporary public attitudes, but also in relation to the prevailing ethical paradigms, which are predominantly concerned with individualism and choice, rather than with the common or public good. Expression of these considerations is found, for example, in relation to debates about labelling and consumer choice.

Applications: ethical issues

Nutrigenomics and nutrigenetics might be involved in public health strategies to reduce the incidence of diseases in which diet plays a part, and in individual consultations to achieve particular targets, e.g. to avoid allergy or obesity. There may also be applications not integrally connected with health; sportspersons, for example, may want to achieve specific targets with diet. The present paper, however, is primarily concerned with public and individual health. There are ethical issues associated with both these aspects, in relation to genetic testing, the control of the information acquired and its use (who has access to the information and what interests need to be protected) and the potential implications for understanding the relationship between individuals and their food. First, there is the question of whether it is worthwhile going down this route, given that any line of research has associated opportunity costs. Is there sufficient reason to think that nutrigenetics and nutrigenomics will deliver?

In other contexts critics have been dubious about the publicity that has surrounded developments in genetics, and they have argued that putting so much emphasis on genetic solutions in health care is neglecting other 'lower-tech' solutions to health-care problems. This argument may be justified, particularly in the case of food. While much is promised from the development of pharmacogenetics in health care, there is a crucial difference between pharmaceuticals and foods. Pharmaceuticals are well-defined compounds aimed at specific targets, whereas foods are complex substances that have multiple effects on different pathways in the body (Müller & Kersten, 2003). There are difficult issues about the size of the studies that will need to be carried out in order to obtain meaningful information, and about interpreting them in the light of queries about the statistical significance of information obtained from population genetic research (Ioannidis, 2003). These considerations give rise to considerable uncertainty over the potential relevance of nutrigenomic research for public health.

On the individual level, there are questions about the extent to which individuals will want personalised dietary advice. Although there have been some moves in this direction (Sciona, 2003), the decisions an individual makes about what to eat are arguably much more complex than the decisions about following a doctor's prescription of a pharmaceutical. These decisions are influenced to a greater extent by factors such as anticipated pleasure. Perhaps, however, the potential for making advice specific to an

individual's genetic makeup would prove attractive. Milunsky (2001), for example, has argued that genetic information is a mechanism of individual empowerment: 'While rapid progress continues, there is much you can do now for yourself and loved ones. Know your family history, be cognizant of your ethnic origin, determine your genetic susceptibilities, opt for necessary gene tests, take preventative actions, establish appropriate surveillance, and seek preemptive treatment where applicable. In this way, you can *exercise control* over your genetic destiny, *secure your health* and – in more ways than you yet realise – *save your life*.'

While Milunsky (2001) does not refer to diet in this passage, it is easy to see how the individualist position outlined here could apply in the context of nutrition, especially where food is viewed essentially instrumentally, i.e. as body 'fuel'. Some individuals will probably regard the new possibilities in this positive light, while others will be less keen. Also, there are clear resource implications over the provision of the testing facility. The White Paper (Department of Health, 2003) envisages an expanded role for pharmacists in participating in genetic testing. The potential impact of genetics on the professional roles of nutritionists should also be considered.

What will be the drivers in this field? Clearly, there are commercial interests at stake, and the potential increase in companies marketing genetic tests direct to the public should be considered. There have been understandable concerns about quality control in this area (Advisory Committee on Genetic Testing, 1997; Chadwick & Hedgecoe, 2002; Human Genetics Commission, 2002). Beyond commercialisation, professional or self-referral of individuals has to be considered.

Milunsky (2001) takes an individualist position. Genetic tests are presented as giving individuals the information to make improvements in their own life and health prospects. Ironically, however, the more individualised the promises of genetics, the more that collective action is required in the form of population-based research, in order to acquire the information to enable the discernment of the differences at genetic level between individuals that will affect their susceptibilities. Thus, individual and public health are integrally connected.

This issue is important because the growth in interest in population-based genetic research gives rise to questions specifically about the predominance of individualistic paradigms in ethics. If there are new paradigms in science, following the completion of the human genome, and new paradigms in medicine and nutrition, then why not in ethics? It is important to be alive to this possibility in considering ethics and nutrigenomics.

