Genetic Testing in the Workplace

A Report by GeneWatch UK

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A Report for GeneWatch UK by Kristina Staley

June 2003

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Executive Summary

Current laws in the UK allow employers to refuse someone a job on the basis of their genetic test results. Genetic tests for susceptibility to occupational disease are being developed and a few have already been used in workplaces in the USA. However, none of these tests can accurately or reliably predict whether an individual is at risk. It is neither scientifically nor ethically valid to use these tests for employment purposes, but there is a real danger that they could be used inappropriately to discriminate unfairly against employees.

Evidence supporting the use of genetic tests in the workplace

The evidence of a link between genes and occupational illness is weak. Since the effect of any gene is small, its impact can only be demonstrated via statistical analysis of large numbers of people. The statistics frequently lead to false associations being made and the results of comparable studies are often contradictory. Moreover, this type of research fails to take into consideration the complexity of the impact of workplace exposures on health. Most researchers agree that using the results of genetic studies for employment purposes would be premature. The results from population studies simply cannot be transferred to the individual.

Most researchers agree that using the results of genetic studies for employment purposes would be premature

Despite its limitations, there is still a considerable amount of interest in research into genetic testing in the workplace, in both the public and private sectors. Chemical manufacturers have expressed an interest in identifying individual genetic susceptibilities to chemical exposures, and the nuclear industry is funding work in this field. Conflicts of interest can arise when companies studying genetic tests are also responsible for exposing their workers to chemicals that are known to cause cancer. These employers and others might see genetic selection of employees as a cheaper and easier alternative to reducing all workplace exposures. However, improving workplace conditions is a more effective way of reducing occupational illness than genetic testing.

Implications for employers

Employers might wish to use genetic tests because they believe that the tests could identify people who are most at risk from hazardous exposures or sudden illness. They might seek to reduce their liability for illnesses caused at work by using genetic tests to exclude the most susceptible individuals from employment. However, not only would the tests prove ineffective, but by shifting the emphasis away from factors in the environment, they could actually lead to deteriorating workplace standards. Workers might be at even greater risk of ill health as a result.

Improving workplace conditions is a more effective way of reducing occupational illness than genetic testing

In a survey carried out by the Institute of Directors, 50% of employers who replied were in favour of using genetic tests to identify workers at risk from occupational hazards and 34% were interested in testing their employees for susceptibility to heart disease.

Employers are likely to be under increasing pressure to use genetic tests as the biotechnology and pharmaceutical industries seek a return from their investment in research and gene patents. Pressure to use genetic tests could

also come from insurance companies. Employers might mistakenly believe they could use genetic tests to identify individuals who are likely to have long periods of time off work or retire early due to ill health. Excluding these individuals could then be seen as a means of reducing premiums. However, since the predictive value of the tests is so poor, misinterpretation is likely to be common.

Legislation does not prevent job applicants from being refused employment on the basis of genetic test results

Current UK legislation relating to workplace safety places a duty of care on employers to protect the health and safety of all their employees. The principles of prevention enshrined in the law are based on protective measures to combat or reduce risks at source. There is no mention of employee selection. Employers' use of genetic tests to exclude *existing* workers would therefore contravene the spirit of their legal role and responsibilities. However, legislation does not prevent job *applicants* from being refused employment on the basis of genetic test results.

Implications for employees

Employees might wish to take a genetic test as they might believe it could help them to avoid any hazardous chemicals that were particularly likely to cause them harm. However, no genetic test is yet able to predict accurately whether an individual is safe from exposure. Nor are workers often in the position where they can freely choose not to take a high-risk job.

There is only a remote chance that genetic tests will provide genuine benefits to employees in the future, but there is a real possibility that such tests could lead to genetic discrimination today. People could be excluded from work on the basis of positive test results even when their condition does not affect their health or their job performance. Since most tests are unreliable, some people may be excluded even though they do not carry a faulty gene. Since gene variations are not distributed evenly in different populations, there is also a danger that decisions based on genetic test results may be influenced by racism – as has happened in the past. Employers' use of genetic tests is likely to cause more harm than good.

There is a real possibility that genetic tests could lead to discrimination

There is no law in the UK to protect employees against this kind of discrimination. In this regard, the UK lags behind many countries in Europe and many of the US States. The use of genetic information by employers should be banned immediately and the UK Government should draft new legislation to ensure that the complex issues raised by the use of genetic tests are adequately addressed.

GeneWatch UK's position

GeneWatch UK concludes that:

> **No employer should demand that an individual takes a genetic test or reveals a genetic test result as a condition of employment. Nor should employers be allowed to use genetic information to determine an employee's terms, conditions, privileges or employment benefits.**

New legislation needs to be introduced to prevent all forms of genetic discrimination and to prohibit employers (and insurers) from using or accessing individual genetic test results. To this end, it is vital that the UK Government

ratifies and signs the European Convention on Human Rights and Biomedicine without further delay.

GeneWatch also recommends that greater emphasis is placed on reducing workplace exposures rather then identifying and removing the 'most susceptible workers'. GeneWatch believes this is the most effective means to reduce the number of cases of occupational illness and to ensure genuine benefits for *all* employees.

Greater emphasis must be placed on reducing workplace exposures rather then identifying and removing the 'most susceptible workers'

1. Introduction

This report is concerned with the potential misuse of genetic information by employers. It provides a brief introduction to the kinds of genetic tests that might be used for employment purposes and reviews the research evidence linking genes to occupational illness. The limitations of this research are then discussed. A short description of current research activity in this area in both the USA and the UK is also provided.

The report goes on to consider why employers might be interested in using genetic tests and whether they would be likely to benefit from their introduction. Current UK legislation surrounding workplace health and safety is reviewed to consider how genetic testing might fit with current employment practice and the legal roles and responsibilities of employers.

The implications for employees are also discussed, highlighting potential benefits and the possibility of genetic discrimination. Finally, the limitations of existing UK laws and safeguards are considered and the changes necessary to prevent genetic discrimination in employment are identified.

2. What types of genetic test might be used in the workplace?

A genetic test involves analysing a person's genetic material (their DNA) to see if they possess a 'faulty' gene. DNA can be isolated from a blood sample or a tissue sample obtained by simply scraping the inside of a person's cheek.

Everyone's genes are different. Some of these differences have no impact but, where these differences are significant, they are thought to prevent genes from working properly and so to lead to disease. However, the relationships are far from straightforward. Very many other factors – for example, lifestyle and diet – have a major influence on whether genes have an impact on health.

There are four types of health-related genetic test that might be considered for use in the workplace. These include tests that might identify whether a person:

- was at risk of a **genetic illness**, such as sickle cell anaemia (a blood disease) or Huntington's disease (a nervous system disease);
- was at risk of a **common illness**, such as heart disease or cancer;
- was at risk of a **work-related disease**, or **susceptible to hazardous chemicals in the workplace** that cause cancer or asthma;
- had been **exposed to harmful levels of a chemical or radiation** at work.

None of the existing genetic tests provide an accurate assessment of individual risk

Currently, none of these tests provide an accurate assessment of individual risk. Some tests can be good at identifying who will get a genetic illness, but poor at predicting when symptoms will start or how severe they will be. Tests for common or workplace-related diseases give considerably poorer predictions. Because of the complex interactions between a person's genes and the environment, simply knowing that someone has a particular gene provides very little information about their current or future health. This fact alone means there is little justification for using genetic test results for employment purposes. However, there is a real danger that employers might unwittingly, or even deliberately, misuse genetic information. They could all too easily misinterpret genetic risk to mean absolute certainty and unfairly exclude people from jobs as a result[1].

The first two types of test listed above might be taken for medical reasons. In such cases, employers would only have access to the results via medical records or directly via communication from their employee. The latter two types of test are specific to the workplace and are therefore more likely to be incorporated into screening programmes instigated by the employer. Some employers might also consider including the first two types of test in screening programmes - particularly for common diseases such as heart disease - that might affect pension costs. All these types of test might also be sold 'direct to the public' without medical involvement. In such cases, employers could only access the results by asking the employee to reveal them. The four different types of genetic test will now be considered in turn, with particular emphasis on their implications for employment.

2.1 Testing for a genetic illness

There are some conditions where possessing a fault in a single gene means that a person will definitely develop a genetic disease. However, even in these

'simple' cases it is not possible to predict exactly when a person will become ill or how severely they will be affected[2;3]. For example, in the case of Huntington's disease, the age of onset can vary by several decades. Finding that someone had a faulty Huntington's gene would give no indication as to when they might succumb to the disease and be unable to carry out their job.

Similarly, there is considerable variation in the symptoms of the single gene disorder β-thalassaemia, where impaired red blood cell production leads to anaemia. People with the faulty gene can be completely healthy, mildly affected or so severely anaemic that they require regular blood transfusions. Over 180 variations in the gene have been identified, but little is known about how these differences relate to a person's symptoms[3]. It is therefore extremely difficult to develop tests that will accurately identify everyone with a fault in this gene and, again, none of the tests would give an indication of how ill a person might become in the future.

There are only a few instances where genes appear to have a strong influence on susceptibility to common illnesses and even these cases are now in doubt

In most cases where people are affected by a genetic illness, they are likely to experience symptoms long before they apply for a job. For example, people with cystic fibrosis are likely to be affected at a very early age. The most important consideration in their employment is therefore whether they are receiving the necessary medical treatment to maintain their general health[4]. If people are not affected by their genetic condition immediately, they are likely to remain healthy for years. A positive genetic test would therefore have no relevance at all to their employment, unless and until they begin to suffer symptoms that limit their performance.

2.2 Testing for risk of a common illness

Much genetic research now focuses on how genes influence our susceptibility to common illnesses such as heart disease or cancer. However, there are only a few instances where genes appear to have a strong influence and even these cases are now in doubt. Based on these kinds of observations, it seems highly unlikely that there will ever be simple tests for risk of cancer based on single genes[5]. For example, the BRCA1 and BRCA2 genes have been linked to breast and ovarian cancer but it has long been known that these genes only account for a minority (5-10%) of cases. More importantly, it seems that the estimates of risk associated with BRCA1 and BRCA2 are almost certainly too high[6]. Researchers have recently shown that women with a faulty BRCA gene as well as a strong family history of breast cancer are at higher risk than women with the same genetic make-up and no family history[7]. Since most estimates of disease risk have come from studies involving women from high-risk families, these results are very likely to be skewed. Therefore, having a faulty gene does not necessarily mean that a person will definitely develop cancer since many other genetic and environmental factors are likely to have an influence[1;7].

Some researchers have questioned whether we will ever be able to develop genetic tests that provide accurate predictions

The development of common illnesses is likely to be influenced by very many genes, each one having only a modest impact[8]. Attempting to understand how a large number of genes interact to influence risk of multi-factorial diseases is a major challenge for researchers[9]. Given this complexity, some researchers have questioned whether we will ever be able to develop genetic tests that provide accurate predictions[3]. At this early stage, it is questionable as to whether people should be offered such genetic tests even as part of general medical practice and certainly not in relation to employment.

2.3 Testing for susceptibility to hazardous chemicals or radiation

People vary in their responses to hazardous chemicals. How any particular individual responds depends on many non-genetic factors such as age, weight, gender, diet, lifestyle (especially smoking), but can also be influenced by a person's genes[10].

Whether a chemical is hazardous to health depends on[11]:

- its concentration in the body;
- how it is distributed round the body;
- which organs are affected;
- how quickly it is broken down and whether it is broken down into a harmless substance or another toxic product;
- how quickly it can be excreted from the body.

