Attitudes to Biotechnology: Estimating the Opinions of a Better Informed Public

Patrick Sturgis*, Helen Cooper, Chris Fife-Schaw

* Corresponding Author

Department of Sociology
School of Human Sciences,
University of Surrey,
Guildford, GU2 7XH.

Email: p.sturgis@surrey.ac.uk

Tel: 01483 686974

Fax: 01483 689551

Paper submitted to New Genetics and Society, December 2003.

Acknowledgement

The support of the Economic and Social Research Council (ESRC) is gratefully acknowledged. The work arises from the ESRC Attitudes to Genomics Project.

ABSTRACT

Public familiarity with basic scientific concepts and principles has been proposed as essential for effective democratic decision-making (Miller 1998). Empirical research, however, finds that public 'scientific literacy' is generally low, falling well short of what normative criteria would consider 'acceptable'. This has prompted calls to better engage, educate and inform the public on scientific matters, with the additional, usually implicit assumption that a knowledgeable citizenry should express more supportive and favourable attitudes toward science. Research investigating the notion that 'to know science is to love it' has provided only weak empirical support and has itself been criticised for representing science and technology as a unified and homogenous entity. In practice, it is argued, how knowledge impacts on the favourability of attitudes will depend on a multiplicity of factors, not least of which is the particular area of science in question and the technologies to which it gives rise (Evans and Durant, 1992).

This paper uses a new method for examining the knowledge-attitude nexus on a prominent area of 21st century science - biotechnology. The idea that greater scientific knowledge can engender change in the favourability of attitudes toward specific areas of science is investigated using data from the 2000 British Social Attitudes Survey and the 1999 Wellcome Consultative Panel on Gene Therapy. Together the surveys measure public opinion on particular applications of genetic technologies, including gene therapy and the use of genetic data, as well as more general attitudes towards genetic research. We focus our analysis on how two different measures of knowledge impact on these attitudes; one a general measure of scientific knowledge, the other relating specifically to knowledge of modern genetic science.

We investigate what impact these knowledge domains have on attitudes towards biotechnology using a regression based modelling technique (Bartels 1996; Althaus 1998; Sturgis 2003). Controlling for a range of socio-demographic characteristics, we provide estimates of what collective and individual opinion would look like if everyone were as knowledgeable as the currently best-informed members of the general public on the knowledge domains in question. Our findings demonstrate that scientific knowledge does appear to have an important role in determining individual and group attitudes to genetic science. However, we find no support for a simple 'deficit model' of public understanding, as the nature of the

relationship itself depends on the application of biotechnology in question and the social location of the individual.

Keywords: biotechnology, knowledge, attitudes, public, science.

PUBLICS, ATTITUDES AND SCIENTIFIC KNOWLEDGE

A concern to document and assess the public's 'understanding' of science now has a longstanding pedigree within mainstream social science (Irwin and Wynne, 1996; Sturgis and Allum, in press). This, it has been argued, emerges out of a 'scientistic' worldview, which sees basic scientific competence as essential for citizens to meaningfully engage with the increasing number of scientific and technological developments that impact on everyday lives. From this perspective, a knowledgeable citizenry is vital to truly democratic decision-making (Durant, Evans and Thomas, 1992; Miller, 1998). Conversely, a lack of knowledge is seen to impede the public's ability to understand and engage in debate on scientific developments, particularly in areas characterised by complexity and disagreement among experts (Doble, 1995), so-called 'science in the making' (Shapin, 1992).

Recent empirical research in this area has sought to measure levels of scientific knowledge within the general public through survey research. Prominent in this regard has been Miller (1983; 1987; 1998) who develops the notion of 'civic scientific literacy' to investigate public comprehension of basic scientific constructs, the process of scientific enquiry and the impact of science on society. Miller's analysis of US and EU survey data reveals that, in 1992, 73 percent of Europeans and 63 percent of American respondents could not be classed as 'literate' on his main dimensions of scientific knowledge (Miller, 1998). Similarly, only 12 percent of Americans and 5 percent of Europeans fulfilled Miller's criteria for being fully 'scientifically literate', by reaching a threshold level on a battery of scientific knowledge items. In Europe, the highest percentage of 'fully literate' adults was in Britain at only 10 percent, underpinning Miller's conclusion that for healthy democratic systems, "there can be little doubt that the current levels of civic scientific literacy are too low" (1998 p.219).

While maintaining that scientific knowledge can be measured via surveys, Durant, Evans and Thomas (1992) reject the notion of an arbitrary threshold signalling 'understanding' of science and all the normative connotations that go with this idea. They measure scientific understanding among the public by ranking scores on two principle underlying dimensions; the factual or theoretical contents of science and the 'process' of scientific inquiry. While the former concerns factual or 'textbook' scientific knowledge, the latter relates to the rationale and processes underlying scientific enquiry. Their scale of scientific knowledge incorporates both these

dimensions into a single variable which they find to be positively associated with self-reported interest in science and in hypothesised directions with socio-demographic variables such as educational level, age, gender and social class. In their study, the population average on this measure was less than 50 percent of items answered correctly (Durant, Evans and Thomas, *ibid*).

For some, findings of this nature are taken as strong empirical confirmations of the existence of a 'scientifically illiterate' public and provide the first pillar in the construction of the pervasive 'deficit model' of public understanding of science (Irwin and Wynne 1996; Sturgis and Allum, 2001). The deficit model sees public resistance to science and technology as underpinned by ignorance, superstition and fear. Public scepticism about technological innovations such as nuclear energy, microwave cooking and genetic science would be markedly reduced if citizens were better able to grasp the science upon which they are based. That is, a judgement, when informed by scientific fact, would tend to be more favourable and consistent with expert opinion than one expressed without recourse to such 'objective' knowledge. And indeed, empirical studies have, on the whole, found the relationship between formal scientific knowledge and attitude toward science to be significant and positive, though moderate in magnitude (Evans and Durant, 1992; Sturgis and Allum, *in press*). Such claims about the status and role of scientific knowledge in the genesis and trajectory of public opinion have, however, been subject to powerful and sustained criticism on a number of levels.

First, what it means to be 'knowledgeable' about science continues to be strongly contested. There is growing consensus that scientific knowledge extends beyond the simple learning of 'facts' that can be straightforwardly defined and measured (Irwin and Wynne, 1996). What has been referred to as the 'contextual model' of public understanding of science highlights the sophistication and value of lay understandings of science that can exist in the absence of formal scientific knowledge (Durant, Hansen and Bauer, 1999). From this perspective, privileging formal scientific knowledge as the sole basis of rational preference formation leads us to overlook other knowledge domains that may be equally, or even more important determinants of attitudes to science. Wynne (1991) and Yearley (2000), for instance, highlight the influence of 'local knowledge' in determining public favourability to science and technology. Bauer, Petkova and Boyadjieva (2000), on the other hand, argue that "institutional knowledge" - how science is funded, regulated and

embedded within more general political systems – might be the most important determinant of public attitudes.

A second line of critique of the deficit model relates to the idea that ignorance of science may actually be entirely rational, given competing demands on time and cognitive resources (Simon, 1978). To be fully cognisant of the ‘facts’ of science would demand more time and motivation than is generally available to the average individual in a lifetime, even leaving aside competing demands on time through work, family and leisure activities. Faced with the impossibility of being fully knowledgeable about science, people become, in Downs’ memorable phrase, “rationally ignorant” (Downs, 1957).

The consequences of rational ignorance, however, need not be uniformly dire for either the individual or society. In the absence of relevant information, members of the public have recourse to a range of information ‘short-cuts’ that act as effective surrogates for formal knowledge in decision making. Contextual cues, or everyday experience, may be used by individuals in order to reach a judgement that articulates with their intrinsic values and interests, neither of which are predicated on understanding scientific facts (Kerr, Cunningham-Burley and Amos, 1998).