Acquisition of nutrigenomic information

In the medical context, association studies may be of different kinds. There are studies on isolated populations, as in the case of Iceland, where the population database programme aims to establish associations between genetic factors and common disease. Also, there are proposals such as the UK Biobank, which aims to collect 500 000 blood samples from individuals aged between 45 and

69 years, again to discover associations between genetic factors and common diseases such as heart disease and cancer (for example, see Parliamentary Office of Science and Technology, 2002). Another kind of association study may be carried out on groups of individuals affected by a specific disorder. For example, as part of a randomised controlled clinical trial of a new drug, a pharmacogenetic arm may be added to establish links between genetic factors and adverse reactions (see Chadwick, 2001). Analogously, population-wide or disease-specific nutrigenomic research could be envisaged.

While it is one aim of the UK Biobank to collect both genetic and environmental information in order to study the causes of common diseases in adult life, establishing links between genetic factors and responses to diet will arguably be more difficult than establishing genetic links with adverse drug reactions. For some time the national dietary surveys have been examining the link between food intake and nutritional status, as indicated through the collection and analysis of blood samples. These surveys have been controversial precisely because they involved the collection of blood samples from healthy individuals. Where the acquisition of genetic information is at stake, the issues become even more complex. Collection and storage of genetic information in a database gives rise to questions about control, access and use of that information.

Participation in association studies and genetic databases

An issue for research ethics committees looking at national dietary surveys has been whether or not individuals give voluntary informed consent. In the case of contributing to genetic research resulting in the establishment of a genetic database, there have been queries about whether such consent is even possible (Chadwick, 2001; House of Lords Select Committee on Science and Technology, 2001). First, there are issues about public awareness; to what extent do participants and potential participants understand what they are being asked to participate in? Their understanding should not be explained in terms of knowledge of genetics *per se*. Arguably it is possible for an individual to understand the issues affecting their interests without having a detailed scientific knowledge. Indeed, there is empirical evidence to suggest a good deal of lay understanding of what the relevant considerations are (Kerr *et al.* 1998).

Rather, the point is that in the case of establishing genetic databases, no one really understands what they might lead to, including the researchers. Participants may be giving their samples at a time when the ethical and regulatory framework is at a relatively early stage of development, so they are being asked to consent in a context of unpredictability. Furthermore, in the case of genetic research, the nature of the risks and benefits is different, what may harm individuals is not an intervention in itself, but the potential uses and abuses of the information discovered from their samples. In this context there have been suggestions that relying on individualistic ethics such as the doctrine of informed consent may be a mistake. A draft report of the World Health Organization

(2001) has stated: 'The justification for a database is more likely to be grounded in communal value, and less on individual gain ... it leads to the question whether the individual can remain of paramount importance in this context. ... The achievement of optimal advances in the name of the collective good may require a reconsideration of the respective claims so as to achieve an appropriate balance between individual and collective interests, including those of ethnic minorities, from a multi-cultural perspective'.

In this situation the development of alternative ethical frameworks, such as solidarity and equity (Chadwick & Berg, 2001), and conceptions of gift and benefit-sharing (Human Genome Organisation Ethics Committee, 2000) are increasingly being seen. The point of these frameworks is to try to introduce the idea that databases are common goods to which there is a moral reason to contribute, as an act of reciprocity for the benefits they bring. Indeed, the language of 'global public goods' has been applied to genomics (Thorsteinsdóttir *et al.* 2003) and to genetic databases (Human Genome Organisation Ethics Committee, 2002). Global public goods are defined as goods that are both non-rivalrous and non-exclusive. They are, in other words, enjoyable by all without detriment to others. Knowledge has been said to be the archetypal public good. It is beyond the scope of the present paper to examine the extent to which this concept is fair. For present purposes the point is that, by extension, genomic knowledge, as contained for example in genetic databases, has been argued to be a global public good. This claim thus provides the basis for the further argument that it provides a moral reason, but not necessarily an overriding one, for individuals to contribute to them, given certain protections of individual interests, such as privacy.