Many of these processes are dependent on enzymes (molecules that affect the speed of chemical reactions in the body) and other signalling molecules that are encoded by our genes. In this way, genetic variations can lead to differences in the way people react to the same toxin. For example, people who are slow 'detoxifiers' are more likely to be affected than people who can break down toxins more quickly, simply because they are exposed to the chemical for longer[12].

When chemicals are broken down in the body, the products are usually inactive and therefore easily excreted. However, the products are sometimes more reactive and able to bind to genetic material (DNA) or other biologically important molecules. If the DNA adducts (chemicals bound to the DNA) are not eliminated by the body's natural repair processes, it is thought they can cause gene mutations which can eventually lead to cancer[13].

Genetic tests are unlikely to deliver real benefits for either employers or employees and are more likely to result in genetic discrimination

Genetic tests that aim to identify individuals who are at high risk from exposure to hazardous chemicals fall into three categories. These tests all identify genetic differences that people are born with. The first category includes tests for differences in the way people break down toxins. This involves testing for faults in the genes that encode enzymes which carry out the breakdown process (see examples in Section 3). These kinds of tests are available now. The second category relates to genetic differences in the way individuals respond to the damage caused by chemicals and involves testing for faults in DNA repair processes. These genes are still being researched. The third category examines differences in the genetic make-up of our immune systems, based on the theory that these differences will affect individual susceptibility to occupational-linked asthma. Again, this research is still in its early stages.

It is claimed that the use of these genetic tests will enable those who are most at risk from hazardous chemicals to avoid workplace exposure. However, it is questionable whether the tests can really be used in this way (see Section 3.2). It seems they are unlikely to deliver real benefits for either employers (see Section 4.2) or employees (see Section 6.2) and are more likely to result in genetic discrimination (see Section 6.3).

2.4 Testing for previous exposure to hazardous chemicals or radiation

Genetic material (DNA) can change over time as a result of workplace exposure to chemicals or radiation. A chemical - or more often its breakdown product - can bind to DNA and cause structural damage. Therefore, there are some genetic tests that will look for changes to people's DNA that have occurred over their lifetime. Researchers are trying to find links between different patterns of DNA damage and chemical exposure in the hope that chemical-specific patterns or 'footprints' may emerge.

Tests for DNA damage are too imprecise to provide a useful assessment of individual risk

It is hoped that assessing the level of DNA damage will provide an indication of risk of future disease. However, as with the other types of genetic test described above, tests for DNA damage are too imprecise to provide a useful assessment of individual risk[13]. The relationships between different types of damage, gene mutation and cancer are complex and unclear. Nor is it evident that examining the damage to only one or a few genes will be useful for predicting illness. Again, the examination of hundreds of genes may be necessary and identifying and validating such a large number of complex interactions is recognised as a 'major challenge'[14]. There is a danger that molecular tools for detecting DNA damage will be used prematurely, simply because they are 'new and fashionable' rather than useful and relevant[13].

3. What evidence supports the use of genetic tests in the workplace?

3.1 Research evidence linking genes and occupational exposure to ill-health

Most of the evidence that genes affect susceptibility to occupational hazards comes from epidemiological research on the gene variations encoding metabolic enzymes (see Box A). These studies involve monitoring groups of people who are known to have been exposed to hazardous chemicals at work (e.g. a group of coke oven workers) and comparing the genetic make-up of those who become ill with those who do not. Alternatively, individuals who are already affected by a disease (e.g. a group of patients with cancer) are compared with people who are unaffected. Comparisons are made between the genetic make-up of the affected and unaffected groups and their previous exposure to chemicals at work.

Box A – The metabolism of hazardous chemicals[11;15;16]

Toxic chemicals are metabolised by the body in two different ways. They are either broken down into their sub-components (Phase 1 reaction) or chemically altered (Phase 2 reaction) so they can be more easily excreted via the kidneys or small intestine. Any given chemical may be broken down in one or other or both phases in a complex series of inter-related steps.

Phase 1 enzymes include:

The **cytochrome P450 (CYP) family** – This is a large group of enzymes involved in the breakdown of many different chemicals. Over 700 different types of P450 have been identified so far. Half of these vary between individuals, although the significance of the differences is still largely unknown[17]. Much more is known about how these differences affect a person's response to drugs than how they affect the body's handling of environmental toxins or food.

Paraoxonase – breaks down organophosphate compounds such as insecticides and nerve gases.

Phase 2 enzymes include:

The **glutathione S transferase (GST) family** – These are divided into six different types. Some have genetic variations that affect enzyme activity. In some people, the gene is missing completely, resulting in no enzyme activity[18].

Arylamine N-acetyltransferase (NAT) – There are two types, NAT1 and NAT2, both of which have genetic variations affecting the enzyme activity.

Statistics frequently lead to false associations being made and the results of comparable studies often contradict one another

Since the effect of any gene is small, its impact can only be demonstrated via statistical analysis of large numbers of people. However, the statistics frequently lead to false associations being made and the results of comparable studies often contradict one another[19;20]. This is a consistent problem with genetic research which aims to find links between gene variations and ill-health. While an initial study may find evidence of a link, subsequent studies

are rarely able to replicate the results[21]. The number of significant and confirmed links is very small, making it difficult to draw strong conclusions[19].

Establishing links between multiple genetic variations and disease - or even single genetic variations and disease - is extremely complex, and both types of investigation are still at a very early stage. As is illustrated by the examples below, the evidence gathered to date linking genes to occupational illness is simply not robust enough to support accurate predictions of risk.

The evidence gathered to date linking genes to occupational illness is simply not robust enough to support accurate predictions of risk

(i) Glutathione S transferases (GST) and risk of cancer

Gene variation: Various members of the family of GST enzymes including GSTM1, GSTM3, GSTT1, GSTP1.

Hazardous chemical: Polycyclic aromatic hydrocarbons (PAHs) - e.g. benzo[a]pyrene.

Exposed population: PAHs are produced by burning processes, so a wide range of workers are affected (e.g. bus drivers, chimney sweeps, foundry or coke oven workers, soldiers, miners, oil refinery workers, and also bar staff exposed to cigarette smoke).

There have been many studies that have aimed to find a link between various members of the GST family of enzymes, exposure to PAHs, and risk of cancer, but so far the results have been ambiguous or inconsistent[15]. Different types and levels of exposure to PAHs (or other chemicals) may be important for different GST enzymes and may have a different impact depending on the particular kind of cancer. One recent study found no significantly increased risk of lung cancer in smokers exposed to PAHs due to any single GST genetic variation, but suggested that a combination of several genetic variations may be important in some cases[22]. The authors conclude that the role of GSTs may be more complex than previously assumed.

(ii) GSTs and risk of occupational asthma

Gene variation: Various members of the family of GST enzymes including GSTM1, GSTM3, GSTT1, GSTP1.

Hazardous chemical: Di-isocyanates – the most common chemicals to cause occupational asthma.

Exposed population: Workers involved in the production of polyurethane foams or paints and lacquers used as industrial finishes (e.g. car coatings).

Occupational asthma occurs in up to 5-10% of people exposed to di-isocyanates. One study found a link between the disease and the lack of a GST**M**1 gene in workers exposed to di-isocyanates, but this finding was based on a small study and has yet to be confirmed with a larger sample[23]. The study did not find any association between GST**P**1 variations and risk of occupational asthma. In complete contrast, a more recent study reported that one form of GST**P**1 does seem to protect workers against asthma if they have been exposed to toluene di-isocyanate for a period of at least ten years[24]. This

second study did not find any link between the disease and variations in GST**M**1 and, again, the findings are questionable as they are based on only a small number of people. Such conflicting results make individual risk predictions impossible.

(iii) Immune system genes and risk of occupational asthma

Gene variation: Human leukocyte antigen (involved in immune system signalling) – HLA-DQ gene variations.

Hazardous chemical: Toluene di-isocyanate.

Exposed population: As in (ii) above.

Many environmental factors and multiple genes are likely to influence a person's risk of asthma

A number of studies have investigated links between human leukocyte antigen (HLA) genes and occupational asthma with conflicting results. Studies in Italy have claimed to find a link between exposure to di-isocyanates, variations in the HLA-DQB1 gene, and risk of di-isocyanate induced asthma[25]. However, the results of such studies are disputed – no evidence has been found of such a link in workers in Germany[26]. Many environmental factors and multiple genes are likely to influence a person's risk of asthma so that tests for one or two genetic variations are unlikely to have any predictive value.

(iv) Cytochrome P450s and risk of lung cancer.

Gene variation: CYP2D6.

Hazardous chemical: Polycyclic aromatic hydrocarbons (PAHs) and asbestos.

Exposed population: Workers exposed to burning processes as in (i), or workers involved in the asbestos industry.

In 1989, researchers claimed that workers who smoked and were exposed to asbestos or PAHs and were also fast metabolisers of a particular drug (debrisoquine) were at particularly high risk of lung cancer[27]. Individual differences in the metabolism of debrisoquine have subsequently been shown to be due to genetic variations in CYP2D6. However, genetic variations in CYP2D6 are no longer thought to contribute to the risk of lung cancer[20]. Two meta-analyses have found either no link with lung cancer[28] or only a very small difference in risk[29]. The authors conclude that early studies showing evidence of a link between genes and ill-health are often over-optimistic[29].

Early studies showing evidence of a link between genes and ill-health are often over-optimistic

Gene variation: CYP1A1.

Hazardous chemical: Polycyclic aromatic hydrocarbons (PAHs).

Exposed population: Workers exposed to burning processes as in (i) above.

Two Japanese studies have found a link between CYP1A1 and the risk of lung cancer[20]. However, a more recent analysis of a large number of studies found little support for this association[30].

(v) N-acetyl transferase and risk of bladder cancer

Gene variation: NAT2.

Hazardous chemical: Arylamines.

Exposed population: Widespread exposure in manufacturing industry (e.g. used in dyes, textile and rubber manufacture).

The statistical link between genetic variations in NAT2 and bladder cancer in people exposed to arylamines in the workplace or cigarette smoke has been relatively well studied. People are known as 'fast' or 'slow acetylators' depending on which version of the gene they have. A meta-analysis of all case-control studies found that 'slow acetylators' on average had a 40% increase in risk of bladder cancer compared to 'fast acetylators'[31]. However, the overall picture remains complex and confusing. The risks vary between Europe and Asia and no increase in risk has been found in the USA[31]. Researchers in this field have argued that using these findings to screen workers for susceptibility to cancer would be ethically unacceptable and scientifically premature[12]. The test's predictive value would be highly variable depending on the exposure and the population. The genetic variation in NAT2 that is thought to increase the risk of bladder cancer is also thought to *reduce* the risk of cancer of the colon[32].

Researchers have argued that using these findings to screen workers for susceptibility to cancer would be ethically unacceptable and scientifically premature

(vi) NQO1 and risk of leukaemia

Gene variation: NQO1 – variation causes loss of enzyme activity.

Hazardous chemical: Benzene found in petrochemicals.

Exposed population: Benzene is used in petroleum refining and rubber tyre manufacture. Affected workers include steel workers, printers, rubber workers, shoe makers, laboratory technicians, firefighters and petrol station employees.