This brings us to a final, central criticism of the deficit model – that general attitudes toward science are of highly dubious ontological status. When the range of practices and activities falling under the general umbrella of ‘science’ are so heterogeneous, is it really possible to say anything meaningful about public preferences at this aggregated level? By way of example, imagine an individual who is strongly opposed to nuclear power, indifferent towards nanotechnology but strongly in favour of gene therapy. How should we characterise this individual’s ‘general attitude’ toward science? A simple average would make them overall indifferent, yet this would surely not be an adequate characterisation of their actual opinions. Such problems have led some to claim that generalised attitudes to science as a whole are of only symbolic value, reflecting individuals’ beliefs about the merits of discovery, progress and open-minded enquiry. To understand how formal scientific knowledge impacts upon public resistance to science and its technological implementation, *specific areas* of science and technology must be examined.

In this paper we focus on the relationship between knowledge and attitude in a specific area of science – biotechnology. We begin by reviewing extant empirical research on public knowledge of and attitudes toward biotechnology. We then

describe the data upon which our analyses are based, set forth our analytical strategy and present the results of our analyses. We conclude by discussing the implications of our results for an understanding of the ways in which public attitudes to this area of science and technology are underpinned by 'general' and 'domain-specific' scientific knowledge.

KNOWLEDGE AND ATTITUDES TO BIOTECHNOLOGY

Biotechnology represents a new and rapidly evolving area of scientific inquiry and technological innovation. In the thirty or so years since it entered public consciousness, it has raised profound moral, ethical and political questions which remain prominently unresolved today. In recent years, a series of biotechnological applications have succeeded in capturing the public's attention through widespread media coverage, with controversies over GM crops and food, animal and human cloning and gene therapy being notable examples. The arguments for advancing public understanding of, and engagement with, biotechnology echo those made for science as a whole; promoting public understanding of genetic science is seen as an essential prerequisite for democratically based policy making and informed public decision making in this area (Agricultural and Environmental Biotechnology Commission, 2001; Nuffield Council on Bioethics, 1993). The public's grasp of human genetic applications, in particular, is set to take on increased importance as techniques such as genetic testing and gene therapy become increasingly commonplace in the 21st Century (Department of Health, 2003). So how have citizens tended to react to the increasing proliferation of technologies emanating from modern genetic science?

Opinion poll data over the past ten to twenty years – focussing as it does on the United States and Europe - reveals a sceptical but not overwhelmingly hostile public response to the dawning genomic revolution. In the 1997 Biotech survey, only about 7 percent of the German public could be characterised as outright opponents or proponents of genetic engineering, with many undecided about whether its applications are, on the whole, good or bad (Hampel, Pfenning and Peters, 2000). In 2002, less than half of Europeans (44 percent) were 'optimistic' about biotechnology, agreeing that it will improve our way of life within the next twenty years (Gaskell et al. 2003a).

As might be expected of such a heterogeneous area of science and technology, public attitudes are actually quite nuanced, differentiating between different applications according to their risk, moral acceptability and usefulness to society. A majority of Europeans encourage and accept biotechnology applications that have clear medical benefits for the diagnosis and treatment of human disease, including the cloning of human cells and tissues and genetic testing for inherited disease (Gaskell et al. 2003a; Pardo, Midden and Miller, 2002; Hampel et al. 2000). If, however, these same technologies are applied in different contexts - genetic tests to decide whether to continue a pregnancy, cloning to create a new human being - survey evidence reveals public opinion to be markedly oppositional (Human Genetics Commission, 2001; MORI, 2003a). Public disquiet is also evident for biotechnology applications that involve the genetic modification of animals or the transfer of genes between animal species (Hampel et al. 2000). Whilst a majority of Europeans in the 1996 Eurobarometer agreed that such applications might be useful, there were strong reservations about the risks and moral acceptability of such research (Pardo et al. 2002).

The genetic modification of crops and use of biotechnology in food production, the so-called 'green-biotechnologies' have been the best documented source of public anxiety toward genomics. In Germany, over half of the surveyed public rejected the use of genetic engineering to improve the flavour or appearance of their food (Hampel et al. 2000). And, although time series data suggests that the British public have become increasingly ambivalent about GM applications in recent years (MORI, 2003b; Gaskell et al. 2003b), a majority still rated GM crops and foods as risky and of limited usefulness in the 2002 Eurobarometer (Gaskell et al. 2003a),

How far can these public appraisals of biotechnology and its applications be seen as judgements based on understanding or ignorance of the underlying science? First let us consider evidence relating to the distribution of what Turney (1995a; 1995b) refers to as the "genetic literacy" of the public. Genetic literacy encompasses the background knowledge citizens are able to draw upon in order to evaluate biotechnological applications. Those familiar with survey based investigations of public awareness of politics (Delli Carpini and Keeter 1996; Bennett 1988) and science in general (Durant, Evans and Thomas 1992; Miller, 1998) will not be surprised to learn that European publics score poorly on factual knowledge batteries on genetic science. Certainly, members of the public seem to regard themselves as ill-informed;

only 2 percent of respondents in the 1997 German Biotech survey rated their knowledge of genetic engineering as 'very good', with a majority conceding they knew nothing about it at all (Hampel et al. 2000). And, although based on a self-selecting sample, the recent *GM Nation?* consultation exercise in the UK revealed that a majority of respondents understood very little about genetic modification, with the arguments surrounding its application being widely perceived as meaningless in the context of everyday lives (Department of Trade and Industry, 2003). Americans, at least, appear to have more confidence in their understanding of genetics; in 1987, two-thirds of the American public felt they understood the term 'genetic engineering' (Office of Technology Assessment, 1987), whilst in the 2001 National Science Foundation Survey, 65 percent of Americans correctly answered that the father's genes determine a child's sex and 45 percent gave an acceptable definition of DNA (National Science Foundation, 2002).

Further evidence relating to public knowledge around biotechnology comes from the Eurobarometer survey series. On a nine item scale of biological (including genetic) knowledge on the 2002 Eurobarometer survey, the mean score in the UK was only 5.3, compared to a European average of 4.9 (Gaskell et al. 2003a). Given that the answers to these questions should be known by someone with high school level biology, this population average is hardly impressive. And, furthermore, as a mean score we also know that a large proportion of the population scored considerably lower than this. Combining biological knowledge scores with information about public awareness of biotechnology, Pardo et al (2002) find that only one in five Europeans could be judged well-informed about biotechnology in 1996-7, with 45 percent of respondents both unaware of, and poorly informed about, basic biotechnology concepts. In 2002, only around one-quarter of UK citizens could be classified as an 'engaged public', using an index of engagement based on awareness, biology knowledge and intended behaviour, a figure which showed little variation across the EU (Gaskell et al. 2003a). A German survey assessing the public's factual knowledge of genetic engineering found that, on average, only 7.4 out of 20 multiple-choice questions were answered correctly. The authors note that, while this score was barely above what would be expected using a guessing strategy, members of the public actually seemed to be applying systematic misunderstandings of basic biology in their responses to these questions (Pfister, Böhm and Jungermann, 2000).

We would appear, then, to have the raw materials necessary for the construction of the deficit model; a broadly disinterested and ignorant public that are in many areas resistant, even hostile, to biotechnological applications. What empirical evidence is there, though, of a causal link between knowledge levels and expressed preferences toward modern genetic science? Hampel et al. (2000) find that Germans who rate their own knowledge levels as 'good' are more likely to be proponents of genetic engineering than those with less self-perceived knowledge. However, self-rated knowledge showed only a weak correlation with attitudes towards genetic engineering in this study and, furthermore, subjective appraisals of knowledge have been found to correspond poorly with factual knowledge of genetic engineering, confounded as they are by people's interest and enthusiasm for the subject (Pfister et al. 2000).