Information, access and control

Privacy has been generally considered to be a principal potential concern in relation to genetic databases. Where information relevant to individuals is stored, and its use could be detrimental to their interests, questions immediately arise about who has access to it. This issue is important, not only in relation to worries about access by third parties who might want to misuse it. For example, suppose that at some point in the future it is common for nutritionists to give individualised dietary advice based on individual differences at the genetic level. The need to consider the potential impact on the professional role of the nutritionist has already been mentioned in general. To be more specific, how would the nutritionist get access to this information? Should it be envisaged that a test would be requested at the time of consultation? Or would there be access to a large population database? Or again, would all individuals carry a 'smart card' containing their genetic profile? It is the latter scenario that might be supposed to give maximum control to the individual over their genetic information. Large population databases need controls relating to who has access and on what terms, and arguably leave less room for exercising individual autonomy.

Autonomy

Autonomy is a concept that arises in the majority of discussions about ethics. Perhaps the most common application of the notion of autonomy in the food context is in connection with consumer choice (choice as to what food to buy and consume). Interpretations of autonomy are multiple, however, and it is worth trying to tease out some differences that might be relevant to the nutrition context. How autonomy is understood, in nutrition as in other contexts, depends on the underlying theoretical perspective, which may not always be transparent. From a utilitarian perspective, individuals are deemed to make choices in order to maximise their own happiness or to maximise the extent to which their preferences may be satisfied. The most important versions require that preferences be informed preferences. Thus, on this model consumers are seen as benefiting, by having information that will enable them to make and act on choices that are most likely to maximise satisfaction. In the context of food, however, nutritionists know only too well that having information about what food is most likely to contribute to health has to compete with other facts, such as the seductive allure of 'bad' foods. There is no constraint that enables us to say that informed preferences will be reflected in healthy choices, rather than choices for pleasure.

If such a constraint is wanted, it is necessary to turn to a competing idea of autonomy, as expressed in the notion of making the rational choice, where 'rational' means not maximising the satisfaction of an individual's preferences, but acting in accordance with what the chooser could will everyone in that situation to choose. This interpretation takes its historical roots from the philosophy of Immanuel Kant, first published in 1782 (see Beck, 1963). Thus, if, for the sake of argument, it is known that certain foods are detrimental to health, there are grounds for thinking that an autonomous Kantian agent would not take them. Surely, the rational agent could not consistently will that everyone knowingly chooses to eat foods that would be likely to shorten life, e.g. by increasing health risks such as obesity. Kant himself, in expounding his philosophical position, said relatively little specifically about food, but he did have quite a bit to say about an individual's duties towards their body. What he did say about food is indicative (although, confronted with an increase in binge drinking and associated violent incidents, it may appear today to be no more than quaint), as in the following extract:

'... the body must be frugal in its needs and temperate in its pleasures ... We must be frugal in eating and drinking ... with regard to food, men may be led to over-eat even when the food is bad. To depart ... from the path of moderation is a breach of our duty to ourselves. ... Which of the two vices, gluttony or drunkenness, is the more contemptible and the baser? Gluttony is the baser of the two, for drink promotes sociability and conversation, and inspires man ... [gluttony] is far baser, because it neither promotes sociability, nor does it enliven the body, but is purely bestial' (see Beck, 1963).

It would be a mistake, however, to present the issue for today's consumers as a choice between making food decisions either as utility maximisers or as Kantian agents. It is important to distinguish between specific (local) eating choices (I want this hamburger now) and making more global choices about what sort of food to eat (I will not eat veal). There is another sense to the notion of making an autonomous choice, and that relates to choosing in relation to an identity. Individuals not only make choices about what to do in particular situations, they also choose, at least to some extent, what sort of person they want to be and this choice is expressed to a large extent through food. Individuals make statements about themselves when they choose to be vegetarian, to patronise Macdonalds, to diet or to embrace obesity.