Most data has been collected from a single population of 74,000 workers exposed to benzene in Shanghai and China. One study of this group showed that individuals who lack the NQO1 enzyme appear to be at 2.6 times greater risk of benzene poisoning than people who do have the enzyme[33]. Symptoms of benzene poisoning are a known risk factor for leukaemia but do not lead to cancer in every affected individual. These risks have only been demonstrated in an Asian population so the same may not necessarily be true for other groups[34]. The same study also claimed that if an individual had a fast-acting CYP2E1 enzyme (from the family of cytochrome P450 enzymes) as well as a defective NQO1 enzyme, their risk of poisoning increased 7.6 fold[33]. However, this finding was based on only a small number of people and, as acknowledged by the researchers, relied upon a rather imprecise measure of CYP2E1 enzyme activity. Other studies that have attempted to link genetic variations in NQO1 with other cancers have produced inconclusive results[35].

(vii) Paraoxonase and organophosphates

Gene variation: Slow form of the paraoxonase (PON1) enzyme.

Hazardous chemical: Organophosphates found in insecticides.

Exposed population: Farmers and agricultural workers.

Different forms of the paraoxonase enzyme metabolise organophosphates at different rates. In one study, a slow form of the enzyme was more commonly found in British farmers who attributed their ill-health to sheep dip[36]. However, many other factors, such as age and diet, have an affect on the metabolism of organophosphates. Researchers have also argued that for PON1 (as with many other metabolic enzymes), it is necessary to measure the actual activity of the enzyme and not just look at the genetic variation if the rate of toxin metabolism is to be accurately predicted[37].

3.2 Limitations of the research evidence

As illustrated by the examples above, to date, none of the studies of links between genes and occupational illness have reached a stage where the results could be used to make accurate predictions. Many researchers conclude that the use of current genetic knowledge for employment purposes would be premature and scientifically invalid[12;34;38].

To date, none of the studies of links between genes and occupational illness have reached a stage where the results could be used to make accurate predictions

The results of this type of research cannot be easily transferred to the workplace for the following reasons:

a) The research is overly simplistic in its approach - usually only one or two genes are studied in relation to a single hazard.

- Individual susceptibility to any chemical is likely to be affected by hundreds of different genes encoding enzymes and molecules involved in many different metabolic pathways[39]. The overall pattern of gene variation, rather than any single genetic difference, will influence how an individual responds.

- A 'faulty' gene may not always confer risk. There may be evidence that one particular form of a gene places an individual at greater risk of ill-health from exposure to one particular chemical. However, the same gene may also reduce their risk from exposure to a completely different toxin or reduce their risk of a completely different disease.

- Individual responses may be oversimplified. People are often categorised as 'fast metabolisers' or 'slow metabolisers' when, in reality, the differences in their enzyme activities are more graded. In the same way that genetic differences result in a range of heights in the population, variations in the genes encoding metabolic enzymes result in a broad spectrum of metabolisers rather than discrete types. This makes it difficult to categorise individuals, particularly those in the middle of the range. Nor is it known where to draw the line between categories to ensure they are meaningful in terms of outcome [40].

- Genetic and environmental factors may interact in complex ways. For example, exposure to high concentrations of a chemical can overwhelm the effects of genetic traits. Under these conditions, even the people

with fast-acting metabolic enzymes are not able to break a chemical down fast enough to prevent any biological damage[41;42].

- The complexity of the workplace environment tends to be ignored. Workers are exposed to many different hazards at the same time, but the risks associated with multiple exposures are unknown and difficult to assess (see Box B). The complexity of different types of workplace exposures also means that research on one group of workers may not be relevant to workers in other situations[10]. Recognising scientific ignorance and uncertainty is critically important in addressing environmental hazards[43].

The complexity of different types of workplace exposures means that research on one group of workers may not be relevant to workers in other situations

- Environmental factors outside of work are not often considered. While most studies control for smoking behaviour, other important environmental factors are not included. For example, poverty will have a major impact on an individual's response through a range of mechanisms such as poor nutrition, infections in childhood, and use of alcohol. The overall increased toxic load may reduce a person's ability to detoxify chemicals, thereby increasing their sensitivity to additional exposures[10].

BOX B – The limitations of chemical risk assessment

Assessing the risk of exposure to hazardous chemicals is complex, poorly understood and difficult to measure. The main problems are:

1. There is very little information available on the risks associated with many chemicals already in use. More than 100,000 chemicals are thought to be marketed in Europe, nearly 2,500 of which are produced in high volume. Basic health and environmental data is only available for 14% of the chemicals in high-volume production[44].
2. Accurately determining workers' exposures to multiple workplace hazards is extremely difficult and needs improvement[45]. It is estimated that 300-350 substances act as occupational carcinogens, while around 3,000 workplace substances cause allergic reactions[46].
3. The consequences of being exposed to mixtures of many different chemicals are unknown. Some chemicals can act together so that their harmful effects are greater than if each chemical worked individually (this is known as 'synergy'). However, very little is known about these effects, particularly when more than two chemicals are involved[47].
4. Some chemicals are harmful in ways that are poorly understood and may be even more difficult to assess or monitor. For example, 'hormone disrupting chemicals' may be harmful in very small amounts to the developing foetus. Women are likely to be exposed to such chemicals in many different occupations, but very little is known about what impact this may have[48].

Assessing the risk of exposure to hazardous chemicals is complex, poorly understood and difficult to measure

b) The research often produces conflicting evidence of correlations – and less often identifies a causal pathway.

- The direct links between genetic differences, their impact on the activity

of different enzymes, and subsequent risks of ill-health are not yet understood. It is not always clear that the statistical associations between gene variations and occupational illness can be explained biologically [49]. Some links may be simply statistical artefacts and due to chance. Other links may in fact be explained by the presence of a different, and as yet unknown, factor.

- Demonstrating that a particular gene variation produces a functional change in enzyme activity is notoriously difficult. Enzyme activity may change over time and is affected by a multitude of environmental factors such as drinking alcohol or smoking. Enzymes may also be affected by disease. Hence, being a 'slow' or 'fast' metaboliser might be a *result* of having cancer rather than the *cause* of ill-health[12].

Demonstrating that a particular gene variation produces a functional change in enzyme activity is notoriously difficult

- The results are often contradictory and dependent on the particular research methods used. For example, there are different ways of measuring DNA damage. The use of one measure may show a correlation between a particular genetic variation, occupational exposure and damage to DNA, but the use of a different measure of DNA damage may not show any association[50].

c) The research is based on observations of populations or groups – these results do not transfer to the individual.

- The effects of most genetic variations are weak[51]. This means that they may only be detectable when the results from many different people are pooled (see Box C). What is relevant to a group has little bearing on estimating an individual's risk of disease. Many other factors will influence the likelihood of disease for any particular individual and most of these will be unknown. Hence, it is not possible to predict accurately the risks for any one person. It is only possible to say that a group of workers *on average* may be more likely to become ill than a different group of workers.

Box C – Interpreting (and misinterpreting) genetic risk

A study of a group of workers exposed to benzidine in a manufacturing plant in Germany showed that, of those who went on to develop bladder cancer, a large majority (80%) had a 'slow' form of the *N*-acetyltransferase gene[52]. This might indicate that having a slow form of the gene greatly increases the risk of bladder cancer. However, the data also shows that people with the 'fast' form of the gene are not free from risk. More importantly, over 50% of the people with the slow form of the gene did not develop the disease. Therefore, if a worker tested positive for the slow form of the gene, it would provide them with very little information about their particular risk of cancer from benzidine exposure.

What is relevant to a group has little bearing on estimating an individual's risk of disease

d) The research is often based on a specific population – the results for one population will not always apply to others.

- Some genetic variations are found more frequently in certain

populations than in others. For example, one form of the GSTT1 gene is claimed to be found in 62% of Asian Americans, 19.7% of Caucasian Americans and 9.7% of Mexican Americans[15]. As all gene variations are likely to be unevenly distributed and an individual's response influenced by the combination of his or her genes and their environment, an association found in one population may not hold true for another[12]. More importantly, it is not a straightforward matter to assign individuals to different populations (see below).

- Some research in this area aims to identify the occupational risks for different ethnic groups, based on the assumption that each group will carry distinct genetic variations. However, the scientific validity of this idea is controversial. Human beings are a single species and ethnic groups (despite many failed and discredited efforts to classify them) are not biologically distinct[53]. The physical characteristics which distinguish ethnic groups result from a small number of genes that are not closely related to disease. Moreover, the genetic make-up of groups overlaps so broadly that an individual could not be assigned to any particular ethnic group based on their genes[54]. A person's ethnicity affects their lifestyle, environment, support systems, education and socio-economic status, all of which are likely to be more important influences on their health than any genetic variations.

Some research aims to identify the occupational risks for different ethnic groups, based on the assumption that each group will carry distinct genetic variations

3.3 Current research activity linking genes to ill-health

BOX D – The European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC)

ECETOC was established in 1978 and is a scientific, non-profit making, non-commercial association, financed by 50 of the leading companies with interests in the manufacture and use of chemicals[56]. It was established to provide a scientific forum to research, review, assess and publish studies on the health and environmental impact of toxic chemicals.

It seems that ECETOC are convinced that genetics research will provide useful predictions of risks for individuals. At a symposium in 2001, a member of ECETOC from the UK - Lewis Smith from Syngenta CTL (one of the world's largest manufacturers of agrochemicals) – concluded that[57]:

> "…contributors to this symposium recognise the necessity to apply gene-based technologies to assess the likely susceptibility of individuals or populations to environmental toxicants.
>
> *"It seems almost certain that with the knowledge of individual polymorphisms it will be possible to combine the results from DNA array technology and proteonomics to begin to determine which individuals are likely to be more severely affected on exposure to specific chemicals."*

Current research into linking genes to ill-health falls into two main categories - research into genetic susceptibility to common diseases and research into genetic susceptibility to occupational exposures. There is a considerable amount of interest in the former, with the goal of improving diagnosis and

medical treatment of common conditions. It is hoped that this research will lead to more effective preventive measures and the development of better-targeted medicines[55]. However, there is also a danger that this genetic information could lead to discrimination in the workplace (see Sections 4.2 and 6.3).

However, it is the research which is directly linked to occupational exposure that causes the most concern. This research has greater potential to be misused by employers as it could be seen as a means of reducing employers' specific responsibilities and liabilities. It is particularly worrying that chemical manufacturers have expressed an interest in identifying individual genetic susceptibilities to chemical exposures, and the nuclear industry is funding work in this field (see Boxes D and G). It is hard to see how these industries can avoid a conflict of interest when they are responsible for exposing their workers to known carcinogens. Under these circumstances, it becomes even more important that safeguards are put into place to prevent employers using genetic information inappropriately.

Research into occupational exposure could be seen as a means of reducing employers' specific responsibilities and liabilities

Box E -The Environmental Genome Project (EGP)

The EGP research falls into five main areas:

- identifying all the variations in human genes known to be involved in metabolism;
- identifying which of these genetic variations make a difference to how the body functions;
- identifying which of these genetic variations are linked to disease caused by environmental exposures;
- developing new technology to support this research;
- researching the ethical, legal and social issues relevant to the whole programme.

Examples of current projects include[59]:

Dr Nevert, from the University of Cincinnati, is investigating the role that cytochrome P1450 plays in toxicity caused by environmental pollutants, including dioxin and polycyclic aromatic hydrocarbons such as benzo[a]pyrene. These toxins are produced by burning processes and so, for example, are found in car exhaust fumes, tobacco smoke and coke ovens.

Dr Garte, at the New York University Medical Centre, is investigating whether the variations in the CYP1A1 gene can be used to monitor exposure to aromatic hydrocarbons and whether the differences in this gene relate to cancer susceptibility in African Americans.

