

HUMAN GENETICS AND INSURANCE ISSUES

BY A. S. MACDONALD

ABSTRACT

We consider the implications of increasing knowledge of human genetics for insurance and the provision of essential services. Mathematical models can provide essential guidance for policy-makers and others. We give an example based upon life insurance, and emphasise the need for more research, especially collaborations between actuaries, geneticists and epidemiologists.

KEYWORDS

Actuarial Science; Genetics; Insurance; Mathematical Models

AUTHOR'S ADDRESS

A. S. Macdonald, B.Sc., Ph.D., F.F.A., Department of Actuarial Mathematics and Statistics, Heriot-Watt University, Edinburgh EH14 4AS, U.K. Tel: +44(0)131-451-3209; Fax: +44(0)131-451-3249; E-mail: A.S.Macdonald@ma.hw.ac.uk

1. THE BASIS OF PRIVATE, VOLUNTARY INSURANCE

Everyone is familiar with the basis of insurance. The 40-year old owner of a modest family car who has never had a motor accident does not expect to pay the same premium as the 17-year old owner of a turbo-charged racer with nine points on his licence. We should expect to pay more for house insurance were we to move to a bigger house. The premium we pay is related to the risk we offer to the insurer. This principle is perfectly well understood by everyone, and is rarely challenged by buyers of motor or house insurance.

In fact, these examples of risk assessment demonstrate two quite different aspects. Part of the assessment is obviously quantitative; a car worth £30,000 costs more to insure than a car worth £10,000. But part appears to be qualitative; the insurer regards the 17-year old driver as a higher risk than the 40-year old driver, even if they drive identical cars.

It is the job of the actuary to quantify the qualitative aspects of risk; to collect and analyse large numbers of insurance histories and to find out whether or not 17-year old drivers are indeed more likely to have accidents than 40-year old drivers, and if so, how much more likely. This is a purely statistical approach; faced with any particular 17-year old driver, it is impossible to say that he or she is in fact a worse driver than the average 40-year old driver. The opposite might be true, but the fact that the insurer relies upon is that he or she belongs to a class of drivers that, on average, has more accidents than 40-year old drivers.

That is a brief, but sufficient, introduction to the mutual principle of insurance. The insured band together to pool their risks for the benefit of all, (which is mutual in principle even if the vehicle that allows them to do so is an insurance company owned by shareholders). Since they are all different, they pay a premium related to the risk of loss that they bring to the pool. That risk depends on:

- (a) a statistical assessment of the chance that a claim will arise, based on the features of the individual; and
- (b) the amount that will be paid if a claim is made. (In practice, the amount of a claim is often uncertain, and also requires a statistical approach, but we ignore that here.)

An alternative insurance principle depends on solidarity rather than mutuality. Under this system, the price paid for insurance is not related to the risk brought to the pool, but is fixed externally. For example, everyone might pay the same, or premiums might be related to ability to pay, as a proportion of income. This solidarity principle underlies the welfare state and the National Health Service in the U.K..

A crucial difference between the two principles lies in their respective abilities to operate in a market in which insurance is purchased voluntarily. An insurer using the solidarity principle might have difficulty coping, because almost no-one would be paying an actuarially fair price for their insurance cover. Those at low risk would be overcharged, and less inclined to insure, while those at highest risk would be undercharged and very willing to insure. In the presence of alternatives, such as other insurers operating under the mutual principle, low risks would defect, and only those paying less than the cost of their insurance would remain. Clearly, this is unworkable, and a insurer using a true solidarity principle cannot compete with mutual insurers unless it is compulsory to insure with it. The mutual principle, on the other hand, does work in a voluntary insurance market, because it prices individual risks.

In the U.K., the solidarity principle has dominated the provision of health care and long-term care, at least since 1945. There are private insurance markets in both cases, but so far these are junior partners. Private health insurance is quite common, but people who buy it do not contract out of the National Health Service. Probably fewer than 30,000 long-term care insurance policies have been sold in the U.K.. The life insurance market, in contrast, is large, mature and entirely run by private insurers under mutual principles. Moreover, the insured event, death, is well-defined and sufficiently undesirable that there is very little manipulation of claims. The same cannot be said of health and long-term care provision, where there is often a strong incentive on the part of the insured (or the insured's relatives) to claim.