Most published work assessing the impact factual knowledge has on attitudes towards biotechnology has been carried out on the Eurobarometer surveys. Comparing 'engaged' or knowledgeable respondents with those less well informed about biotechnology, Gaskell et al. (2003a) find differences in attitudes that are independent of educational background. On the whole, the engaged public were significantly more likely to find applications of biotechnology morally acceptable and useful. Being well-informed did, however, have less effect on public appraisals of risk, suggesting that risks are perceived but tolerated by more knowledgeable citizens. A similar pattern was found in the 1996 survey, where public knowledge and awareness of biotechnology was unrelated to the perceived risks of biotechnology but showed a moderate, positive correlation (0.25) with an index of perceived benefits (Pardo et al. 2002).

While the idea that knowledge of biotechnology fosters a more positive outlook does find some empirical support in these studies, there is also evidence that the relationship may work in the opposite direction, depending on how questions are framed. Pardo et al (2002) find that, while members of the informed public perceive the benefits of biotechnology most favourably, they were less convinced of the potential biotechnology has to improve quality of life. Similarly, Midden et al. (2002) find the better informed public more likely to have negative expectations about the outcomes of biotechnology over the next twenty years. And, although based on a

knowledge scale that would appear more a measure of attitude¹, MORI report that respondents with high knowledge were most critical about the wider uses of genetic information by employers and insurers (HGC, 2001).

A second strand of evidence on the relation between knowledge of, and attitude toward, biotechnology comes from an ambitious panel study conducted in Great Britain by the National Centre for Social Research and the Wellcome Trust (Stratford et al. 2002). This study aimed to assess the impact of information on public attitudes toward the science, ethics, regulation and potential applications of gene therapy. The study began in 1999 with a baseline survey of attitudes and then, over the period of about a year, respondents were given information relating to gene therapy, first in the form of a magazine and then, some months later, by video and group discussion. Participants were re-interviewed six months after the baseline survey, following exposure to this information, to assess the impact it had on their attitudes. Analyses of the panel data found some, but not all, of the interventions were associated with change in public attitudes (Wellcome Trust, forthcoming). Respondents who attended group discussions and watched the video became generally more positive about human genetic research. However, at the same time, their reservations increased for specific applications, such as germ-line therapy, and for treatment of specific non-medical conditions such as baldness. No significant relationships were found between general attitudes to gene therapy and reading the gene therapy magazine after taking into account differences between those who chose to read it and those who did not. Providing information in written form appears to have been more effective in increasing knowledge and reassurance about regulation of gene therapy than it was in changing people's opinions. Over the course of the panel, the provision of any kind of information served to increase the public's engagement with genetics and to some extent their knowledge. Out of nine factual knowledge questions, the mean number answered correctly increased from 4.83 in the baseline survey to 5.19 just over a year later in the final wave of the panel.

The notion that providing specific relevant information to lay members of the public can change opinions is also supported by research focused on group discussions. A study by the Wellcome Trust questioned the public about their

¹ The scale was formed by scoring as 'correct or 'incorrect', responses to questions about the degree to which particular traits are determined by genes or by environment; the answers to several of which are highly contested.

opinions on human cloning before providing them with factual information on the scientific processes and regulation involved (Wellcome Trust, 1998). When reconvened up to a month later to assess how, if at all, this information had modified their attitudes, it was found that concerns about reproductive cloning persisted but that attitudes towards therapeutic cloning had changed. However, rather than promoting more favourable attitudes, better informed respondents in this study became more critical and reserved about its application. These latter studies suggest that information is unlikely to allay public resistance to genetic technologies if it means people begin to raise and question issues that they had not, hitherto, thought about.

In this paper we use a regression-based modelling technique which provides estimates of what opinion might look like if the public were better informed about the issues in question (Bartels, 1996; Delli-Carpini and Keeter, 1996; Althaus, 1998; 2001; Gilens 2001; Sturgis, 2003). Using nationally representative British survey data, and taking into account the influence of a wide range of socio-demographic characteristics, we show the magnitude and direction of 'information effects' at both the aggregate and individual level on a range of general and specific attitudes towards biotechnology. We frame our analysis with regard to two primary working hypotheses. If we accept the general critique of the deficit model of public understanding of science then *we would not expect general scientific knowledge to have a positive effect on public attitudes towards biotechnology, net of other factors*. Second, we examine the possibility that the *specificity* of information that people possess may additionally shape how they reach an opinion (Gilens, 2001). Someone who scores highly on general science knowledge questions is likely to draw on an amalgam of information that is wide-ranging and diffuse. Hence, it is possible that very little of this information will pertain to genetic science at all. It does not necessarily follow, therefore, that those who are well-informed about science in general will also be knowledgeable about the science underpinning biotechnology. If the degree of specificity of scientific knowledge is important, then, *we should expect a domain specific measure of scientific knowledge to have a stronger influence than a general measure in determining opinion*.

DATA AND MEASURES

We use two different data-sets as the focus of our analysis in this paper; the 2000 British Social Attitudes Survey and the 1999 Wellcome Consultative Panel on Gene Therapy. These data-sets were chosen because the former can be used to derive a measure of general scientific knowledge, while the latter measures knowledge more specific to genetics.

The British Social Attitudes Survey uses a multi-stage, stratified random sample design to obtain a nationally representative sample of adults aged 18 and over resident in private households in Great Britain. In the 2000 survey, a total of 3426 adults were interviewed, an overall response rate of 62 percent (Park et al. 2001). The survey design meant that three different versions of the questionnaire were administered, each with its own self-completion section, to approximately one-third of the sample. Two thirds of the sample were asked a module of questions on genetics (N=2258). A battery of six questions, used here to assess respondents' knowledge of general science, was administered via self-completion to one-third of the sample (N=1134). With a response rate of 86% for these self-completion questions, this analysis is based on a weighted sample² of 976 respondents who answered questions about general science and attitudes to genetics.

We examine questions on general attitudes towards science and towards genetic research. In addition, a number of specific applications of genetic technology are covered: the use of genetic data by an employer or insurance company, gene therapy, abortion and pre-implantation genetic diagnosis. The majority of questions had 5-point ordinal response scales. These were dichotomised so that all responses that could be seen as consistent with a pro-science or pro-biotechnology position were coded 1, all other responses zero (see appendix for wording of individual items). None of the six items in the battery of knowledge questions related specifically to genes or genetics. Respondents were given statements on topics that included the greenhouse effect, exposure to radioactivity and man-made chemicals, and asked to rate each on a 5 point scale ranging from 'definitely true' to 'definitely not true' (see appendix for wording of items). To construct a measure of general scientific knowledge, responses on each item that were definitively correct were scored +1 and all other answers (including a more tentative 'probably correct' response) were coded zero. The six items were then summed to produce a 7-point

scale ranging from zero to six (Cronbach's Alpha = 0.66). A histogram of knowledge scores is presented in the Appendix.

In 1999, the Wellcome Trust commissioned a consultative panel survey on attitudes to gene therapy to assess how the provision of information affects public opinion on this application of genetic technology. Our analysis uses data from the baseline survey of public attitudes based on a representative sample of adults aged 18 and over in Great Britain. A total of 696 interviews were achieved for this survey, representing a response rate of 58 percent (Stratford, White & Park, 2002).

As well as gauging the general attitudes of the public towards science and genetic science, questions in the survey also probed respondents about particular applications of gene therapy they found acceptable or unacceptable. Scenarios were developed for different medical conditions ranging from cystic fibrosis to baldness. For each medical condition, respondents were questioned about their attitudes towards the use of somatic gene therapy (where changes made to genes would not be inherited by any future children), germ-line gene therapy (where changes would be inherited) and in-utero therapy (where changes would be made before birth but could not be inherited). Appraisals were based on whether each application should be 'definitely allowed' through to 'definitely not allowed'. For these items and for expressed agreement or disagreement with general attitude statements, responses were dichotomised so that all responses that could be seen as consistent with a pro-science or pro-biotechnology position were coded 1, all other responses zero (see appendix for wording of individual items).