Dr Valdes, at the University of Louisville, is aiming to identify individuals with increased risk of vinyl chloride induced liver cancer. No-one survives this particular form of cancer, which explains the intense interest in trying to identify 'high-risk' individuals currently working in the industry. Vinyl chloride is used in the manufacture of PVC plastic.

Dr Kaufmann, at the University of North Carolina, Chapel Hill, is trying to find out which genes are linked to the variation in response of workers exposed to vinyl chloride. The goal is to determine whether specific gene differences will provide a useful predictor of those at high risk of developing liver cancer.

Dr Ward, at the University of Texas, is examining links between genes encoding detoxifying enzymes and susceptibility to cancer following exposure to 1-3-butadiene. This chemical is widely used in the manufacture of synthetic rubber.

In 1997, the US National Institute of Environmental Health Sciences (NIEHS) launched a major initiative called the Environmental Genome Project[58;59]. With $60 million of investment, this project aims to understand the links between genetic variation and responses to environmental exposures. It is claimed that this research will allow *"more precise identification of the environmental agents that cause disease"* and *"better estimates of the true risk of exposures"*. This is presumed to lead to increased measures to prevent disease and to enable individual workers to make informed decisions about the risks they are prepared to accept. However, it is not clear that any of the research projects to date will be able to overcome the limitations discussed in Section 3.2. The idea that workers always have freedom to choose their level of exposure to hazards is also naïve (see Section 6.2). Details of some of the current research activities are described in Box E.

In November 2001, the NIEHS announced that it would be awarding five-year grants totalling $37 million to five research organisations to form a toxicogenomics consortium[60]. The goal of this research is to use new micro-array technology to examine the molecular details of how individuals respond to toxic chemicals - some genes will be switched on while others will be switched off. It is claimed that the new technology will allow researchers to look at how every single gene responds to different hazards. However, there are some researchers who doubt whether the technology and associated mathematical analysis is sophisticated enough to allow useful predictions to be made from this type of data[61].

The idea that workers always have freedom to choose their level of exposure to hazards is naïve

3.3.2 Research in the UK

There are a number of active UK research programmes focused on genetic susceptibility to workplace exposures. Some of these are funded by government agencies including the Medical Research Council and the Health and Safety Executive (see Box F). Others are closely linked to industry (see Box G). These latter projects are of greatest concern since the research appears to be funded by the industries that are most likely to want to use genetic tests to identify susceptible employees.

Further evidence that UK industry is interested in this type of research comes from the United Kingdom Environmental Mutagen Society[62]. The Society has established an Industrial Genotoxicology Group which:

- provides a forum for informal discussion of the scientific and technical aspects of genetic toxicology tests among representatives of industrial genetic toxicology laboratories, academic researchers and the regulatory authorities;
- co-ordinates collaborative work to support the development and validation of new tests.

Box F – Government funded research into genetic susceptibility to occupational ill-health in the UK

(1) The Medical Research Council (MRC)

One of the topics the MRC has identified as a priority area for research is the investigation of how *"environmental factors, possibly in conjunction with other factors (e.g. genetic), affect human health"*. They have established a joint initiative with the Natural Environment Research Council (NERC) to invite proposals from environmental and medical scientists for research on the relationship between human and environmental variables[63].

The MRC is also jointly funding research in this area with the HSE. For example, they are supporting a project to investigate the links between genes and susceptibility to lung cancer in mice following exposure to dioxin. This work is being carried out at the MRC Toxicology Unit, University of Leicester, and will be completed in 2004.

The MRC has also committed funding to the UK Biobank, which is also being funded by the Wellcome Trust and the Department of Health[64]. The current protocol claims that *"the more precise identification of individuals at increased risk of disease through both exposure and genotype will allow improved targeting of various interventions"*. The data collected on participants will include occupation as one of the few indicators of exposure to hazardous chemicals or radiation. This means there is a danger that commercial companies using the Biobank for research could try to develop genetic tests to identify individuals with susceptibility to occupational disease. It is not clear that there are sufficient safeguards in place in the UK to ensure that misuse of Biobank data will be avoided[65].

There is a danger that commercial companies using the UK Biobank for research could try to develop genetic tests to identify individuals with susceptibility to occupational disease

(2) The Health and Safety Executive (HSE)

The HSE's Strategic Research Outlook for 2002 identified the topic of *"human variability and susceptibility to chemical toxicity"* as one of their priorities for research[66]. This involves looking at a range of environmental and genetic factors that affect individual responses to chemicals and forms a key aspect of the research required by statute to support the Health and Safety Commission's remit under the Health and Safety at Work Act 1974. Examples of projects funded by the HSE include[67]:

- an investigation of the links between variations in the serum paraoxonase gene and ill-health in farmers following exposure to organophosphates in sheep dip - University of Manchester, completed in 1999;
- an investigation of the possibility that some people may be more genetically susceptible to neurological disease following exposure to organic solvents found in paint - University of Aberdeen, completed in 2001;
- a review of all available data on the variation in the way people respond to the damage caused by chemicals, i.e. variation in biological systems of repair - University of Southampton, completed 2001;
- a project that aimed to develop a new computer model that will provide a more accurate estimate of the range of responses to toxic chemicals by including information on genetic variation - Health & Safety Laboratory, completed 2002.

Evidence of predisposition to cancer or sensitivity to radiation could be used to exclude people from employment at Sellafield

Box G – An example of industry funded research into genetic susceptibility to occupational ill-health in the UK

The North Cumbria Community Genetics Project (NCCGP) has established a store of genetic samples from around 8,000 babies and mothers in Cumbria for use in epidemiological research[68]. Some of the research that is being carried out on these samples is trying to identify links between DNA damage, variations in genes encoding DNA repair enzymes, and possible occupational exposure to radiation[69]. One of the main funders of this research is British Nuclear Fuels Ltd (BNFL) and many of the researchers have strong links to the company. This has caused great concern among the local people, particularly as many of BNFL's workers or their families are likely to be taking part in the study[70]. They are worried that evidence of predisposition to cancer or sensitivity to radiation could be used to exclude people from employment at Sellafield or to blame people's genes, rather than radiation exposure, for cancers in the area.

4. Why would employers want to use genetic tests?

4.1 Perceived benefits to employers

Based on the belief that genetic tests could provide accurate risk assessments, employers might wish to use such tests to screen job applicants or current employees in order to:

- exclude individuals who may be more susceptible to workplace chemicals from jobs where they are likely to be exposed. Whilst claiming that this would protect workers' health, employers may also see this as a means to reduce liability and compensation claims. Screening for cancers associated with toxic chemicals is likely to be of the greatest interest as these are associated with the most substantial claims;
- avoid hiring workers who might need considerable time off work or retire early due to ill-health. This could also cut the costs of sickness benefits;
- exclude individuals from health insurance or other employee benefit schemes on the basis that they might use these benefits excessively;
- monitor the health of employees to assess whether any individuals have been exposed to dangerous levels of chemical hazards. This could result in individuals being removed from their job if they appear to be at greater risk from further exposure or, more positively, could be used as a means of redressing workplace standards (see Section 5.2);
- exclude some individuals from certain jobs on the grounds that they may pose a threat to others if they develop a predicted illness suddenly.

Employers could avoid hiring workers who they believe might need considerable time off work or retire early due to ill-health

To date, few employers have asked their employees to take a genetic test. In the UK, the Ministry of Defence used to ask its pilots to take a test for sickle-cell disease, based on the belief that the condition could cause problems if oxygen pressures fell at high altitudes. This policy has since been reversed[71]. The US Department of Defence also reversed its policy of excluding people with sickle-cell trait from pilot training[4], having realised that the risks of depressurisation were far less than other risk factors that affect flying safety. The testing programme had also been based on the unlikely assumption that a pilot would develop sickle-cell unnoticed and have their first blackout when flying a plane.

Two other tests were also popular in the US in the early days of enthusiasm for genetic screening. The first was a test for alpha-1-anti-trypsin deficiency, which is thought to be a risk factor for chronic obstructive pulmonary disease in workers exposed to irritant materials. The second was a test for glucose-6-phosphate dehydrogenase deficiency, which is thought to affect people's response to particular types of chemical toxins. Both have now been shown to be irrelevant and unsuitable for worker selection[16].

A large number of UK employers have expressed an interest in the use of genetic tests

Nevertheless, a large number of UK employers have expressed an interest in the use of genetic tests. In a survey carried out by the Institute of Directors[72], 50% of respondents were in favour of using genetic tests to identify workers at risk from occupational hazards. This support was conditional on the employee being asked for their consent. There was less support (16%) for making genetic tests compulsory because of concerns surrounding threats to civil liberties. As many as 34% of those surveyed were interested in testing their employees for general heart disease. Although this has even less relevance to occupational health, employers may feel that knowing an employee's genetic

risk of common illnesses such as heart disease could help cut pension costs by excluding such employees from the early retirement provisions of the occupational pension scheme[70].

Irrespective of their personal views, employers are likely to come under increasing pressure to use genetic tests in the future because of:

Irrespective of their personal views, employers are likely to come under increasing pressure to use genetic tests in the future

(a) Marketing by the biotech industry

As genetic research advances, the costs of testing will decrease and manufacturers will intensify their efforts to sell their test kits. Companies such as Millennium Pharmaceuticals and Glaxo SmithKline see selling genetic tests as a way of generating near-term revenue from genes that they have patented and as a means of expanding the market for their pharmaceutical products[73;74].

A number of smaller companies have begun to make misleading claims about their genetic tests, overstating their predictive value[75]. One consequence of this over-marketing is that the use of genetic tests could become thought of as 'good managerial practice'. Employers might be persuaded that it is their duty to provide these tests to employees in spite of their limited relevance or usefulness.

The use of genetic tests is currently unregulated in this country but, with the impact of global markets, this issue requires international attention. Employers' policies on the use of genetic tests in other countries will also become an important local issue since so many multinational companies are based in the UK[76].

(b) Pressures from the insurance industry

In September 2002, the Association of British Insurers (ABI) called for *"a radical reform of employers' liability"* since workplace compensation and pay-out levels have escalated over the past five years[77;78]. Insurance premiums have been raised by over 100% to meet the demand, but this is thought to be unsustainable. As a cutback measure, the ABI have recommended that employers are encouraged to invest more in health, safety and risk management procedures. This could extend to asking employers to make more detailed assessments of the risk status of their employees, perhaps through the use of medical or genetic tests. Employers might be encouraged to hire a 'less risky' workforce in order to reduce their premiums. Such close links between employment and insurance issues have led the Human Genetics Commission (HGC) to conclude that these issues should not be considered in isolation[71].

Some employers might see selecting workers on the basis of genetic tests simply as a more economic and efficient means of employee selection

(c) Changing employment practice

There is increased deregulation of employment practice across Europe and rising unemployment in some countries. This is evidenced by the increasing number of closures, relocations and redundancies, as well as the increase in workloads and longer working hours. Some employers might see selecting workers on the basis of genetic tests simply as a more economic and efficient means of employee selection[79]. A large pool of unemployed people from which

to select workers with the desired genetic test results and the lack of a unionised workforce are factors that could make genetic discrimination more likely.

(d) Public and financial pressures

Based on the belief that genetic tests could identify groups of genetically vulnerable workers, there could be some public pressure to use genetic tests to protect those groups of workers.

If a genetic screening programme proved cheaper than improving health and safety for the workforce as a whole, employers would be likely to prefer a screening programme in spite of its severe limitations.