Discrimination in insurance means charging different premiums for the same cover, because of different personal characteristics, such as age, sex or health, called 'risk factors' by insurers. This is sometimes controversial, leading to demands that the same premiums should be charged regardless of certain risk factors, such as race and sex. More recently, the possibility that genetic make-up might be used as a risk factor has led to rather heated debate between those who would see its use as unacceptable discrimination, and insurers who see dangers in grafting solidarity onto mutuality.

In this article, we will consider the costs that might arise if life insurers were not allowed to use genetic information known to applicants for insurance. Our conclusion is that they should not be great, but the maturity of the life insurance market, and the relative regularity of its claims, means that this conclusion might not carry over to the health and long-term care markets.

2. ADVERSE SELECTION AND THE RIGHT TO UNDERWRITE

Adverse selection means any increased tendency, on the part people at higher risk, to buy insurance. In the case of life insurance, this could take two forms:

- (a) a greater likelihood of buying insurance; and
- (b) a tendency to insure for higher amounts.

Under some other forms of insurance, where the amount insured is more closely linked to the delivery of care, the latter may be less important.

If adverse selection takes place, insurers will find that they are consistently undercharging for the risks they actually bear, and they will make losses. This, they would argue, is in nobody's best interests.

Clearly, adverse selection can only appear if the person has information that the insurer does not have, or is not allowed to use. Moreover, the information must be such as to motivate the person to buy insurance. Insurance law recognises this possibility, and is based on the principle of 'utmost good faith', which compels an applicant for insurance to make full disclosure of any relevant information known to them, the presumption being that the insurer may use this information to decide on a premium. Non-disclosure can be grounds for voiding the contract or refusing to pay a claim. The process of obtaining and evaluating information about an applicant is called "underwriting". Many insurers would say that their very soundness depends on "the right to underwrite", and thereby to protect their existing policyholders from adverse selection (Leigh, 1996).

There is little doubt that adverse selection can be a problem, but there is surprisingly little published information with which to prove it. Partly this is because the commercial nature of insurance does not usually lead either to the sharing of information — an insurer's data base can be a major asset — or to paying for research; and just possibly it is also because underwriting has been quite successful. An unfortunate result is that when underwriting becomes contentious, the debate is not illuminated by facts.

Insurers do not always underwrite to the full extent that the law would permit. It can be an expensive process, if reports from medical attendants or medical examinations must be called for, and modern life insurance is a mass market. Consequently, simplified underwriting is often used, especially for life insurance in connection with a mortgage; the aim is to accept as many proposals as possible on the basis of answers to a few questions on the proposal form, and to keep further expense to a minimum. Here, insurers make an explicit trade-off between cost and risk; the expense of admitting a few higher risk individuals into the risk pool is outweighed by the lower underwriting costs.

Underwriting leads to discrimination, by definition, and certain kinds of discrimination are now vigorously opposed. Chief among these are race, sex, disability and now genetic makeup.

3. ANTI-DISCRIMINATION LEGISLATION AND INSURANCE

In the United Kingdom, discrimination on the grounds of race, sex and disability is outlawed, though with exceptions. To the great irritation of many who oppose discrimination, insurance is among the exceptions in the cases of sex and disability (though not

race). The exemption is conditional, however, and the nature of the conditions could be very important as laws concerning genetic discrimination evolve in future.

The Sex Discrimination Act 1975 allows insurers to charge different premiums to men and women, provided there is actuarial evidence to justify the difference. Only one major case (*Pinder v. Friends' Provident* 1984) has exposed the meaning of actuarial evidence to the test, and it was won by the insurer.

The Disability Discrimination Act 1995 is more precise. Based on a model law from New Zealand, it allows insurers to discriminate provided it is on grounds for which there is relevant and reliable evidence, upon which it is reasonable to rely, having regard to other relevant factors. If we assume that a similar criterion might be applied to the use of genetic test information, the question comes almost within the grasp of the actuary or statistician.

In one sense, insurers might have understandable reasons to worry about genetic information more than sex or disability. Knowing one's sex, or that one is disabled, does not seem to carry an immediate incentive to buy insurance (though this does depend on how wide a definition of disability is used). Males suffer higher mortality than females, but do not for that reason rush to buy insurance and unbalance insurers' risk pools. The incentive that is needed for adverse selection is absent, or very weak. If men and women had to pay the same premiums, the insurer would have a little less knowledge about the composition of the risk pool, but that is all. Genetic test information, on the other hand, may seem to carry a powerful message of disease and death, and with it a desire for insurance. This is understandable, but it is perhaps exaggerated, as long as genetic testing takes place in a responsible, well-supported clinical setting, as is the case in the U.K..