The survey included a battery of nine factual questions, relating specifically to biology and genetics, to which respondents gave a true or false answer. To construct an additive measure of genetic knowledge for this analysis, correct responses on each item were scored 1 and all other answers (including 'don't know') were coded zero. Raw scores on the summed scale range from zero, when none of the nine questions were answered correctly, to nine for a fully correct set of responses (Cronbach's Alpha = 0.51)³. A histogram of scale scores is presented in the appendix.

² Data weighted to reflect the probability of selection of addresses, households and individuals.

ANALYSIS

We examine how knowledge in the domains of general science and genetic science are related to attitudes toward biotechnology using a regression-based modeling technique. This technique was developed in political science to investigate the impact of political knowledge on issue and vote preferences (Bartels, 1996; Delli-Carpini and Keeter, 1996; Althaus, 1998; 2001; Gilens 2001; Sturgis, 2003). It provides statistical estimates of how public opinion might look if everyone shared a higher (or lower) level of relevant formal knowledge. In accordance with Althaus (1998; 2001), Gilens (2001) and Sturgis (2003) the simulation models are logit regressions with the following structure:

$$\text{Ln}(P/(1-P)) = \alpha + \beta_1 I_i + \sum \beta_k D_{ik} + \sum \delta_k (I_i * D_{ik}) + e_i$$

Where $\text{Ln}(P/(1-P))$ is the log of the odds of being in category 1 of a binary variable indicating respondent endorsement of an attitudinal proposition; I_i is respondent i 's level of scientific knowledge; D_{ik} is respondent i 's score on the k^{th} socio-demographic variable; $I_i * D_{ik}$ is the interaction of respondent i 's level of scientific knowledge with their score on the k^{th} socio-demographic variable; and e_i is the error of prediction. β_1 , β_k and δ_k are the respective regression coefficients for the main effects and the interaction terms of knowledge and socio-demographic variables.

The analysis proceeds in three stages. First, a logistic regression model is fitted to predict the likelihood of a favourable attitude toward biotechnology using just demographic variables as predictors. At stage two, the knowledge variable and interactions between this variable and all demographic variables are added to the model. The interaction terms allow for the possibility that the direction of the relationship between knowledge and attitude varies across individuals and groups. At this stage we should observe a significant improvement in model fit (as indicated by the difference in Likelihood Ratio between the two nested models) if knowledge is significantly related to attitude. At the third stage, predicted probabilities are run out from the parameters estimated at stage two, but with knowledge scores changed to the highest possible score on the scale for all respondents. These predicted

³ While this is below the traditional 0.7 benchmark of acceptable scale reliability, a Confirmatory Factor Analysis reveals that a one factor model fits the data well, according to conventional fit indices.

probabilities can then be compared to those from the model with unadjusted knowledge scores at both the individual and aggregate level. The difference between the two figures provides a measure of how individual and collective opinion might look if everyone were as well-informed as the currently best informed members of the population.

The following socio-demographic covariates were included in the models fitted to both data-sets: age (years); gender; educational qualifications; social class; parental status; reported genetic illness in the family; self-reported long-term disability or illness; religion and current employment status. These covariates cover many of the characteristics found to be associated with the distribution of scientific and genetic knowledge (Durant et al. 1992; Miller, 1998; Midden et al. 2002; Gaskell et al. 2003a). Following Bartels (1996) and Sturgis (2003), more proximal attitudinal variables, which might improve overall model fit, were omitted as covariates in the models as these are likely themselves to be partially determined by scientific knowledge.

RESULTS

First we consider the results of the models fitted to the British Social Attitudes Survey data. Table 1 shows 25 attitudinal items from the BSA, with the percentage of respondents who endorsed a view that can be seen as broadly favourable towards biotechnology in column 2. The estimated proportion of the sample who adopt the same viewpoint under full information⁴ is given in column 3 and the magnitude and direction of the change in opinion in column 4. Statistically significant ‘knowledge effects’ at the 95% confidence level or below are indicated by an asterisk adjacent the change score in column 4.

TABLE 1 ABOUT HERE

The table shows significant shifts in opinion for 10 out of the 25 (40 percent) items examined under full general scientific knowledge. Taken together, the average magnitude of aggregate change across all 25 items in table 1 is 10 percent, with the majority of items changing by 10 percent or less under full information. In 20 out of

⁴ We use the term ‘full information’ to denote opinions estimated assuming the top score on the science knowledge measure.

25 items (80%), informed opinion became more favourable, that is, people expressed a view that can be interpreted as more supportive of science, biotechnology or its applications. However, in only 8 of these 20 items were the changes statistically significant ($p < 0.05$). Of these, most notable were the strong positive shifts in general attitudes towards science (items 1a and 1b). The largest shift in opinion was found for item 1d, namely, 'research into human genes does more harm than good' where disagreement with this proposition increased from 48 percent to a majority of 80 percent when opinion was 'fully informed'.

Similar changes, though of smaller magnitude, were evident for specific applications of genetic technologies. In all four items relating to Pre-implantation Genetic Diagnosis (PGD), a technique whereby embryos created by in-vitro fertilisation are genetically screened prior to implantation in the womb, informed opinion became more favourable. Under full information, a majority endorsed this technique as a way of preventing serious mental or physical disability in children (items 4a and 4b). The magnitudes of these changes were generally large (15% or more) and all were statistically significant. The pattern of change was similar for attitudes to abortion as a result of genetic tests conducted on foetuses (3a to 3d in table 1). Simulating full scientific knowledge showed a majority condoning the use of abortion for serious mental or physical disability diagnosed in a foetus. Informed opinion was also more tolerant toward the abortion of a foetus that would become a healthy child but die early (item 3c) or grow no taller than an 8-year old (item 3d). Only in the last of these items, however, was opinion change statistically significant.

Simulating better informed opinion did not, though, have a uniformly positive effect on attitudes towards biotechnology. Items relating to uses of genetic data generally had less public support under full information. Informed opinion was more strongly against the use of genetic data by insurance companies (item 2a) and the right of employers to have access to the genetic test results of employees (item 2b), but not the right of employers to make job applicants take genetic tests (item 2c). Under full information, respondents were less likely to endorse the right of employers to compel employees to undergo genetic tests to assess their sensitivity to workplace chemicals, but at 72 percent, this retained the support of the clear majority. Information effects for attitudes to gene therapy tended to be small, with six out of nine items showing a change of 5 percent or less and none significantly different from zero at the 95% level of confidence or below. In general, changes were

in a positive direction; with opinion moving to a more favourable position in all but two items.

Overall, then, these models show that general scientific knowledge does appear to influence the favourability of opinion toward genetic science and its applications. In the majority of items analysed, informed opinion became more favourable toward genetic research, although most of these shifts in opinion were rather modest in magnitude. However, general scientific knowledge did not have a uniform impact across all contexts; informed opinion showed a marked increase in support for techniques that prevent or treat specified medical conditions but a more negative appraisal of the wider uses of human genetic information.

INSERT TABLE 2 ABOUT HERE

Table 1, of course, shows only how informed opinion might look at the aggregate level. However, because equivalent increases in knowledge can shift individual level opinion in opposite directions, it is likely that many of these aggregate effects mask a good deal of opinion change at the individual level. This is because people moving in opposite directions on these attitude measures will cancel one another out, reducing the apparent overall level of opinion change as a result of increased knowledge. Table 2 shows the average magnitude of opinion change at the individual level for each item that was statistically significant in Table 1 along with the percentage that became more positive or more negative on each item under full information⁵.