If it proved cheaper than improving health and safety for the workforce as a whole, employers would be likely to prefer a screening programme in spite of its severe limitations

4.2 Actual benefits to employers

The benefits to employers of using genetic tests to determine who gets a job or compensation are likely to be limited. In many cases, employers could end up paying for genetic tests that are meaningless or wrong. In the few cases where a gene has been consistently linked with an increased risk of illness (e.g. the NAT2 gene and risk of bladder cancer), the increase in risk is small and variable and depends on other environmental and genetic factors[31]. However, there may be some specific circumstances in which employers might benefit from using genetic tests (at the expense of employees). In particular, some employers might believe that they can use workplace genetic testing as a way of avoiding the costs of improving workplace safety standards for everyone.

The issues for employers are considered below.

(a) The tests are unlikely to provide useful or relevant information.

The research evidence (see Section 3.2) shows that most of the claims of links between genes and occupational ill-health are unreliable. Most research results have not been replicated and, in many cases, genes that were thought to be important for some time have since been shown to be irrelevant or of little importance compared to other factors. There is therefore a real danger that employers could base a genetic screening programme on spurious results and exclude the wrong people from the workplace.

Employers could base a genetic screening programme on spurious results and exclude the wrong people from the workplace

Even if the research did show consistent links between genes and occupational ill-health, genetic tests based on these findings would still have little predictive value (see Section 3.2). It is simply not possible to predict future health-status on the basis of a test for a single factor linked to only one disease[80]. Even where genes do appear to have an effect, their impact is weak[18;38;81]. Moreover, not everyone with a particular gene fault is at an increased risk of illness. They could have a lower or higher risk depending on many other factors. Because the risks of many occupational exposures are unknown (see box B), it would be impossible to predict the risks for individual workers, even if everyone had the same genes.

It has been argued that testing workers for multiple gene variations might have

greater predictive power. However, there would still be the following limitations[80]:

- The effect of one gene variation may cancel out the effect of another as far as toxicity of a chemical is concerned, or the results may be inconsistent, with one gene variation suggesting increased risk while another suggests decreased risk to a particular exposure[18].
- The use of more tests increases the chances of false positive and/or false negative results (see below).
- The interpretative tools used to analyse data from multiple genetic tests may not yet be sophisticated enough to generate meaningful results[61].

The interpretative tools used to analyse data from multiple genetic tests may not yet be sophisticated enough to generate meaningful results

(b) No genetic test is 100% accurate.

Even if a genetic variation is consistently linked with a higher risk of disease, mistakes can be made when the tests are carried out and any single test may not detect all the variations that can exist in any one gene. Therefore, all genetic tests are somewhat unreliable. Every test carries the possibility of false positives – people wrongly identified as possessing a particular gene variation - and false negatives – people who possess the gene variation but are not detected[12;80]. Common diseases involve many different genes, but if a battery of tests were carried out, this would become an even bigger problem since the number of false results would multiply[82]. There is a danger that large numbers of people could be excluded on the basis of incorrect results (see Box H).

Box H – The reliability and usefulness of genetic tests for susceptibility to occupational disease

As illustrated by the hypothetical example below, it is possible to calculate how many people might be wrongly excluded from employment because of inaccuracies in genetic tests[80]:

Suppose there was a test that could identify individuals who were at high risk of cancer from exposure to vinyl chloride and that this test could be used with 90% sensitivity and specificity. This would mean that 90% of high-risk workers and 90% of low-risk workers would be identified correctly.

Suppose that this test was used to screen out hyper-susceptible workers from a pool of job applicants and that the gene variation in question was found in 5% of the population. If 1,000 people applied, 50 individuals (5%) would in reality be at high risk and the test would correctly identify 45 (90%) of these people.

There would be 950 people in the low-risk group, but the test would only identify 855 (90%) of them. This means that 95 people (10%) from the low-risk group would be wrongly identified as high-risk individuals. Therefore, the test would predict that 140 people fell into the high-risk category, although only 45 of those people would really do so. 95 people would be excluded inappropriately. The accuracy of the test (% of people correctly identified as being at high risk) would be even less if the prevalence of the gene in question were any lower.

(c) There are better ways to control risk.

Excluding the most susceptible workers has no impact on the hazards that are present in a workplace and there will still be people with some degree of vulnerability left behind. Being at risk from occupational exposures is not a problem for a minority, but a general issue that is likely to affect all workers in almost any exposure situation[83]. Therefore, improving workplace conditions is the most effective way of reducing occupational illness. It will have an impact on all workers and is therefore bound to have more success than any attempts to manage individual differences. Removal or reduction of a single workplace exposure (such as cigarette smoke) can also often reduce the risk of many different diseases, whilst each gene usually only plays a small part in a single disease[84].

Using genetic tests may not have a significant impact on the number of cases of occupational disease (see Box H). However, some employers might still wish to invest in genetic screening and exclude workers rather than improve safety measures if it proved to be much cheaper.

(d) Screening out susceptible workers may not be cost-effective.

One of the proposed benefits of genetic screening in the workplace would be to reduce healthcare and compensation costs associated with occupational disease. However, a screening programme may not necessarily reduce the number of people who become ill, as illustrated in Box H. There could also be extra costs for employers from running the programme and providing appropriate care and counselling, afterwards. However, these costs could be negligible if genetic testing and follow-up treatment became routine within the NHS so that an employer only had to ask for existing test results.

Improving workplace conditions is the most effective way of reducing occupational illness

One published analysis of two hypothetical scenarios has demonstrated that genetic testing is not always cost-effective and many factors will influence its success, including the sensitivity and accuracy of the test and the number of people affected[85]. These scenarios are shown in Boxes I and J, using the figures given in the paper. However, they leave many questions still unanswered and depend very much on the assumptions made.

These scenarios did not consider the comparative costs and benefits of reducing overall workplace exposure and implementing a screening programme. Even with limited accuracy, a cheap screening programme could be financially attractive to employers in some circumstances, although reducing everyone's exposures will always be more beneficial for employees.

Box I - Genetic screening for benzene-induced cancer

A genetic screening programme could be implemented using studies that suggest that individuals with relatively high levels of CYP2E1 and relatively low levels of NQO1 are at higher risk of liver poisoning and cancer when exposed to benzene.

On average, 2,500 people would need to be screened to hire 1,000 workers of 'normal' susceptibility – with 1,500 potential workers excluded. On average, this screening programme would prevent one case of cancer (three cases would occur in the screened workforce compared to four in an unscreened workforce). However, because the predictions are so uncertain, there would be a high probability that the screening programme would make no difference, especially when false positive and false negative results are taken into consideration. It is hard to say if the employer would gain or lose financially, but many people would lose their jobs unnecessarily.

Reducing beryllium exposure, rather than genetic testing of the workforce, would be a more effective way to reduce the incidence of beryllium disease

Box J - Genetic screening for chronic beryllium disease

A genetic screening programme could be implemented using studies that suggest genetic variations in the immune system gene known as HLA increase the risk of chronic beryllium disease (CBD).

On average, assuming the genetic variation in HLA occurs in 30% of the workforce, 1,429 workers would need to be screened to employ 1,000 with 'normal' susceptibility – 429 workers would therefore be excluded. If CBD normally occurs in 5% of the workforce, 50 cases would be expected if there was no genetic screening. If the genetic variation increases the risk eight-fold, 34 cases of chronic beryllium disease might be avoided by the screening programme (16 cases would be expected instead of 50). False results are likely to make the programme less effective, but such a screening programme is still likely to be financially beneficial to the employer. On the other hand, many people would lose their jobs unnecessarily because genetic testing for HLA has a low predictive value[86].

One US beryllium materials manufacturer is conducting a pilot genetic testing programme, offering HLA genetic testing to job applicants. The Los Alamos nuclear weapons laboratory is also considering offering a genetic testing programme for its beryllium workers[87].

The current US workplace exposure limit for beryllium has been heavily criticised, as has the industry's attitudes to safety standards[88;89]. It seems likely that reducing beryllium exposure, rather than genetic testing of the workforce, would be a more effective way to reduce the incidence of beryllium disease.

5. How would the use of genetic tests fit with current employment practice and the legal responsibilities of employers?

5.1 Pre-employment health checks

Pre-employment health checks are a common feature of recruitment procedures and, according to a survey carried out in 1999, are used by just under a third of companies in the UK[90]. A health check usually involves filling out a questionnaire or undergoing a medical examination. Any health problems that emerge are subsequently followed up. The goal is to:

- **ensure that an individual is fit for the job** - unsuitable applicants can be screened out if their illness puts them or their colleagues at risk. According to the Disability Discrimination Act (see Section 7.2.1), the employer would need to justify this exclusion and show that no reasonable adjustments could be made to the job or workplace;
- **identify workers' work-related needs** – the results may help an employer to tailor a job if necessary and make adjustments to meet the health needs of the new employee;
- **enable employers to offer advice on health promotion** – employers may seek to reduce the risk of ill-health through advice on risk factors and how to avoid them;
- **meet company pension or insurance scheme requirements –** some employers offer optional company pension schemes and/or healthcare insurance as part of their remuneration package. These policies may require information about the health of key personnel or the general workforce.

The usefulness of any pre-employment health checks is questionable, irrespective of whether genetic tests form part of the process

Evaluation of the risk of occupational disease has become an increasingly important part of the pre-employment health check because of the escalating costs of employers' liability (see Section 4.1). However, current medical tests have not proved useful in this context. The interpretations of test results have been shown to reflect *"prejudice, groundless assumptions about illnesses and misunderstanding of the risks"* [16]. It is sometimes proposed that genetic tests will provide a more precise and accurate risk assessment. However, given all the limitations of genetic information (see Sections 3.2 and 4.2), introducing genetic tests is unlikely to improve the existing scenario.

The usefulness of any pre-employment health checks is therefore questionable, irrespective of whether genetic tests form part of the process. In many cases, they may channel funds away from more beneficial activities such as providing healthcare for employees or taking action to reduce occupational risks. If pre-employment checks are going to be used, they must be strictly regulated. A pre-employment health check should always be the last step in the recruitment process. The candidate can then be certain that if their job application is unsuccessful, it is solely because of health reasons. This would then provide them with a secure platform from which to appeal[91]. It would also allow the employer to consider making reasonable adjustments to the job or workplace – this is a legal requirement for those employees who are protected by the Disability Discrimination Act (see Section 7.2.1).

5.2 Regular health surveillance of the workforce

Employers may offer regular health checks for all their employees in order to ensure the early diagnosis and proper treatment of work-related conditions. This is sometimes a legal requirement in particular areas of employment[90]. For example, under the Ionising Radiations Regulations of 1999, employees exposed to radiation require regular health checks, while all employees using display screens must undergo regular eyesight checks under the Health and Safety Regulations of 1992.

Genetic tests that measure DNA damage might be considered a useful tool for monitoring workplace exposure, but *only* for the workforce as a whole. At the group level, the presence of increased DNA damage could indicate unacceptable levels of exposure to chemical hazards. It could also reveal the presence of a toxic chemical that was previously unknown. These results would indicate that action should be taken to reduce exposure or eliminate the hazard. However, it would be important to communicate that these tests for DNA damage would be of no use in predicting risks for the individual (see Sections 3.2 and 4.2).

The use of genetic tests to exclude people from the workplace would appear to contravene the occupational health physician's professional code of practice

5.3 Roles and responsibilities of occupational health doctors

Pre-employment and employment health checks are frequently carried out by occupational health professionals or, alternatively, the employee's own GP. Some, but not all, of the assessments they make measure people's fitness to do a particular job against statutorily defined standards[92]. It is always made clear to the worker or job applicant that the information will be passed on to the employer. If a person refuses to disclose relevant information or does not give their consent to the results of their examination being disclosed, they risk being turned down or disqualified from their job[92].