4. GENETICS AND INSURANCE IN THE UNITED KINGDOM

Before 1995, the insurance industry appeared to pay little attention to developments in human genetics. In particular, it seemed to assume that it would not, and should not, encounter any serious obstacles to using such genetic test information as might become available in future. The House of Commons Science and Technology Select Committee reported on human genetics in 1995, including insurance issues. The Association of British Insurers (ABI), in its evidence, concentrated on the dangers of adverse selection, but the Select Committee appeared to give more weight to other concerns, and gave the industry a year to formulate proposals that would meet demands for access to insurance. The Government did not accept this, but the problem did not go away.

The lack of published research on underwriting and adverse selection was mentioned above: the Select Committee episode is a striking example. There was no quantitative evidence on either side, even allowing for the problems of quantifying the impact of very new research. The insurers could not say whether lack of access to genetic test results might cost the industry £1 or £1,000,000,000, and therefore had to base their case on the principle of the 'right to underwrite'. Those opposing the insurers had mostly anecdotal evidence (including the treatment, a decade before, of applicants who had been tested for HIV).

In September 1996, a joint meeting of the Royal Society, the Institute of Actuaries and the Faculty of Actuaries took place, at which the actuarial speakers took the view

that genetic testing was not likely to be much of a problem for life insurance, with two exceptions:

- (a) if applicants for very high sums assured need not disclose genetic test results; and
- (b) in the case of the relatively small number of rare single gene disorders, which are currently underwritten on the basis of family history.

These conclusions were in agreement with the results of the first quantitative work on insurance costs (Macdonald, 1997) which were presented at the meeting, and which are summarised in Section 6. No conclusions were reached in respect of other kinds of insurance.

Early in 1997, the ABI announced:

- (a) the appointment of Professor J. A. Raeburn, a clinical geneticist, as its genetics adviser;
- (b) a 2-year moratorium on the use of genetic test results for applications for life insurance of up to £100,000, if made in connection with a mortgage;
- (c) a ban on charging lower premiums to applicants with 'good' genes; and
- (d) a code of conduct with which member companies had to agree to comply.

The implementation of the ABI's code was a considerable achievement, since the ABI represents but does not command its member companies, among which there is a wide range of views on genetic testing. Some companies would like to treat it on a purely commercial basis, like any other risk factor; others are genuinely concerned about the potential for adverse selection; some go even further than the ABI, and have announced that they have no wish to see any genetic test results for the foreseeable future.

At the same time, the Government announced the formation of the Human Genetics Advisory Commission (HGAC), which would advise it on all aspects of human genetics. It made insurance its first priority, and reported in December 1997. Like the Select Committee, it proposed a moratorium on the use of genetic test results, and it was particularly critical of the research base of the insurance industry. The Government responded to the HGAC in late 1998, and announced the formation of a Genetics and Insurance Committee (GAIC), acting under the auspices of the Advisory Commission on Genetic Testing (ACGT). The GAIC's job would be to assess the accuracy and reliability of specific genetic tests, and to rule on whether or not insurers could use them. Thus, the legal principle of allowing discrimination based on statistical evidence was upheld, but a formal method of assessment was created.

The GAIC met for the first time in early 1999. It will be interesting to see what criteria it adopts, and how it deals with the list of seven (originally eight) single-gene disorders which Professor Raeburn advised the ABI were significant for underwriting applications outside the terms of the moratorium. Even more interesting will be the reception of any decision that a given genetic test can be used by insurers; it is possible that the current period of relative calm will end then.

5. LIFE INSURANCE UNDERWRITING

The surprising feature of life insurance underwriting is its relative simplicity. There is one basic premium rate, called the ‘Ordinary Rate’ (OR), though nowadays this is split by gender and smoking habits. The OR rate is the rate paid by an applicant who is in reasonably good health. It has not been the custom to try to identify super-fit lives, and offer them preferential rates. This practice, called ‘cherry-picking’ or ‘preferred lives underwriting’, is more common in the United States, and it could spread to the UK, but so far it has only been adopted by a few UK insurers.

Because of its inclusiveness, the OR class includes people of slightly poorer than average health; some estimates are of up to 130% or 150% of the average rates of mortality. If the information provided to the underwriter indicates a poorer outlook than this, because of past poor health or family history, then an increased premium may be charged, typically a multiple of the OR premium. Once the increased premium exceeds about 400% of the OR premium, the application is usually declined.