Two important things should be noted from Table 2: first, individual level change is typically greater than that found in the aggregate; second, individual level opinion becomes both more positive and more negative under full information on all but one of the items examined. For attitudes towards the use of genetic data, for instance, Table 2 shows that relatively modest aggregate changes in opinion can mask considerable individual level volatility. Agreement that employers should have the right to see a genetic test of an employee (item 2d) decreased by 5 percentage points in the aggregate but the mean amount of change at the individual level for this item was more than double this, at 12 percent.

⁵ Note, these proportions do not sum to 100% because on all items some respondents showed no opinion change.

However, Table 2 also shows that, on a number of items, individual level change was very similar to that found in the aggregate. For, example, general attitudes towards science and biotechnology (items 1a, 1b) showed only 1-2% more change at the individual level than they did in the aggregate and approximately 90% of opinion change was positive. This suggests that the magnitude of aggregate level information effects is determined as much by the direction of the knowledge-attitude relationship across social groups, as it is by the strength of the relationship *per se*.

Next, we turn to a consideration of the results of the models fitted to the Wellcome data, where we use a domain-specific measure of genetic knowledge as opposed to a measure of general scientific knowledge. The 23 attitudinal items listed in this table all relate to general and specific attitudes toward different applications and contexts of gene therapy.

INSERT TABLE 3 ABOUT HERE

Table 3 shows significant shifts in opinion for 10 out of the 23 (46%) items examined in the Wellcome data. Nearly three-quarters of these changes were of 10 percentage points or less, with the average magnitude of aggregate change across all items being 9 percent. Increased knowledge of genetics had a positive impact on all of the more general attitude items (1a to 1n). That is, with a high level of genetic knowledge, respondents were more likely to agree with the general idea that genetic science will improve lives and should be encouraged by society and to disagree with arguments to the contrary. The magnitude of these information effects did, however, vary quite considerably. The largest effect was for the item ‘changing genes should be forbidden as tampering with nature’ with 26 percent more respondents disagreeing with this statement under full information. It is notable that for this item and other general attitudes where the magnitude of change was 15% or above (1a, 1h and 1j), the baseline percentage already shows majority support. In no instance did informed opinion change the majority viewpoint to show a switch in collective preference - these attitudinal propositions already had a high level of public endorsement. In contrast, however, the baseline percentage supporting the testing of new genetic treatments on children was low (14%) but significantly increased to one-quarter of respondents under full information. So, quite large changes in opinion were evident across a broad range of baseline, or starting values.

Items 2a to 2i in Table 3 focus on public attitudes to applications of gene therapy and distinguish between somatic therapy, germ-line and in-utero therapy. Respondents were asked about the acceptable uses of gene therapy for three named conditions - cystic fibrosis, heart disease and baldness - permitting comparison of the information effects for conditions of differing severity and impact on the individual. Although the information effects on these items were generally small in magnitude - 6 out of the 9 items changed 5 percent or less, there was some indication that a more knowledgeable public would be more supportive of gene therapy for the more serious conditions of heart disease and cystic fibrosis but not for the far from life-threatening condition of baldness. Indeed, none of the items relating to gene therapy for baldness showed an increase in favourability under full information and two showed a decline in support, though these were non-significant.

Table 4 shows that, as with the models fitted to the BSA data, the statistically significant changes in aggregate opinion under full information conceal considerable individual level change. Average change scores across items were 15% and 20% at the aggregate and individual levels respectively. Although the majority of opinion change was in a positive direction, all items showed some degree of movement in both a more favourable and a more negative direction. Being more knowledgeable about biology and genetics does not therefore have a uni-directional effect on attitudes, but causes opinion to move in a more negative or more positive direction, depending on the issue and the social location of the individual.

INSERT TABLE 4 ABOUT HERE

How do these effects for a domain specific knowledge measure compare with those found for general scientific knowledge in the BSA data? A straightforward comparison is not, of course, possible as we are dealing with different sample sizes and different attitudinal dependent variables in each data set. These reservations notwithstanding, though, the pattern of results is remarkably similar across studies. Simulating full information produced statistically significant shifts in opinion on approximately 40 percent of the items examined using either a domain specific or a general measure of scientific knowledge. Similarly, the majority of items became more favourable toward genetic science in both the Wellcome and the BSA data and the average aggregate change figures across all items were almost identical at

approximately 10% and 9% respectively. Overall then, there appears to be little to discriminate between the effects of these two different measures of scientific knowledge; both seem reliably related to public attitudes, moving opinion in a predominantly more favourable direction and both exert considerably greater influence on individual level opinions than they do in the aggregate.

DISCUSSION

The accepted wisdom in sociological treatments of public opinion toward science and technology has come to be that what individuals and groups 'know' about science is unrelated to the preferences they express. Indeed, the idea that attitudes are underpinned by scientific knowledge (or ignorance) has come under such sustained attack of late that the Third House of Lords report on Science and Technology (2000) concluded that the term 'public understanding of science' should be dropped from future funding initiatives. In many ways, this springs from a wholly appropriate reaction to a longstanding and patronising view of citizens which casts resistance to technological 'innovation' as based on ignorance, superstition and fear. In the light of recent sociological work in this area, it is clearly no longer legitimate for scientists and policy makers to assert that public opposition to new technologies emanates from a lack of understanding of the underlying scientific 'facts'. The extant literature on what is now becoming known by the more neutral moniker of 'science in society' is replete with empirical demonstrations that to concentrate solely on scientific knowledge overlooks other, more important determinants of public attitudes toward science and technology.

We do not seek here to disagree with this general position but argue instead that the empirical evidence does not support so strong a rejection of scientific knowledge as a factor which serves to, at least partially, shape and mould the distribution of opinion toward science. Across two different, nationally representative data sets, we find statistically significant 'information effects' on approximately half of the nearly fifty different items examined. These effects are, of course, net of other important determinants of public attitudes such as, *inter alia*, age, sex, education and social class. We do not present these covariates as an exhaustive list of all possible determinants of attitudes to genetic science; our goal here is not to maximise the explanatory power of our model but to examine how scientific knowledge impacts on attitude within a broad range of more or less fixed

demographic characteristics. We purposely excluded from our analysis other, more psychological variables such as trust and risk perception (Priest, Bonfadelli and Rusanen, 2003), that may themselves moderate the knowledge-attitude relationship, as these are likely themselves to be partially determined by knowledge. The exclusion of such variables means that our estimates of 'informed opinion' must be treated with some caution and should not simply be considered as straightforward estimates of what a better informed public would think on specific aspects of genomic science and technology. In future work we aim to extend this analysis to focus on how these more proximal variables impact on the findings we have presented here.

These reservations notwithstanding, the over-riding direction of opinion change in these models was in a direction more favourable toward science in general and biotechnology in particular. That is to say, these results should lead us to expect a more scientifically knowledgeable public to be broadly more positive about science and the biotechnology applications examined here, all of which pertain to human genomics. This conclusion must be qualified by two important caveats; on several issues informed opinion became more oppositional and on almost all items the direction of opinion change was not uni-directional at the individual level. The latter point is often overlooked or misunderstood in critiques of analyses which point to a positive relationship between knowledge and attitude. A positive correlation should not lead us to conclude that more knowledge will lead to more favourable attitudes in all individuals. Indeed, the evidence presented here should lead us to quite the opposite conclusion. However, in any analysis of preference change on a single dimension over time, individuals moving in opposite directions will cancel each other out, with the majority movers appearing to 'win' in the aggregate. So, while knowledge appears to affect different individuals' attitudes in different ways, the general pattern in the items we have examined here suggests that the dominant direction of movement is toward increased support of science and biotechnology.