The role of occupational health doctors is to protect workers' health at the same time as helping them to gain or remain in employment. According to their professional code of ethics, occupational health professionals aim to ensure that any worker with the necessary skills can work safely without endangering the health of themselves or others. This means maximising the opportunities for each individual to be employed in a meaningful job or, for those already in employment, providing treatment or support to help them to retain their positions or to change jobs if this becomes necessary for health reasons[16].

The use of genetic tests to exclude people from the workplace would therefore appear to contravene the occupational health physician's professional code of practice. However, the profession is currently under increasing pressure to change its role and to move towards using health assessments as a means of reducing absenteeism, decreasing insurance costs and increasing productivity[80]. There is a danger that the introduction of genetic tests could reinforce this unwelcome trend. As with employers, occupational health doctors are also coming under increasing pressure from the aggressive marketing of genetic tests by their manufacturers[93].

5.4 Roles and responsibilities of employers

Under the Health and Safety at Work Act of 1974, *"it is the duty of every employer so far as is reasonably practicable, to ensure the health, safety and*

welfare at work of all their employees" [94]. This covers all aspects of work and includes the safety of the environment, plant and processes, and providing workers with adequate training to ensure their health and safety.

Exposure to hazardous chemicals at work is controlled legally by the COSHH Regulations (Control of Substances Hazardous to Health), which are enforced by the Health and Safety Executive (HSE)[95]. Under these regulations, employers are required to:

- assess risks and decide what precautions are needed;
- prevent exposure wherever possible or control exposure where this is not practical;
- monitor exposure if necessary and carry out health surveillance;
- ensure employees are properly informed, trained and supervised.

A list of occupational exposure limits for hazardous chemicals is produced and regularly updated by the Health and Safety Commission (HSC)[96]. There are two types of limit:

- Maximum Exposure Limits (MELs) - set for chemicals which may cause the most serious illnesses, such as cancer and occupational asthma, but where the safe level of exposure is not known or where it is not practically possible to keep exposure below a known safe threshold. COSHH regulations require that exposure is reduced as far below the MEL as is reasonably practicable.
- Occupational Exposure Standards (OESs) – set for chemicals where, based on current scientific knowledge, there is no indication of risk to the health of workers even with daily exposure. COSHH regulations require that exposure to a substance with an OES is reduced at least to that level.

Current UK legislation emphasises that it is the employer's responsibility to maintain the safety of the workplace in order to benefit all employees

Current UK legislation therefore emphasises that it is the employer's responsibility to maintain the safety of the *workplace* in order to benefit *all* employees. The principles of prevention enshrined in the law are based on protective measures to combat or reduce risks at source. There is no mention of employee selection. The removal of the worker from employment is always an action of last resort, since the law requires the workplace to be safe for all employees. Employers' use of genetic tests to exclude existing workers would therefore contravene their legal role and responsibilities. However, legislation does not prevent job *applicants* from being refused employment on the basis of genetic test results.

The Disability Discrimination Act (see Section 7.2.1) also requires that people with disabilities are accommodated wherever possible through reasonable adjustments to the job or workplace. However, it does not apply to people who have genetic test results that indicate a risk of a future illness but who have not yet developed any symptoms.

6. What are the implications for employees?

6.1 Perceived benefits to employees

It is sometimes suggested that workers might wish to take a genetic test for susceptibility to a workplace-related illness as they would then be able to avoid the hazardous chemicals or environmental factors that were particularly likely to cause them harm. Similarly, it is argued that workers might support workplace screening since early detection of illness and timely medical treatment could lead to better health outcomes. The issues are sometimes simplified to a matter of consent. It is argued that employees should have free choice as to whether to take a genetic test and subsequently free choice as to whether to take a high risk job[16]. However, these arguments are fundamentally flawed since no genetic test is yet able to (or likely to be able to) predict accurately whether an individual is at risk (see Sections 3.2 and 4.2). Nor are workers (or job applicants) often in a position where they can truly exercise freedom of choice (See section 6.2).

If genetic research is to be of benefit to health, the environment should be improved to suit all workers rather than workers being selected to suit a particular hazardous environment

There is only one area where workers might genuinely benefit from a better understanding of susceptibility to occupational exposures and that is in setting stricter workplace standards. The results from epidemiological research (See sections 3.1 and 3.3), if replicated and shown to be robust, could be relevant to setting exposure limits, but only if applied to groups of workers and not to individuals (see Section 5.2). If genetic research is to be of benefit to health, the environment should be improved to suit all workers rather than workers being selected to suit a particular hazardous environment.

Given that there are potential benefits from research into susceptibility to occupational exposures, it is essential that this research is not stifled through fear of genetic discrimination at work. This type of research relies heavily on the co-operation of workers exposed to occupational hazards and their participation should be encouraged by ensuring adequate safeguards are in place to protect their individual interests.

6.2 Actual benefits to employees

The use of genetic tests for employment purposes is unlikely to provide any benefits to employees for the following reasons:

(a) Genetic tests are unlikely to improve workers' health.

Genetic tests could result in many - perhaps hundreds - of workers being excluded to prevent one case of a workplace-related disease

Genetic tests could result in many - perhaps hundreds - of workers being excluded to prevent one case of a workplace-related disease (see Boxes H, I and J). The majority of those excluded would suffer the ill-effects of unemployment on their health and finances, even though they might not actually belong to a higher-risk group. They could also face stigma and anxiety as a result of being labelled as having 'high genetic risk'.

Genetic tests alone are unlikely to provide an accurate assessment of risk of work-related disease. Even for single gene disorders, it is now accepted that there is little value in testing people at the beginning of their careers for a condition that may not arise for many years and for which there is no effective preventative measure or effective treatment (see Sections 2.2. and 3.2).

(b) There are more effective ways of improving employees' health.

In terms of reducing the number of cases of occupational disease, it would be far more effective to improve working conditions for the entire workforce than to select out the most vulnerable individuals. All employees should expect their employer to have a duty of care towards them and that risks in the workplace will be eliminated, reduced or, at the very least, effectively controlled[94].

The hazards currently under investigation in studies of genetic susceptibility include exposure to sheep dip, pesticides, chemicals used or produced during the manufacture/disposal of PVC plastic (vinyl chloride and dioxins), tobacco smoke and radiation (see Section 3.3). The need for widespread exposure to such hazards has been questioned. Alternatives such as changing agricultural systems to use less or no harmful chemicals, increasing use of renewable energy, tightening controls on tobacco marketing, and switching to cleaner plastics or alternative materials also require consideration.

(c) Employees may not be able to exercise freedom of choice in relation to genetic tests or high-risk jobs.

The imbalance in power between employer and employee makes it difficult to ensure that an employee is giving their voluntary consent to a genetic test or can exercise their right 'not to know' about their genetic makeup. Although existing employees have some legal protection and may benefit from the support of a union, job *applicants* are likely to be particularly vulnerable. They may fear they will not be hired if they refuse to take a test. Refusal to take a genetic test may also be held against an employee if they subsequently develop an occupational illness since they could be said to be responsible for their ill-health on the basis that they were given an earlier opportunity to avoid it.

The imbalance in power between employer and employee makes it difficult to ensure that an employee is giving their voluntary consent to a genetic test

Nor is it clear that genetic tests would enable workers to make a free choice about the level of risk they are prepared to tolerate. Some people simply cannot choose to avoid a high risk job if it is their only possible source of income. Moreover, the law may not allow individuals to determine their own levels of risk (see Box O in Section 7).

(d) Taking a genetic test for employment purposes may have wider implications.

If an employee were obliged to take a genetic test, there may be repercussions for other members their family since blood-relatives may also be affected by the same condition. In other contexts, an employee might be required to disclose that they had taken a genetic test for employment purposes and this could be detrimental to other job applications and insurance policies.

(e) Using genetic tests for employment purposes is unethical.

A key ethical principle relating to society's use of genetic information is that of respect for human rights and dignity[71]. The UNESCO declaration on the genome and human rights states in Article 6 that:

"No one should be subjected to discrimination based on genetic characteristics if this has the effect of infringing human rights, fundamental freedoms or human dignity"[97].

Excluding people from employment on the basis of their genetic make-up would therefore constitute a violation of this fundamental principle. Choosing people to fit a particular environment according to their genetic-make up, rather than improving the environment for all, has disturbing implications for everyone's rights.

If people with genetic faults were to become generally unemployable, they could become part of a 'genetic underclass'

6.3 The potential for discrimination

Using genetic tests to identify individuals who might be at risk of ill-health at work is likely to lead to discrimination:

- Interpreting the results of the tests is so complex that employers are likely to misinterpret them and make inappropriate decisions based on the results.
- The unreliability of genetic tests means that many people could be excluded from work on the basis of falsely positive results. This is true even if, on average, people with a particular genetic make-up are at higher risk.
- Even if a test did accurately reveal that an individual was at risk, denying them employment could still be discriminatory if they were healthy and their condition did not affect their job performance.
- Since gene variations are not distributed evenly, some populations may be disproportionately affected when these groups may already be stigmatised or disadvantaged. A good example is the past screening for sickle cell trait in African Americans who wanted to be pilots, even though the presence of the trait does not affect their ability to safely do this job (See Section 7.2.1).

The consequences of such discriminatory practices could have wider repercussions for public health[98]. If people with genetic faults were to become generally unemployable, they could become part of a 'genetic underclass'. Their health would suffer as a direct consequence of unemployment and living in poverty. This has the potential to reinforce existing health inequalities. People who are more likely to work in industry and be exposed to chemical hazards could suffer more genetic discrimination than the 'white-collar workers' who are never exposed and never submitted to genetic testing. Discrimination against individual workers could therefore become a broader social issue with significant economic and political implications.

The fear of discrimination may make people reluctant to take genetic tests even though these could be beneficial to their health

The fear of discrimination may have far-reaching effects. It may make people reluctant to take genetic tests even though these could be beneficial to their health[99]. The US Department of Labour found that many women avoid breast cancer screening because they believe the results would appear on their records and be made available to employers or insurers[99]. The risk of discrimination may even deter people from taking part in useful medical research.

These fears of discrimination are not unfounded. There have been numerous examples of misuse of genetic information in the USA. In a 1996 survey of individuals who were deemed to be at risk of developing a genetic condition, 200 people had experienced genetic discrimination among the 917 who

responded. Details of individual cases are summarised in boxes K to N. In the UK, no cases of genetic discrimination have yet been reported. However, in 2002, one employer did contact the Health and Safety Executive to ask whether a person should be given preferred employment if there was evidence that they were *not* genetically susceptible to the effects of certain hazards[76].

Box K - Cases of genetic discrimination in the USA

Case 1: A man who discovered he was a carrier of a single gene variation that causes Gaucher's disease and revealed this fact in his job application was subsequently denied employment[100]. He was not at all affected by the condition but risked passing the disease on to his children.

Case 2: A woman in the US who notified her existing employers of a positive test for Huntington's disease was fired from her job. During the previous eight months, she had received a promotion and several outstanding performance reviews[100].

Case 3: A woman who was experiencing slight breathing difficulties went to her doctor for a genetic test because her brother had previously died from alpha-1antitrypsin deficiency. She tested positive for the condition and received life-saving treatment since the deficiency is treatable if detected early. When her employer found out, she was fired[101].