This issue of choice will also be important in the context of genetics and food. It has been seen in relation to GM food; now it should be considered whether individuals want to be the type of person who, as a way of life, takes genetic tests before deciding what to eat. Here, again, there is a potential difference between pharmacogenomics and nutrigenomics. In the case of pharmacogenomics, individuals who are already in a patient role will be prescribed medication in accordance with their genetic condition. Perhaps the same situation will apply in the nutritional context for individuals who are constructed as self- or other-referred patients. Of course, as with any advice of this sort, there is a potential problem about compliance or adherence to a specific regimen. However, when the potential for public health is considered, is it reasonable to suppose that individual consumers will choose, on a sizable scale, to make purchases in the light of genetic information, when the items in question are in a super-market competing with many others?

The answer would seem to depend much more on construing oneself as a certain sort of person than on what is a rational choice. Furthermore, there is evidence to suggest that in the food context there is a great deal of anxiety associated with genetics that has precisely the effect of discouraging individuals from taking the genetic route. Although the anxiety might with good cause be laid at the door of GM food rather than genetic testing, it is arguably genetics itself that has become associated with public worries and concerns. This point is not new. Deborah Lupton (1996), in *Food, the Body and the Self*, drew attention to the ways in which anxiety leads to the reinforcement of distinctions between the 'natural' and the 'artificial', and an increased tendency to seek comfort in the natural and familiar. The author states: 'In the context of a climate of risk and uncertainty, being able to hold on to such binary oppositions and their moral associations makes it easier to live one's everyday life'.

In addition to the worries about genetics there is the potential for raising anxiety through misinterpretation of information about individual risk. This prospect will be an issue in both individual testing and in public health.

Public health: screening

When considering public health interventions, what is at stake might be population screening rather than individual

testing. Genetic screening is typically defined as the determination of the prevalence of a gene in an asymptomatic population or population group, where for any given individual there is no reason to believe that he or she has the gene in question. It is normally contrasted with the genetic testing of an individual for whom there may be some reason to think he or she is at risk (Chadwick, 1998). If nutrigenomics is ever to be implemented in public health, where can ethical guidelines be found? There are general guidelines available on DNA sampling (Human Genome Organisation, 1998) and on genetic databases (Human Genome Organisation, 2002), but what is needed is a way of assessing when applications of nutrigenomics in public health would be worthwhile.

The Wilson & Jungner (1968) principles on screening generally have been applied in the genetic context to establish under what circumstances it is appropriate to introduce population genetic screening. There will be no attempt to give an exhaustive discussion of all the criteria in this context, but two of the most important criteria are that the condition sought should be an 'important problem' and that there must be an acceptable treatment. In the context of genetics, 'treatment' has been interpreted widely to mean that there must be some 'scope for action' available. Population screening for phenylketonuria clearly satisfies these criteria. Phenylketonuria is a serious disorder that can be treated with a diet low in phenylalanine (Gütter & Guldborg, 2003).

Phenylketonuria, however, is a single gene disorder. It is not the case that most of the information coming out of research in nutrigenetics and nutrigenomics will be of this type. What is at stake will concern individual risk factors and predispositions. Thus, the question arises as to the circumstances under which it would be appropriate to undertake population-wide programmes involving genetic information, in order to achieve public health targets. A possible example, which is arguably identified as an important health problem, will be considered.

Obesity

It is now generally accepted that there is a national (and indeed international) problem with obesity. This problem has been traced to well-recognised causes such as over-eating and the 'couch potato' lifestyle. The 'mystery' of the prevalence of slimness in France, in the light of dietary patterns, has been attributed, among other factors, to portion sizes and to the protective effect of red wine (Defeat Diabetes Association, 2003). However, suppose it was found that there was a genetic variant, call it variant A, that predisposed to obesity when combined with food Y. At what point would it be worth carrying out population screening for variant A, as opposed to giving generic dietary and lifestyle advice? The scope for action, in the event of a positive result, would be to counsel those so diagnosed that they had a higher-than-average risk and then give dietary advice specific to their situation.