Our choice of biotechnology as the focus of these analyses was quite deliberate; public knowledge is low and opposition high in most contexts in which it has been studied. A strong candidate, therefore, for claims – and counter-claims – that resistance to its associated applications and technologies is rooted in ignorance of the underlying science. Furthermore, by focussing on a specific area of modern science, rather than science in general, we can be more confident that our findings

relate to real citizen preferences toward the practices which together constitute the field of modern genetic science, as opposed to symbolic responses to some abstract notion of 'science'. Our findings, then, lead us to conclude that knowledge of science, whether at a more general or a domain specific level, is one of a number of important determinants of public attitudes toward applications of biotechnology that focus on human genomics. And, while we would not wish to endorse a return to a naive deficit model of public understanding, we would contend that an outright rejection of a role for scientific knowledge is, perhaps, as empirically myopic as the position it sets out to critique.

BIBLIOGRAPHY

Agricultural and Environment Biotechnology Commission (2001) *Crops on Trial*. AEBC: London.

Althaus, S.L. (1998) Information Effects in collective preferences. The American Political Science Review, 92, 3: 545-58.

Althaus, S.L. (2001) Who's voted in when the people turn out? In Hart, R.P and Shaw, D. (eds) Communication in US Elections: new agendas. MD: Rowman & Littlefield.

Bartels, L.M. (1996) Uninformed votes: information effects in presidential elections. American Journal of Political Science, 40, 1: 194-230.

Bauer, M., Perkova, K., and Boyadjieva, P. (2000) 'The Public Knowledge of and Attitudes to Science: Alternative Measures That May End the 'Science War'', in Science, Technology, & Human Values, 25, 1: 30-51.

Bennett, S.E (1988) "Know Nothings" Revisited: the meaning of political ignorance today. Social Science Quarterly, 17: 422-35.

Delli Carpini, MX. and Keeter, S. (1996) What Americans Know About Politics and Why It Matters. New Haven, CT: Yale University Press.

Department of Health (2003) Our inheritance, our future: realising the potential of genetics in the NHS. Cm 5991. London: The Stationary Office.

Department of Trade and Industry (2003) GM Nation?: The findings of a public debate. HMSO: London.

Doble, J. (1995) Public opinion about issues characterized by technological complexity and scientific uncertainty. Public Understanding of Science, 4: 95-118.

- Downs, A. (1957) An Economic Theory of Democracy. Harper and Row: New York.
- Durant, J., Evans, G. & Thomas, G. (1992) Public understanding of science in Britain: the role of medicine in the popular representation of science. Public Understanding of Science, 1: 161-82.
- Durant, J., Hansen, A., Bauer, M. (1999) Public understanding of the new genetics. Chapter 11 in Marteau, T. & Richards, M. (Eds) The Troubled Helix: social and psychological implications of the new human genetics. Cambridge: Cambridge University Press.
- Evans, G. & Durant, J. (1992) The relationship between knowledge and attitudes in the public understanding of science in Britain. Public Understanding of Science, 4: 57-74.
- Gaskell, G., Allum, N. & Stares, S. (2003a) Europeans and Biotechnology in 2002. Eurobarometer 58.0. A report to the EC Directorate General for Research from the project 'Life Sciences in European Society'.
- Gaskell, G., Allum, N., Bauer, M., Jackson, J., Howard, S., & Lindsey, N. (2003b) Ambivalent GM Nation? Public attitudes to biotechnology in the UK, 1991- 2002. Life Sciences in European Society report: LSE.
- Gilens, M. (2001) Political ignorance and collective policy preferences. American Political Science Review, 95, 2: 379-96.
- Hampel, J., Pfenning, U and Peter, H. (2000) Attitudes towards genetic engineering. New Genetics and Society, 19, 3: 233-49.
- House of Lords Science and Technology select committee (2000) Science in Society. Third Report of session 1999-2000. HMSO: London.

Human Genetics Commission (2001) Public attitudes to human genetic information. People's Panel Quantitative Study. HGC: London. URL: www.hgc.gov.uk

Irwin, A. & Wynne, B. (1996) Misunderstanding Science? The public reconstruction of science and technology. Cambridge: Cambridge University Press.

Kerr, A., Cunningham-Burley, C. & Amos, A. (1998) The new genetics and health: mobilizing lay expertise. Public Understanding of Science, 7: 41-60.

Midden, C., Boy, D., Einsiedel, E., Fjæstad, B., Liakopoulos, M., Miller, JD, Öhman, S. & Wagner, W. (2002) The structure of public perceptions. Chapter 7 (pp. 203-223) in Durant et al. (Eds.) Biotechnology: the making of a global controversy.

Miller, J.D. (1983) Scientific Literacy: a conceptual and empirical review. Daedalus, 112: 29-48.

Miller, J.D. (1987) Scientific Literacy in the United States. In Communicating Science to the Public. Evered, D. and O'Connor, M. (Eds) London: Wiley.

Miller, J.D. (1998) The measurement of civic scientific literacy. Public Understanding of Science, 7: 203-223.

MORI (2003a) Seven in ten members of the public support the use of embryos for medical research. MORI poll for Association of Medical Research charities, April 2003.

MORI (2003b) 'GM food opposition continues'. MORI Social Research Institute, July 2003.

National Science Foundation (2001) NSF Survey of public attitudes toward and understanding of Science and Technology. National Science Foundation.

Nuffield Council on Bioethics (1993) Genetic screening: ethical issues. London: Nuffield Foundation.

Pardo, R., Midden, C. & Miller, J.D. (2002) Attitudes towards biotechnology in the European Union. Journal of Biotechnology, 98: 9-24.

Park, A., Curtice, J., Thomson, K., Jarvis, L. and Bromley, C. (2001) The British Social Attitudes Survey: 18th Report. National Centre for Social Research. London: Sage.

Pfister, H., Böhm, G. and Jungermann, H. (2000) The cognitive representation of genetic engineering: knowledge and evaluations. New Genetics and Society, 19, 3: 296-316.

Priest, S.H., Bonfadelli, H. and Rusanen, M. (2003) The 'Trust Gap' Hypothesis: predicting support for biotechnology across national cultures as a function of trust in actors. Risk Analysis, 23, 4: 751-66.

Shapin, S. (1992) Why the public ought to understand science in the making. Public Understanding of Science, 1, 27-31.

Stratford, N., White, C. and Park, A. (2001) Consultative panel on gene therapy: technical report. Report submitted to Wellcome Trust, London.

Sturgis, P. (2003) Knowledge and collective preferences: a comparison of two approaches to estimating the opinions of a better informed public. Sociological Methods and Research, 31, 4: 453-85.

Sturgis, P. and Allum, N. (in press) Science in Society: re-evaluating the deficit model of public attitudes. Public Understanding of Science.

Sturgis, P. and Allum, N. (2001). Gender differences in scientific knowledge and attitudes toward science: reply to Hayes and Tariq. Public Understanding of Science, 10(4), 427-430.

Turney, J. (1995a) The Public Understanding of Genetics - where next? European Journal of Genetics in Society, 1, 2: 5 - 20.

Turney, J. (1995b) Signs of Life – Taking Genetic Literacy Seriously. The Genetic Engineer and Biotechnologist, 15, 2&3: 181- 87.

U.S Congress, Office of Technology Assessment (1987) New Developments in Biotechnology – Background paper: Public perceptions of biotechnology. OTA. Washington, DC: US Government printing office.

Wellcome Trust (1998) Public Perspectives on Human Cloning. London: Wellcome Trust.

Wellcome Trust (forthcoming, 2004) Consultative Panel on Gene Therapy. London: Wellcome Trust.

Wynne, B. (1991) 'Knowledges in context', Science, Technology and Human Values, 16, 1: 111-21.