There have been numerous examples of misuse of genetic information in the USA

Box L - First US Government court case involving genetic discrimination at work

In May 2002, the Burlington Northern Santa Fe Corporation agreed to pay $2.2 million in damages for illegally testing their workers for genetic defects. They had been taken to court by the Equal Employment Opportunity Commission in the first US Government court case against genetic discrimination in the workplace. The company had been charged with testing a group of employees affected by work-related carpel-tunnel syndrome without their prior knowledge or consent. It seemed that the company was hoping to avoid paying compensation by arguing that the individuals would have developed this condition anyway. Although the company had not used genetic tests to screen out employees, the Commission took the view that merely gathering employee DNA constituted a violation of the Americans with Disabilities Act of 1990. The company still maintains that none of its actions were against the law[102].

Box M – Workers sue US Department of Energy over medical examinations involving genetic tests

In 1995, seven employees from the US Department of Energy (DoE) laboratory took their employer to court, arguing that tests for pregnancy, sickle-cell trait and syphilis had been carried out in occupational health checks without their knowledge. They accused the DoE of sexual and racial discrimination as well as invasion of privacy. The case was initially dismissed but, in 1998, the US Court of Appeal concluded that: *"the conditions tested for were aspects of one's health in which one enjoys the highest expectations of privacy".* In 2000, the DoE reached a settlement with the employees but continued to deny any wrongdoing. They claimed that the tests were part of routine medical screening to which the employees had consented and that the tests were consistent with good medical practice[103].

Box N - Discrimination on the basis of family history in Hong Kong

In October 2000, three men were awarded a total of £250,000 in damages because they had been refused employment by the Hong Kong Government purely on the grounds that their parents were affected by schizophrenia. The three men had either been refused a job or dismissed from their post without being given a clear reason. An investigation by the Hong Kong Equal Opportunities Commission revealed the link to their family history. It seems that the government employers had completely misunderstood the risks of inheriting this condition. Statistically, someone who has a parent with schizophrenia has a greater chance of developing the disease - a 10% chance compared to a 1% chance in the rest of the population. In fact, the risk for these men was much less since they were in all their early 20s and long past the age when the disease usually appears. More importantly, the symptoms of schizophrenia never start suddenly. Behavioural abnormalities develop well in advance of the full illness so even if these men had become ill, it is not evident that they would have constituted any real danger in the workplace[104].

Genetic discrimination at work has the potential to impact on all of us

Genetic discrimination at work has the potential to impact on all of us. If employers were to test for risk of common illnesses, it is likely that everyone would be affected since we all probably carry at least one gene variation that predisposes us to cancer. If employers were to test for susceptibility to hazardous exposures, large numbers of the UK workforce would be affected. It is estimated that 4.2 million (15%) of the workforce are employed in manufacturing[105]. Although there has been a recent decline in heavy industry, there are still large numbers of people involved in construction or maintenance (e.g. manual welding or woodwork) where exposure to chemicals is a major factor. Exposure to hazardous chemicals also occurs in many service sector jobs and in a wide range of other work including farming, printing, mining and firefighting.

7. Are there adequate legal safeguards to protect the interests of employees?

7.1 Health and safety at work

There are three major issues relating to the health and safety of employees at work:

- Are the legal health and safety standards adequate?
- Who decides what is an acceptable level of risk to health?
- What effect will genetic testing have on employees' right to compensation?

There are different laws that address these issues, which will now be considered in turn.

7.1.1 Health and safety standards

Health and safety standards for chemicals are regulated via COSHH (Control of Substances Hazardous to Health) and legally enforceable through the Health and Safety at Work Act 1974. For radiation, the Ionising Radiations Regulations (IRR) 1999 apply. There are many other regulations made under the Act which cover specific activities or industries[106]. These standards aim to protect the average worker but may not be effective for the people who are most vulnerable. Since so little is known about how people vary in their response to hazardous chemicals, we cannot be certain that current health and safety standards are really adequate[107].

Since so little is known about how people vary in their response to hazardous chemicals, we cannot be certain that current health and safety standards are really adequate

Improved knowledge of the range of people's responses, whether these are influenced by genetic or environmental factors, could help to set more accurate exposure limits (see Section 5.2). However, assessing the risk of occupational exposure is not a purely scientific process. It also involves considerable uncertainties and value judgements, including judgements about what is 'practicable' and 'cost-effective'. There is always an element of negotiation between employer, regulator and employees about what levels of exposure are acceptable. There has been a long history of resistance in some industries to reducing workplace exposures to hazards such as benzene, asbestos and radiation[43]. Setting standards alone is also not sufficient if there are ways for employers to ignore them – enforcement is an equally vital issue.

7.1.2 Acceptable health risks

There has been a long history of resistance in some industries to reducing workplace exposures to hazards

Some people have argued that it is appropriate for employers to protect workers from taking unnecessary risks (for example, by preventing them from taking on jobs that are dangerous to their health or that of others) and therefore appropriate to exclude genetically susceptible workers from employment in high-risk jobs.

It is already accepted that employers can remove some employees from particular hazards – for example, pregnant women can be excluded from some hazardous work situations. The obligations of an employer towards pregnant women vary according to the regulations that apply. In the case of radiation, the employer is required to carry out a new risk assessment once an employee has stated in writing that she is pregnant. The risk to the baby must then be

kept within a certain limit, which may require some temporary changes to the woman's job[108]. The Control of Lead at Work Regulations go further and legally prohibit the employment of *"women of reproductive capacity"* in some activities involving lead[109]. In both cases, action is taken to protect the unborn child, which will be more vulnerable to the workplace hazard as long as the employee is pregnant. Although the effect of the lead regulations is to exclude almost all pre-menopausal women from some jobs, it is not the same as defining certain sections of the population as permanently unsuitable to carry out certain types of work purely on the basis of their genetic make-up.

Others have argued that it may be appropriate for the individual to make their own judgement as to acceptable levels of risk. However, in a recent US court case, a worker was refused a job in order to reduce the risks to his own health (see Box O). In this case, the worker had an illness that was certain to affect his ability to tolerate workplace toxins. The case therefore differs from the use of genetic information since genes are poor predictors of who is susceptible to hazards and the excluded individual is more likely to be harmed than to benefit from their exclusion. However, this case has set an important precedent. For the first time, employers have been allowed to use a direct threat to an individual's health as a legitimate reason for refusing that person employment. This may have implications for employers' use of genetic information.

Box O –The case of Chevron vs Echazabal[110]

A refinery worker in the US was denied employment on the basis of having hepatitis C. The oil company, Chevron, argued that since the employee's liver function was impaired, he would be subject to further harm if he experienced the chemical exposures characteristic of refinery work.

The Americans with Disabilities Act 1990 contains a 'direct threat' provision. This is defined as *"a significant risk of substantial harm that cannot be eliminated by reasonable adjustments"*. In previous court rulings, it has been assumed that the direct threat provision only applies when the individual's condition poses a direct threat to others. The courts had therefore concluded that employers could not exclude individuals at risk if they did not have the potential to harm others.

In this recent case, however, the Supreme Court sided with the oil company's decision, interpreting the law differently. As a consequence, it now means that a direct threat to the *individual* can serve as a basis for workplace exclusion. This may have relevance to employers' use of genetic information.

Employers might seek to avoid paying compensation by claiming that genetically susceptible workers would have developed the condition in any case

7.1.3 Compensation for occupational illness

There is a concern that employers could seek to avoid paying compensation to workers for occupational illness by claiming that genetically susceptible workers would have developed the condition in any case. However, if an employer were at fault - by not maintaining health and safety standards, for example - all workers would be eligible for compensation, even if some were shown to be particularly susceptible. This is due to the principle known as the 'egg-shell skull rule' whereby an action is judged harmful on the general likelihood of it causing injury, not the particular response of the injured party[15].

Therefore, employers are legally obliged to protect all employees from hazards, even if their workers are genetically vulnerable.

7.2 Genetic discrimination at work

Genetic discrimination at work could result in an individual being denied a job or employee benefits purely on the basis of their genetic make-up. There are no laws in the UK that would protect a potential or existing employee from such discriminatory practices:

- An employer could ask a job applicant to take a genetic test or reveal the results of a genetic test that they had already taken. In the absence of any existing disability, it would not be illegal to use the results to decide whether or not to employ that person.
- Existing employees may be offered some protection from exclusion from work on the basis of genetic tests by the Health and Safety at Work Act (see Section 5.4 and Section 7.1.1), which makes the removal of a worker from employment an action of last resort. However, this protection is limited by what is 'practicable' for the employer. There is no legislation to protect existing employees from being denied access to employee benefits (e.g. a new pension scheme) on the basis of genetic test results – once hired, an employer may request employees to provide any medical information that is 'job related' and consistent with 'business necessity'.

There is no legislation to protect existing employees from being denied access to employee benefits on the basis of genetic test results

While there are laws that protect the confidentiality of personal information and prevent discrimination against people with existing disabilities, these do not adequately address the complex issues relating to genetic information. It seems that genetic discrimination could only be prevented by the introduction of new UK legislation[71]. This would allow a more thorough consideration of all the issues relating to confidentiality of test results and proper use of genetic information.

7.2.1 UK laws relating to genetic discrimination

The Disability Discrimination Act 1995

The Disability Discrimination Act (DDA)[111] states that it is unlawful for employers to discriminate against a disabled person:

- in the arrangements which they make for the purpose of determining to whom they should offer employment;
- in the terms on which they offer that person employment;
- by refusing to offer, or deliberately not offering, employment.

Employers with fifteen or more employees are required to make all reasonable adjustments to their premises to provide people with disabilities who qualify under the Act an opportunity to work. The DDA outlines a number of factors which would have to be taken into account by a court in deciding whether particular adjustments were reasonable.

The DDA does offer some protection to employees with 'faulty genes' but only if they are currently disabled or have been in the past. The definition of 'disability' in the Act does not cover people who have a susceptibility to ill-

health in the future. It has been suggested that the definition should be changed to offer the same level of protection to people at risk of genetic conditions[90;111]. A counter argument is that extending the definition in this way may not be appropriate because the Act applies to situations far wider than employment (such as the provision of services). It is not clear whether it would also be appropriate to include people with no symptoms under the definition of 'disability' in all these other areas. However, parts of the DDA already apply to people who have no current symptoms or impairment but have had a disability in the past. These people do not need some of the DDA provisions (such as special provisions for access to public transport) but they do need protection from discrimination.

The Data Protection Act 1998

Under the Data Protection Act (DPA)[112], there are conditions which must be met before personal data can be processed in any way, which includes collecting and destroying data. These conditions require that personal data must be processed in line with the Act's standards of fairness and lawfulness. For example, if an employer were to use their power to coerce an employee into taking a genetic test, then this would be considered unfair and in breach of the Act.

The Information Commissioner, the independent authority overseeing the enforcement of the DPA, is in the process of consulting on, and publishing, a Code of Practice that provides details on how employers should implement the DPA. Part 4 of the Code relates to medical information, which includes genetic test results, but is not yet available. Part 1 provides guidance on recruitment and selection[113]. This part of the Code states that an employer is allowed to collect, store and use or disclose sensitive data (this includes information on physical and mental health), but only to:

The Data Protection Act does not provide sufficient guidance on what is adequate or relevant data in relation to genetic information

- ensure the health, safety and welfare of workers;
- select safe and competent workers;
- ensure a safe working environment.

Employers are prohibited from discriminating against employees on the grounds of race, sex or disability and must obtain the explicit and freely given consent of employees to process their personal information. However, it is not yet clear how the terms of the Code of Practice relate to the employers' use of genetic tests.