There are different aspects to the judgment about whether the genetic screening is worth doing. First, there are both advantages and disadvantages to undertaking the screening (Shickle & Chadwick, 1994). Even putting

aside the issue of false negatives and false positives, there is a concern that those identified as negative may feel able to eat anything they like with impunity. There is a parallel to be drawn here with the cases of smoking and alcohol. Not everyone who smokes will contract lung cancer, not every drinker will succumb to alcoholism. There are differences between individuals at the genetic level, which affect their risks of these outcomes. It is easy to understand the attractions to an individual who likes smoking of being given the 'all-clear' to the relevant genetic predisposing factors. However, that does not mean that there will be no other deleterious effects as a result of smoking cigarettes. This situation is where potential problems about interpreting risk information become relevant.

Functional foods

Another possible application of nutrigenomic and nutrigenetics might be in relation to 'functional foods'; but surely, it might be argued, all food is functional in some sense. This reasoning indicates the need to be more precise about what exactly is meant by 'functional'. Functional foods are those that have, or claim to have, a specific health-promoting or enhancing effect over and above their nutritional content (see Chadwick *et al.* 2003). On this basis they are arguably closer to drugs than to foods as conventionally understood. Products currently on the market include cholesterol-lowering foods and probiotic yoghurts.

There have been a number of ethical concerns associated with functional foods, arising partly from the fact that, being foods, they are tested for safety but not for efficacy, unlike drugs. They are placed in supermarkets alongside traditional products and yet they might not be suitable for all those who buy and consume them. The way in which they are advertised, moreover, is potentially misleading, using role models, for example, who are apparently not in the relevant high-risk group, to eat the products in TV advertisements. As the range of products including particular ingredients increases, there are further concerns about overdosing, e.g. in the case of children's diets. As the regulatory system approves these products on a case-by-case basis, there are clear difficulties about how to control the global effect on diet.

As noted earlier, currently food and drugs are regulated differently, which reflects views about the essential differences between them. One purported difference is that while food is a necessary requirement of survival of the whole organism, even in the absence of ill-health, pharmaceuticals contribute to survival in so far as they target specific processes when healthy functioning is damaged or at risk.

For functional foods the case for using genetic information to inform dietary advice may be stronger than that for other foods. They are foods introduced into the market with a specific health-promoting claim, but as their number increases it may be important to have regulatory mechanisms that ensure they are used in the intended manner. As the boundary between food and drugs is increasingly undermined, their regulation will, arguably, increasingly need to consider both safety and effectiveness.

In so far as they are more akin to drugs, the issues will become closer to those in pharmacogenomics, as what will be assessed will be susceptibility to benefit from well-characterised ingredients.

Conclusion

The extent of the role that nutrigenetics and nutrigenomics will play in individual and public health is unclear. In so far as they do have a role to play, however, there will inevitably be associated ethical issues. Those issues concerning individuals cannot be fully distinguished from those of public health, as both will depend on collective action in the form of association studies and databases. This link in turn leads to questioning the reliance on individualistic models of ethics, and in particular of autonomy and informed consent. At the very least the interpretation of autonomy is not transparent. Individuals make food choices for a variety of reasons, in part expressing their sense of identity. Much depends, ethically, on the mechanisms of intervention: how will individuals be tested and who will control the information? The challenges for the professional roles of nutritionists need careful thought, in relation to their role in genetic testing and conveying genetic information. Where public health is concerned guidelines are needed as to the circumstances in which it would be worthwhile to undertake population screening, as what is at stake is likely not to be clear-cut disorders such as phenylketonuria, but risk information with all the associated problems of accuracy and interpretation. Functional foods may provide an example of where nutrigenomics and nutrigenetics may be particularly useful and offer added value over and above generalised dietary advice. Functional foods take us closer to pharmaceuticals, where establishing a link between genetic factors and response may be easier to establish.

Acknowledgements

The support of the Economic and Social Research Council is gratefully acknowledged. The work was part of the programme of the Economic and Social Research Council Research Centre for Economic and Social Aspects of Genomics.