About 95% of applications are accepted at OR, 4% are accepted with an increased premium, and 1% are declined. This pattern is repeated reasonably consistently elsewhere in Europe. It has significant consequences for the impact of genetic test data on life insurance:

- (a) Single gene disorders, such as Huntington Disease, can present a significantly increased risk to the insurer, because death at relatively early ages, when most people still have some life insurance cover, is more likely.
- (b) Multifactorial disorders, in which one or more genes, along with environment and lifestyle, alter the predisposition to some disease, have much less significance. Their effect on the mortality rates may often be small; given the composition of the OR class, an increase of 10% or even 20% of average mortality rates will not usually matter. Moreover, it may be very difficult to disentangle the contribution of each gene, the environment and lifestyle, which is of great significance in view of the task given to the GAIC.

Moreover, these considerations exclude the possibility that genetic research will lead to improvements in health, through gene therapy, better targetted drugs or changes in lifestyle.

Good references for further information are Leigh (1990) and Brackenridge & Elder (1992).

6. A MATHEMATICAL MODEL OF GENETIC TESTING AND INSURANCE

Macdonald (1997, 1999) used a simple mathematical model to represent the life history of a person who might have a genetic test, buy insurance, and die. The mathematical details can be found in these papers; they are omitted here. Figure 1 represents the model.

The boxes are called ‘states’, and the arrows show possible transitions between states. A person starts in the first state, with no life insurance and not having had a genetic test. From there, the person can buy insurance without having a genetic test, or can have a genetic test with a positive (adverse) or negative result, and then can decide whether or

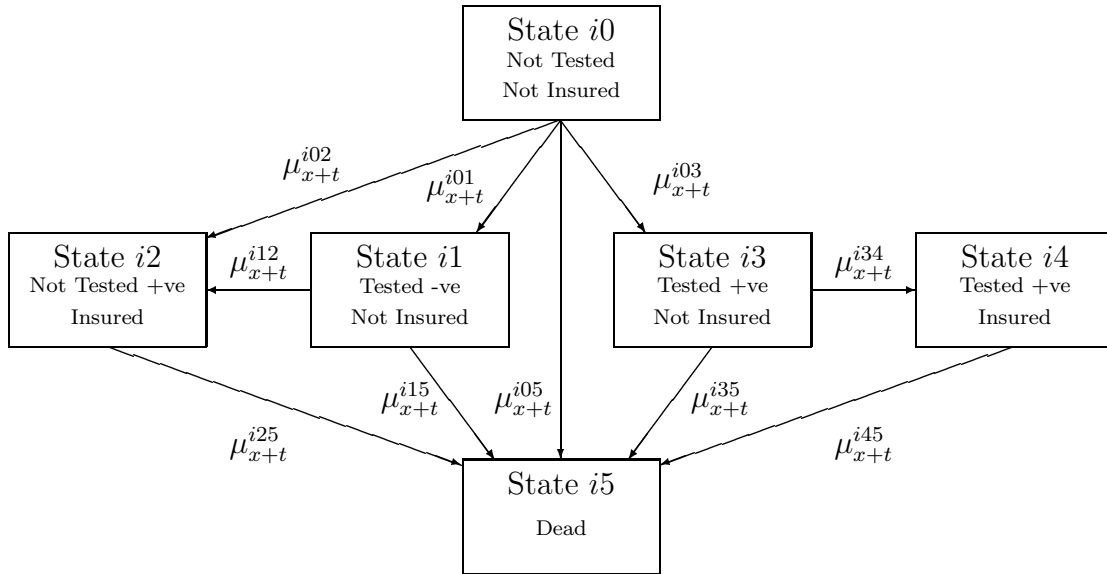


Figure 1: A model for the i^{th} of M sub-populations.

not to buy insurance. The probabilities of transitions taking place are governed by the quantities shown symbolically beside each arrow, in which $x + t$ represents the person's age. The higher these quantities, the more likely the transitions are, so it is possible to model the first element of adverse selection, namely lives with a positive test result being more likely to buy insurance.

While a person is in one of the insured states, they pay life insurance premiums. The premiums charged in the two insured states can be different, so we can model the effect of the insurer charging a higher premium on the basis of a genetic test. If a person dies while in one of the insured states, a sum assured is payable. This too can depend on which of the insured states was occupied, so we can model the second element of adverse selection, namely people with a positive test result being more likely to buy high sums assured.