Yearly, S. (2000) 'Making systematic sense of public discontents with expert knowledge: two analytical approaches and a case study'. Public Understanding of Science, 9, 2: 105-22.

APPENDIX

1. 2000 British Social Attitudes Survey (BSAS)

Wording & Coding of Items in measure of General Scientific Knowledge

1. Antibiotics can kill bacteria but not viruses (true).
2. Human beings developed from earlier species of animals (true).
3. All man-made chemicals can cause cancer if you eat enough of them (false).
4. If someone is exposed to any amount of radioactivity, they are certain to die as a result (false).
5. The greenhouse effect is caused by a hole in the earth's atmosphere (false).
6. Every time we use coal or oil or gas, we contribute to the greenhouse effect (true).

Response options for these questions were: definitely true; probably true; probably not true; definitely not true or can't choose. Correct answers are given next to each question above. Only definitively correct responses were scored + 1, all other answers (including non-substantive responses and item non-responders) were coded zero. Items were then summed to produce a 7-point scale ranging from 0 to 6. Figure A1 shows the distribution of knowledge scores on this measure.

Wordings & Coding of Attitude Items

Response categories for the following items were: strongly agree; agree; neither agree nor disagree; disagree and strongly disagree. Dichotomies were formed by coding responses consistent with a pro-science/biotechnology position as 1, all other responses 0.

General Attitudes

- **Item 1a:** [Disagree that] we believe too often in science and not enough in feelings and faith.
- **Item 1b:** [Disagree that] overall, modern science does more harm than good.
- **Item 1c:** [Agree that] people at risk of having a child with a serious genetic disorder should not start a family.
- **Item 1d:** [Disagree that] research into human genes will do more harm than good.

Use of Genetic Data

Response categories for the following items were: definitely should; probably should; don't know; probably should not; definitely should not. Dichotomies were formed by coding 'definitely should' and 'probably should' as 1, all other responses 0.

People can take genetic tests to tell them whether they are likely to develop a serious genetic condition in the future. In your opinion...

- **Item 2a:** [Agree genetic tests should be used] by insurance companies to accept or refuse people for life insurance policies.
- **Item 2b:** [Agree the employer should] have the right to see the result of this test.
- **Item 2c:** [Agree the employer should] have the right to make [job] applicants have a test.
- **Item 2d:** [Agree the employer should] have the right to make applicants have a test to see if they are particularly sensitive to chemicals that may be used in the workplace.

Abortion and Pre-Implantation Genetic Diagnosis (PGD)

Response categories for the following items were: always right; sometimes right and never right. Dichotomies were formed by coding 'always right' as 1, other responses 0.

[Agree] it would be always right for the woman to have a legal abortion if the child was very likely to ...

- **Item 3a:** be born with a serious mental disability and would never be able to live an independent life.
- **Item 3b:** be born with a serious physical disability and would never be able to live an independent life.
- **Item 3c:** be born with a condition that meant it would live in good health, but then would die in its twenties or thirties.
- **Item 3d:** be healthy but would never grow taller than an eight year old.

There is another way in which couples can try and avoid having a child with a serious medical condition. The woman's eggs are fertilised outside her body with her partner's sperm and genetically tested. Only eggs without the condition are put back and may then grow into a baby. Suppose it was likely that a couple would have a child ...

- with a serious mental disability (**item 4a**).
- with a serious physical disability (**item 4b**).
- which would live in good health but then would die in its twenties or thirties (**item 4c**).
- which would be healthy but would never grow taller than an eight year old (**item 4 d**).

Gene Therapy

Response categories for these items were: definitely allowed; probably allowed; probably not allowed; definitely not allowed. Dichotomies were formed by coding 'definitely allowed' and 'probably allowed' as 1, all other responses 0.

Suppose it was discovered that a person's genes could be changed. Do you think that this should be allowed or not allowed to ...

- make a person taller or shorter (**item 5a**)
- make a person more intelligent (**item 5b**)
- make a person straight, rather than gay or lesbian (**item 5c**)
- reduce a person's chances of getting heart disease (**item 5d**)
- make a person of average weight, rather than very overweight (**item 5e**)
- determine the sex of an unborn baby (**item 5f**)
- to give someone a full head of hair, rather than being bald (**item 5g**)
- to stop someone having schizophrenia (**item 5h**)
- to make them less aggressive or violent (**item 5i**).

2. Wellcome Consultative Panel on Gene Therapy (1999)

Wordings & Coding of Items in measure of Genetic Knowledge

1. Identical twins have the same genes (true)

2. There are test tube babies who grew entirely outside the mother's body (false)
3. Genes of all living things on earth are made up of different combinations of only 4 or 5 chemical building blocks (true).
4. Down's Syndrome is an inherited disease (true)
5. Children look like their parents because they share the same type of red blood cells (false)
6. Half your genes come from your mother and half from your father (true)
7. Whether a couple have a girl or a boy depends on the woman's genes (false)
8. We have around 150,000 different chromosomes which contain our genes (false)
9. Most cells in our body contain a copy of all our genes (true).

Response options for these questions were: true, false or don't know. Correct answers are given next to each question above. Correct answers were scored + 1, all other answers (including non-substantive responses and item non-responders) were coded zero. Items were then summed to produce a 10-point scale ranging from 0 to 9. Figure A2 shows the distribution of knowledge scores on this measure.

Wordings & Coding of Attitude Items

Response categories for the following items were: agree strongly; agree; neither agree nor disagree; disagree and disagree strongly. Dichotomies were formed by coding responses consistent with a pro-science/biotechnology position as 1, all other responses 0.

- [Disagree] overall, modern science does more harm than good (**item 1a**).
- [Agree] science and technology make our lives healthier, easier and more comfortable (**item 1b**).
- [Disagree] science makes our way of life change too fast (**item 1c**).
- [Agree] genetic treatments for illness will do a lot to reduce human suffering (**item 1d**).
- [Disagree] changing a person's genes is too risky, whatever the benefits might be (**item 1e**).

- [Disagree] it is better to try to cure illness without changing people's genes (**item 1f**).
- [Agree] that in the end, research into human genes will do more to help us than to harm us (**item 1g**).
- [Disagree] it would be better if we did not know how to change people's genes at all (**item 1h**).
- [Agree] people worry too much about the risk of changing human genes (**item 1i**).
- [Disagree] we should never interfere with people's genes (**item 1j**).
- [Disagree] scientists should not look for genetic cures because the world will become too overpopulated (**item 1k**).
- [Disagree] changing genes should be forbidden as it is tampering with nature (**item 1l**).
- [Disagree] that rather than change the genes of disabled people we should provide facilities to make life easier for them (**item 1m**).
- [Agree that it] should be allowed to test new genetic treatments on children (**item 1n**).

Specific Applications of Gene Therapy

The following questions were asked about heart disease, baldness and cystic fibrosis. Response categories for these items were: definitely allowed; probably allowed; probably not allowed; definitely not allowed or it depends/need more information. Dichotomies were formed by coding 'definitely allowed' and 'probably allowed' as 1, all other responses 0.

I'd like you to think of [someone in their 20s who has serious heart disease/ a man in his 20s who is bald and feels very embarrassed about it/ someone in their 20s born with cystic fibrosis]. Suppose it was discovered that changing some of their genes by giving them an injection could [help treat their heart disease/ help his hair to grow back/ help treat their cystic fibrosis]. These new genes would not be passed onto any children they might later have. Do you think this should be allowed or not allowed? (items 2a, 2d, 2g).