References

- Advisory Committee on Genetic Testing (1997) *Code of Practice and Guidance on Human Genetic Testing Services Supplied Direct to the Public*. London: Department of Health.
- Beck LW (editor) (1963) *Lectures on Ethics*. New York: Harper Torchbooks.
- Chadwick R (1998) Genetic screening. In *Encyclopedia of Applied Ethics*, vol. II, pp. 445–449 [R Chadwick, editor]. San Diego, CA: Academic Press.
- Chadwick R (2001) Informed consent in genetic research. In *Informed Consent in Medical Research*, pp. 203–210 [L Doyal and J Tobias, editors]. London: BMJ Books.
- Chadwick R & Berg K (2001) Solidarity and equity: new ethical frameworks for genetic databases. *Nature Reviews Genetics* **2**, 318–321.
- Chadwick R & Hedgecoe A (2002) Commercial exploitation of the human genome. In *A Companion to Genetics*, pp. 334–345 [J Burley and J Harris, editors]. Oxford: Blackwell.
- Chadwick R, Henson S, Moseley B, Koenen G, Liakopoulos M, Midden C, Palou A, Rechkemmer G, Schröder D & von Wright A (2003) *Functional Foods. Wissenschaftsethik und Technikfolgenbeurteilung Series*, vol. 20. Heidelberg, Germany: Springer Verlag.
- Defeat Diabetes Association (2003) Food Portions may Explain the 'French Paradox' of Rich Foods and a Thin Population (posted 28/08/03). <http://www.defeatdiabetes.org/Articles/diet030828.htm>
- Department of Health (2003) *Our Inheritance, Our Future: Realising the Potential of Genetics in the NHS*. London: The Stationery Office.
- Gütter F & Guldberg P (2003) Phenylketonuria. In *Encyclopedia of the Human Genome*, vol. 4, pp. 568–572. London: Nature Publishing Group.
- House of Lords Select Committee on Science and Technology (2001) *Human Genetic Databases: Challenges and Opportunities*. London: The Stationery Office; available at <http://www.parliament.the-stationery-office.co.uk/pa/ld200001/ldselect/ldstech/57/5701.htm>
- Human Genetics Commission (2002) *The Supply of Genetic Tests Direct to the Public: a Consultation Document*. London: Human Genetics Commission.
- Human Genome Organisation Ethics Committee (1998) *Statement on DNA Sampling: Control and Access*. London: HUGO.
- Human Genome Organisation Ethics Committee (2000) *Statement on Benefit-sharing*. London: HUGO.
- Human Genome Organisation Ethics Committee (2002) *Statement on Human Genomic Databases*. London: HUGO.
- Ioannidis JPA (2003) Genetic associations in large versus small studies: an empirical assessment. *Lancet* **361**, 567–571.
- Kerr A, Cunningham-Burley S & Amos A (1998) Drawing the line: an analysis of lay people's discussions about the new genetics. *Public Understanding of Science* **7**, 113–133.
- Lupton D (1996) *Food, the Body and the Self*. London: Sage.
- Milunsky A (2001) *Your Genetic Destiny: Know Your Genes, Secure Your Health, Save Your Life*. London: Perseus Publishing.
- Müller M & Kersten S (2003) Nutrigenomics: goals and strategies. *Nature Reviews Genetics* **4**, 315–322.
- Parliamentary Office of Science and Technology (2002) *The UK Biobank. Postnote* no. 180. London: Parliamentary Office of Science and Technology; available at <http://www.parliament.uk/post/pn180.pdf>
- Sciona (2003) Nutrition screen. <http://www.sciona.com/coresite/products/nutrition7.htm> (accessed 2 September 2003).
- Shickle D & Chadwick R (1994) The ethics of screening: is screening-itis an incurable disease? *Journal of Medical Ethics* **20**, 12–18.
- Thorsteinsdóttir H, Daar AS, Smith RD & Singer PA (2003) Genomics – a global public good? *Lancet* **361**, 891–892.
- Wilson JMG & Jungner G (1968) *The Principles and Practice of Screening for Disease. Public Health Papers* no. 34. Geneva: WHO.
- World Health Organization (2001) *Genetic Databases: Assessing the Benefits and the Impact on Human and Patient Rights Report for Consultation*. Geneva: WHO.