The other aspect of the model is the increased or decreased mortality associated with any particular gene. In this model, we reflect mortality differences only very broadly: we suppose that there are two or three sub-populations of people, each with a given level of mortality compared with the average. Each of these sub-populations is represented by a model like that in Figure 1. Figure 2 shows an example, in which the OR class is represented by a sub-population with below average mortality (75% of the average) and a sub-population with above average mortality (125% of the average). Half the population is in each sub-population, and we suppose that a person in the higher mortality sub-population has a higher chance of a positive genetic test result. In this way, we reflect the fact that 'adverse selectors' are all or mostly in the higher mortality group.

Using the model, we first calculate what premium should be charged, in the absence of genetic testing, to a person picked at random from the whole population being modelled (such as the OR class in Figure 2). The person is picked at random in the sense that

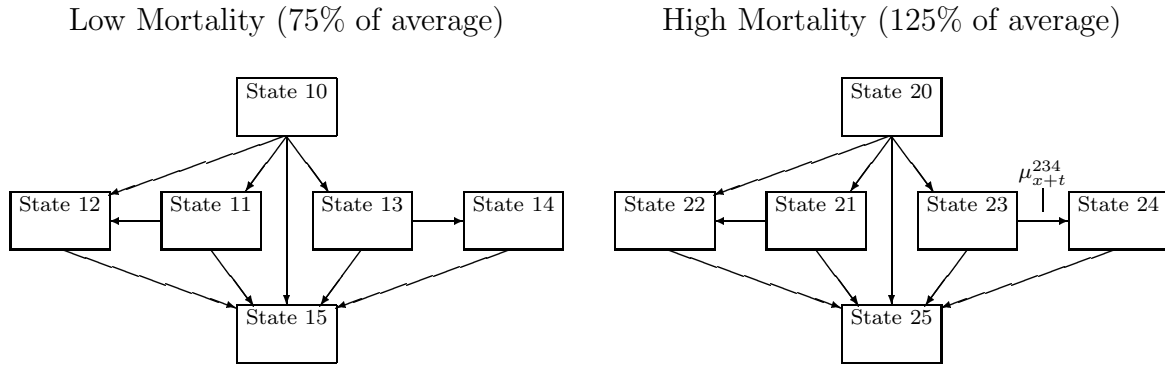


Figure 2: A model of the OR class with two sub-populations.

neither they nor the insurer know to which sub-population they belong. By definition, this premium is set so that the insurer can exactly cover the expected value of the claims arising. Next, we calculate the expected value of the claims arising if there is genetic testing, and the applicant but not the insurer knows the results. Then adverse selection can occur, and the claims become more likely and possibly larger in the higher mortality sub-population. Their expected value therefore increases; the percentage increase over the premiums calculated in the absence of genetic tests is precisely the percentage increase in premiums that would be needed to pay for the adverse selection.

A practical problem is that we lack realistic data with which to calibrate the model, especially in respect of the OR class in which genetic disorders might mostly be multifactorial. There are, however, two ways in which a statistical model can be of use, even in the absence of data:

- (a) it can help to identify what data should be collected in future; and
- (b) it might still be possible to make assumptions that we are confident lie on the extreme side; the resulting answers then give us an upper bound on premium increases arising from adverse selection.

Here we pursue (b). We make assumptions about the rates at which people buy insurance (depending on their knowledge), the rate at which people have genetic tests and the proportion which are positive, and the composition of the population in terms of number of sub-populations and their relative rates of mortality. We do not give details here, as that would require a technical discussion of the parameters; we refer the reader to Macdonald (1997, 1999) for full details. All we will say is that the assumptions made were all intended to be far worse than is likely in reality.

Tables 1 and 2 show the percentage increases in premiums in two cases:

- (a) Table 1 uses the model of the OR class shown in Figure 2.
- (b) Table 2 uses a model with three sub-populations: one including 94% of the population, with 81.2% of average mortality; one including 5% of the population, with 206% of average mortality; and one including 1% of the population, with 490% of average mortality. These figures were based roughly on data from Le Grys (1997), and represent the three insurance classes (those charged OR, those charged higher

Table 1: Percentage increases in premiums arising from adverse selection in a model of the Ordinary Rates underwriting class.