Now, what if the new genes were passed onto their future children *[to give them less chance of getting serious heart disease in their 20s?/ so that they would not go bald in their 20s/ so that they would not have cystic fibrosis]*. Do you think this should be allowed or not allowed? **(items 2b, 2e, 2h).**

Now suppose a *[person's/ man's]* genes could be changed before they were born – by treatment while still in their mother's womb –*[to give them less chance of getting serious heart disease in their 20s/ to stop him going bald in his 20s/ so they would not have cystic fibrosis]*. The new genes would not be passed onto any children they later have. Do you think this should be allowed or not allowed? **(items 2c, 2f, 2i).**

Figure A1: Histogram for measure of General Scientific Knowledge (BSAS)

Figure A2: Histogram for measure of Genetic Knowledge (Wellcome Panel)

Table 1: **Information Effects for General Scientific Knowledge:**
Aggregate change: BSA 2000

BSAS ITEM	Actual %	Simulated %	Diff
1. General Attitudes			
a. Disagree that we believe too often in science, not enough in feelings & faith.	19	42	+ 23*
b. Disagree modern science does more harm than good.	49	73	+ 24*
c. Agree people at risk of child with genetic disorder should not start family.	41	43	+ 2
d. Disagree research into human genes does more harm than good.	48	80	+ 32*
2. Use of Genetic Data			
a. Agree tests used by insurance companies to set premiums.	16	13	- 3
b. Agree employers have right to see genetic test result.	18	13	- 5*
c. Agree employers have right to make applicants take genetic test.	8	12	+ 4
d. Agree employers right to test sensitivity to	83	72	- 11*

workplace chemicals.			
3. Abortion			
a. Agree abortion for serious mental disability.	49	60	+ 11
b. Agree abortion for serious physical disability.	42	54	+ 12
c. Agree abortion for child that will die in its 20s or 30s.	16	22	+ 6
d. Agree abortion for healthy child no taller than 8 yr old.	14	33	+ 19*
4. Pre-Implantation Genetic Diagnosis (PGD)			
a. Agree PGD for serious mental disability.	39	52	+ 13*
b. Agree PGD for serious physical disability.	38	53	+ 15*
c. Agree PGD for child that will die in its 20s or 30s.	29	52	+ 23*
d. Agree PGD for healthy child no taller than 8 year old.	27	49	+ 22*
5. Gene Therapy			
a. Agree gene therapy to make someone taller or shorter.	25	33	+ 8

b. Agree gene therapy to make someone more intelligent.	21	24	+ 3
c. Agree gene therapy to make someone straight, rather than gay or lesbian.	19	20	+ 1
d. Agree gene therapy to reduce chances of heart disease.	67	73	+ 6
e. Agree gene therapy to make someone of average weight.	40	44	+ 4
f. Agree gene therapy to determine sex of unborn baby.	15	15	0
g. Agree gene therapy to prevent baldness.	23	26	+ 3
h. Agree gene therapy to stop schizophrenia.	68	69	+ 1
i. Agree gene therapy to make less someone aggressive.	58	51	-7

All models control for: age (years); sex; genetic illness in family; long-term disability/illness; religion; RG social class; employment status; children; educational qualifications.

Source: British Social Attitudes Survey, 2000

Table 2: **Information Effects for Scientific Knowledge: Individual-level
change: BSA Data**

BSAS ITEM	Actual %	Simulated %	Aggregate Change	Absolute Individual Change	% +	% -
1. General Attitudes						
a. Disagree believe too often in science, not enough in feelings or faith.	19	42	23	24	89	10
b. Disagree modern science does more harm than good.	49	73	24	26	93	5
d. Disagree research into human genes does more harm than good.	48	80	32	32	98	0
2. Use of Genetic Data						
b. Agree employers have right to see genetic test result.	18	13	5	12	19	79

d. Agree employers should test for sensitivity to workplace chemicals.	83	72	11	15	29	69
3. Abortion						
e. Agree abortion if healthy child never taller than 8 year old.	14	33	19	21	74	24
4. Pre-Implantation Genetic Diagnosis.						
a. Agree PGD for severe mental disability	39	52	13	16	75	23
b. Agree PGD for severe physical disability.	38	53	15	18	86	13
c. Agree PGD for child that will die in its 20s or 30s.	29	52	23	24	86	13
d. Agree PGD for healthy child never taller than 8	27	49	22	24	84	14

year old.						
-----------	--	--	--	--	--	--

All models control for: age (years); sex; genetic illness in family; long-term disability/illness; religion; RG social class; employment status; children; educational qualifications.

Source: British Social Attitudes Survey, 2000.

Table 3: **Information Effects for Genetic Knowledge:**
Aggregate change: Wellcome Data

WELLCOME PANEL ITEM	Actual %	Simulated %	Diff
1. General Attitudes			
a. Disagree modern science does more harm than good.	69	85	+ 16*
b. Agree science & technology make lives healthier, easier and more comfortable.	79	82	+ 3
c. Disagree science makes our way of life change too fast.	37	47	+ 10
d. Agree genetic treatments will reduce human suffering.	76	84	+8*
e. Disagree changing genes is too risky whatever benefits	27	41	+ 14*
f. Disagree better to cure illness without changing genes.	11	18	+ 7
g. Agree research into human genes will do more to help us than harm us.	13	14	+ 1
h. Disagree better if not know how to change	58	77	+ 19*

genes.			
i. Agree people worry too much about risk of changing genes.	41	48	+ 7*
j. Disagree should never interfere with genes.	52	72	+ 20*
k. Disagree scientists should not look for genetic cures as world will be overpopulated.	68	80	+ 12*
l. Disagree changing genes should be forbidden as tampering with nature.	60	86	+ 26*
m. Disagree that, rather than change genes of disabled, should provide facilities for them.	20	28	+ 8
n. Agree with allowing new genetic treatments on children.	14	25	+ 11*
2. Gene Therapy			
a. Allow somatic gene therapy for heart disease.	82	87	+ 5*
b. Allow germ therapy for heart disease.	64	62	- 2
c. Allow in-utero therapy for heart disease.	49	59	+ 10
d. Allow somatic gene therapy for cystic	91	96	+ 5

fibrosis.			
e. Allow germ therapy for cystic fibrosis.	80	85	+ 5
f. Allow in-utero therapy for cystic fibrosis.	62	70	+ 8
g. Allow somatic gene therapy for baldness.	64	64	0
h. Allow germ therapy for baldness.	41	40	- 1
i. Allow in-utero therapy for baldness.	20	14	- 6

All models control for: age (years); sex; genetic illness in family; long-term disability/illness; religion; RG social class; employment status; children; educational qualifications.

Source: Wellcome Consultative Panel on Gene Therapy, 1999.

Table 4: **Information Effects for Genetic Knowledge: Individual-level change: Wellcome Data**

WELLCOME PANEL ITEM	Actual %	Simulated %	Aggregate Change	Absolute Individual Change	% +	% -
1. General Attitudes						
a. Disagree modern science does more harm than good.	69	85	16	16	88	9
d. Agree genetic treatments will reduce human suffering.	76	84	8	15	82	15
e. Disagree changing genes is too risky whatever benefits.	27	41	14	19	71	25
g. Disagree better not to know how to change genes.	58	77	19	22	96	1
h. Agree people worry too much about risk of changing genes.	41	48	7	17	59	38

i. Disagree should never interfere with genes.	52	72	20	24	85	11
j. Disagree scientists should not look for genetic cures as world will be overpopulate d.	68	80	12	20	78	18
k. Disagree changing genes should be forbidden as tampering with nature.	60	86	26	29	97	<1
n. Agree with allowing new genetic treatments on children.	14	25	11	15	68	28
2. Gene Therapy a. Allow somatic gene therapy for heart disease.	82	87	5	10	75	22

All models control for: age (years); sex; genetic illness in family; long-term disability/illness; religion; RG social class; employment status; children; educational qualifications.

Source: Wellcome Consultative Panel on Gene Therapy, 1999.