The DPA itself also states that any personal data held by employers must be adequate, relevant and not excessive in relation to the purpose for which it is held. It must also be accurate and, where necessary, kept up to date. These requirements might ensure that no more is read into genetic test results than can be properly supported by the current state of scientific knowledge[90] and that genetic test results may not be kept by an employer for longer than is necessary. However, the Act does not provide sufficient guidance on what is adequate or relevant in relation to genetic information. Would the data have to be beneficial to the health of the employee or just useful to the employer seeking to cut costs?

If an employee or job applicant believed an employer had misused their personal information, they might be able to claim compensation under the

terms of the DPA. Similarly, an existing employee can ask the Information Commissioner to assess whether their employer's processing of data is in compliance with the Act. Evidence of any breaches of the Act could lead to prosecution.

There is some debate as to whether the DPA would provide adequate protection in the context of genetic information. The Information Commissioner has expressed the following doubts as to its effectiveness[71]:

- A standard way of protecting data is to anonymise the information by removing personal identifiers such as people's names and addresses. However, this is not feasible with genetic information since the genetic data itself can be used to uniquely identify a person.
- The Act makes provisions for the Information Commissioner to assess whether processing of personal data is fair. However, the Commissioner has concluded that the specifications are not clear enough for this to be practical or feasible in the context of processing genetic information.

There is some debate as to whether the Data Protection Act would provide adequate protection in the context of genetic information

Again, it would seem that the introduction of new legislation would be necessary to adequately address the specific issues relating to the complexities of genetic information.

The Human Rights Act 1998

The Human Rights Act may be relevant in protecting the privacy of genetic information in line with respect for private and family life[114]. However, it is not yet clear how the British courts would apply the human rights principles in this context.

Other anti-discrimination laws

The Sex Discrimination Act 1975 and the Race Relations Act 1976 might provide some protection against discrimination in a few rare cases where genetic conditions occur primarily in one sex (e.g. haemophilia) or in particular ethnic groups (e.g. thalassaemia). The best known example is the (now abandoned) sickle cell screening programme in the US, which was applied only to those of African descent and, until 1981, prevented African Americans with sickle cell trait from becoming military aircraft pilots[115].

An employee who refused to take a genetic test might be protected from unfair dismissal by the Employment Rights Act 1996, but this law only covers employees who have worked for an employer for over a year. Even so, it is not clear that the courts would consider dismissal unfair in these circumstances as an employer could try to argue that their action was justified. There is also the danger that an employee could be held responsible for any future work-related ill-health on the grounds that they had refused to take a test.

An employee could be held responsible for any future work-related ill-health on the grounds that they had refused to take a test

7.2.2 Comparison with legal safeguards in other countries

The situation in the UK contrasts with many other countries where genetic discrimination has been restricted or prohibited. The anti-genetic discrimination legislation in other countries is summarised in Table 1.

Table 1: Anti-genetic discrimination legislation in other countries[116;117]

Country	Relevant Legislation	Implications of the Legislation
Australia	The Genetic Privacy and Non-Discrimination Bill 1998	The draft Bill made genetic information available to employers in certain circumstances. The Australian Senate concluded that the Bill did not fully address privacy and discrimination issues and recommended that further legislation be developed[116]. In February 2001, the Federal Government asked the Australian Law Reform Commission to consider what sort of regulation might be needed in relation to genetic testing and information[118]. They are due to report in 2003.
Austria	The Gene Technology Act 1995	This Act prohibits employers and insurance companies from requesting, collecting or using information derived from genetic tests.
Denmark	Act on the use of health information in the labour market 1996	The Act places strict limits on employers' rights to ask for health information, including the results of genetic tests. They can only ask for health information where it is relevant to the ability of an employee to perform a specific job or to the protection of the employee's health in the workplace[119].
France	Law on respect for the human body 1994	This law specifies that the study of an individual's genetic characteristics can only be carried out for medical purposes or scientific research.
Netherlands	The Medical Checks Act 1997	This prohibits employers from applying medical criteria to recruitment unless there is an unambiguous health requirement for the job. Employers are obliged to assess a job applicant's suitability against other criteria first, and then to make the offer of employment subject to medical checks. However, the use of pre-symptomatic genetic tests for serious, untreatable conditions is prohibited.
Norway	The Act Relating to the Application of Biotechnology in Medicine 1994	The Act states that genetic testing may only be carried out for medical purposes when it has a diagnostic and/or therapeutic objective. It is prohibited to request, receive, possess or make use of genetic information resulting from a genetic test on any person or to ask if genetic tests have been carried out.

7.2.3 Legislation in the US

Genetic discrimination appears to be of particular concern in the US because there is already evidence of cases of discrimination by insurers and employers, and because employees are dependent on employer-subsidised health insurance. As in the UK, existing legislation seems inadequate. The Americans with Disabilities Act 1990 protects those with existing illness but not those at risk of future disease. As a result, a number of US states have enacted state laws to specifically protect genetic privacy but, as yet, there is no federal law that directly and comprehensively prevents employers from misusing genetic tests.

In March 2000, President Clinton issued an Executive Order that prohibits federal departments or agencies from using genetic information when hiring or promoting employees. He also endorsed a bill that would extend this ban on discrimination to all employers and insurers. However, this legislation has been

under debate for over six years and has still not been adopted. In 2002, two competing bills were sponsored in Congress, one by Democrats and one by Republicans[120]. A new consensus version of the bill was recently approved by a Senate Committee, breaking the impasse on this issue[121]. Some form of legislation will probably be adopted, particularly as the Bush administration has added its support to a ban on employment and insurance discrimination on the basis of genetic information[122].

7.2.4 European Legislation

The Council of Europe's Convention on Human Rights and Biomedicine 1997[114;123] states in Article 11 that:

> *"Any form of discrimination against a person on grounds of his or her genetic heritage is prohibited"*.

Article 12 restricts the use of predictive genetic tests to medical contexts and states that:

> *"Tests which are predictive of genetic diseases or which serve either to identify the subject as a carrier of a gene responsible for disease or to detect a genetic predisposition or susceptibility to disease may be performed only for health purposes or for scientific research linked to health purposes, and subject to appropriate genetic counselling".*

Article 26 allows for some exceptions to Article 12, but only when prescribed by national law and *"when necessary in a democratic society in the interest of public safety for prevention of crime, protection of public health or protection of rights and freedoms of others*".

The UK is amongst 13 out of 43 countries that have not yet signed the European Convention on Human Rights and Biomedicine

If the UK were to sign up to the Convention, it would have to become an integral part of UK law, but the UK is amongst 13 out of 43 countries that have not yet signed[114;123].

7.3 Improving the situation in the UK

The UK Government has stated that, although it would not be appropriate for employers to require or request genetic test results to assess the long-term health of employees or job applicants, *"…it might…be appropriate to use specific genetic tests to assess whether an employee's genetic constitution affects his or her susceptibility to specific features of a working environment that do not present any hazard to the majority of people"* [124]. The Government's former advisory committee, the Human Genetics Advisory Commission (HGAC), has argued that an individual should be required to disclose the results of a genetic test if there is clear evidence that the information it provides is needed to assess either their current ability to do a job safely or their susceptibility to harm from doing a particular job[90]. This is worrying because it implies that excluding such workers could be a valid option if alternatives, such as reducing everyone's exposures, are not considered 'reasonably practicable'.

It is sometimes argued that employers will not use genetic test results because they are poor predictors of an individual's future health. However,

discrimination in employment has often taken place in the absence of good evidence – for example, pay and promotion prospects are often still unequal for men and women doing the same job. In addition, some historic attempts to reduce harm by excluding part of the workforce instead of reducing exposures have led to serious impacts on health. The most notorious of these was the Ministry of Works' advice to employers in the 1940s that they should only employ people over 40 to work with asbestos[125]. Many of these workers later suffered and died from asbestos-related disease.

Some historic attempts to reduce harm by excluding part of the workforce instead of reducing exposures have led to serious impacts on health

Some commentators, including the Trades Union Congress (TUC)[76], the British Medical Association (BMA)[126] and the Human Genetics Commission (HGC), the Government's current advisory committee[71], recognise that there may be rare circumstances where employees might conceivably receive some benefit from tests that do not yet exist[91]. However, there is often a wish to impose strict conditions on when genetic tests might be used, as follows[127]:

- There should be a clear link between a genetic test result and disease caused by occupational factors, supported by reliable scientific evidence.
- The condition may arise quickly and cause serious danger to public safety or the health of other workers.
- There should be no way in which exposure to the hazard in question could be eliminated or controlled - all technically possible preventative measures must have been taken.
- Any exceptions must be authorised by public authority and regularly reviewed.

Whilst the TUC recognises a theoretical possibility that some future tests might meet the above conditions, it has grave concerns about the future use of genetic screening. It is opposed to susceptibility screening on the grounds that it will remove the emphasis on an employer's legal duties to make the workplace safe for all and would like to see the Disability Discrimination Act (DDA) amended now to prevent genetic discrimination.

The TUC has grave concerns about the future use of genetic screening

Given what we know about human illness and genetic influences on ill-health, it seems extremely unlikely that any genetic test will ever meet these conditions. However, the risk of genetic discrimination in employment is here today. It would be far preferable for immediate action to be taken now to prevent discrimination than to hesitate because of the remote chance of benefits in the future. Moreover, it makes more sense to introduce legislation before serious problems arise rather than to wait for the worst case scenario to happen.

8. Conclusions

GeneWatch UK concludes that:

> **No employer should demand that an individual takes a genetic test or reveals a genetic test result as a condition of employment. Nor should employers be allowed to use genetic information to determine an employee's terms, conditions, privileges or employment benefits.**

The TUC has also endorsed these principles and they are consistent with the concerns expressed by many other groups, including the EU Trade Union Confederation, the Human Genetics Commission and the British Medical Association.

The UK Government has endorsed the view that *"genetic tests should not be used to predict future health of potential or existing employees or to exclude people from employment"* in its response to an early assessment of the implications of genetics for employment[71]. However, its suggestion that it might be appropriate to use genetic tests to assess susceptibility to workplace hazards gives cause for concern.

Many epidemiological researchers conclude that preventative measures to improve workplace conditions are scientifically and ethically far more defensible than excluding workers on the basis of genetic screening. However, research to identify 'genetically susceptible' workers is continuing without legislation to ensure that these people are not excluded from employment in future.

Research to identify 'genetically susceptible' workers is continuing without legislation to ensure that these people are not excluded from employment in future

It therefore seems imperative that:

- New legislation should be introduced to prevent all forms of genetic discrimination and to prohibit employers (and insurers) from using or accessing individual genetic test results.
    - ⇨ UK legislation should be drafted now rather than waiting for the proposed government review of the use of genetic information in employment in 2005.
    - ⇨ Employment and insurance issues need to be considered together since the two are linked by issues such as employers' insurance costs and compensation claims.
- The UK Government should ratify and sign the European Convention on Human Rights and Biomedicine without any further delay.
- Greater emphasis should be placed on raising awareness and increasing expertise among employers as to how to reduce workplace exposures instead of trying to identify susceptible workers.
- Greater investment should be made in re-assessing the problem of occupational illness with a view to creating healthier workplaces rather than wasting money on dissecting the problem 'gene by gene'.

Genetic research in the workplace might sometimes improve scientists' understanding of workplace-related hazards and diseases, but laws banning genetic discrimination by employers are essential before workers are asked to

give their DNA samples for such research. Telling employees that genetic research will lead to improvements in health and safety is misleading and unethical unless such safeguards have been put in place.

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