Sum Assured of Adverse Selectors	Age 30 Term			Age 40 Term		Age 50 Term
	10 yrs	20 yrs	30 yrs	10 yrs	20 yrs	10 yrs
	%	%	%	%	%	%
Average	4.3	2.5	1.3	4.3	2.3	4.3
2 × Average	10.0	6.7	4.7	10.2	6.5	9.9
4 × Average	21.4	15.1	11.4	21.7	14.9	21.4

Table 2: Percentage increases in premiums arising from adverse selection in a model of the whole population.

Sum Assured of Adverse Selectors	Age 30 Term			Age 40 Term		Age 50 Term
	10 yrs	20 yrs	30 yrs	10 yrs	20 yrs	10 yrs
	%	%	%	%	%	%
Average	10.7	7.7	5.8	10.3	7.3	9.7
2 × Average	19.7	15.8	12.0	20.9	14.9	19.7
4 × Average	42.6	31.9	24.5	41.8	30.1	38.5

premiums and those declined).

The tables show the percentage increases in premiums for lives starting in the originating state at ages 30, 40 and 50, for different policy terms, assuming that ‘adverse selectors’ opt for sums assured 1, 2 or 4 times the average sum assured.

Remembering the extremity of the assumptions, the following conclusions seem reasonable:

- (a) Freedom to choose higher sums assured is the most costly part of adverse selection, and therefore the greatest threat to insurers. Insurers do set limits on the sums assured that can be obtained without further investigation, and it would seem reasonable to allow genetic test information to be disclosed if a particularly high sum assured is sought. The ABI’s moratorium operates in broadly this way, though for mortgage-related business only.
- (b) If high sums assured are excluded, 10% seems to be a reasonable order of magnitude for any necessary premium increases. That does not mean that increases of more than 10% are impossible; it means that (for example) 5%, 10% or 15% are within reason, while 50%, 100% or 150% are not.
- (c) Multifactorial disorders are unlikely to be of much significance for life insurance underwriting.

It must be emphasised that this model, and these conclusions, relate to life insurance only. Other kinds of insurance could face more severe problems. The model above is

capable of being extended to represent many possibilities; two examples that are the subject of continuing work in the Department of Actuarial Mathematics and Statistics at Heriot-Watt University are:

- (a) Estimating the costs of adverse selection arising from particular single gene disorders. In this case, each sub-population in the model represents a given genotype
- (b) Estimating the impact on long-term care costs, and insurance premiums, of tests for the apolipoprotein $\epsilon 4$ allele, which predisposes to earlier onset of Alzheimer disease (Macdonald & Pritchard, 1999a, 1999b). The market for long-term care insurance in the UK is currently tiny, so the effect of adverse selection could be disproportionately large.

7. CONCLUSIONS

After a shaky start, the insurance industry and other interested parties have begun to co-operate to find practical and acceptable ways to deal with the impact of genetics on insurance. Much credit must be given to the ABI for introducing its code and appointing a genetics advisor, moves that are likely to be copied in other countries. Few, if any, other countries have reached a position in which time has been granted for the problems to be explored in a reasonably rational fashion, and several have already enacted restrictive legislation that has closed down the options, perhaps prematurely.

It is perhaps unlikely that the insurance industry will ever be in a position to investigate directly the impact of genetic disorders; it will not usually be able to collect the necessary data. Actuarial studies will therefore depend mainly on published medical and epidemiological research, from which actuarial models of the insurance process can be constructed. This will take time, but it must be done if the actuarial contribution to genetics issues is to keep pace with genetics itself.

In the opinion of this author (a full-time academic and an actuary) the primary purpose of research at this stage is to provide quantitative information that will:

- (a) inform policy-makers when methods of providing care and services are discussed, especially if private insurance and public welfare are alternatives;
- (b) identify potential problems, such as serious risks of adverse selection that would make provision of some service through private, voluntary insurance difficult; and
- (c) help to allay fears where these are groundless, such as the exaggerated popular view of the impact of genetics on access to life insurance.

In the short term, the greatest interest will focus on the work of the GAIC. It is not expected that this body will itself carry out statistical or epidemiological research, so the most important questions, as yet unanswered, are:

- (a) what criteria of accuracy and reliability will it use?; and
- (b) what sort of evidence will it accept? For example, will it give equal weight to independent research published in refereed journals and internal research carried out by insurers?

In the long term, the attention that genetics has drawn upon insurance underwriting might lead to more consideration being given to medical underwriting generally. Medical

practitioners are being held more and more to account for the decisions they make, and the grounds for those decisions ('evidence based medicine' is an example); how likely is it that other users of medical information will not have to follow suit?

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