

## Postprint

This is a pre-copyedited, author-produced PDF of an article accepted for publication in *Theoretical Medicine and Bioethics* following peer review. The definitive publisher-authenticated version [Newson, A.J. (2004) "The nature and significance of behavioural genetic information." *Theoretical Medicine and Bioethics*, 25: 89–111.] is available online at <http://link.springer.com/article/10.1023/B:META.0000033764.50604.85>

# The nature and significance of behavioural genetic information

Ainsley Newson BSc (Hons) PhD, 2004

## Abstract

In light of the human genome project, establishing the genetic aetiology of complex human diseases has become a research priority within Western medicine. However, in addition to the identification of disease genes, numerous research projects are also being undertaken to identify genes contributing to the development of human behavioural characteristics, such as cognitive ability and criminal tendency. The permissibility of this research is obviously controversial: will society benefit from this research, or will it adversely affect our conceptions of ourselves and each other?

When assessing the permissibility of this research, it is important to consider the nature and deterministic significance of behavioural genetic information. Whilst to date there has been much discussion and debate about the properties of genetic information *per se* and genetic determinism, this has not been applied to behavioural genetic research and its ethical implications. Therefore, this paper elucidates how behavioural genetic information can be distinguished from different from other types of genetic and non-genetic information and also synthesises the determinative significance of genetic factors for the development of human behavioural traits. Undertaking this analysis enables the ethical issues raised by this research to be debated in an appropriate context and indicates that separate policy considerations are warranted.

**Key Words:** Behavioural genetics, genetic determinism, genetic information.

## Introduction

Western medicine currently supports research into the molecular genetic aspects of many complex human diseases, such as cancer, heart disease and diabetes. However, genetic knowledge is not only being sought for pathogenic conditions - projects are also underway to identify genes involved in human behaviours such as cognitive ability and criminal tendency. Contrary to traditional quantitative research in behavioural genetics, these molecular genetic projects may lead to information which can be 'individualized' to particular people.<sup>1</sup>

Potential applications arising from the identification of genes involved with human behaviour raise ethical and social issues for individuals and society. For example, should the results of behavioural genetic tests be used when making social policy decisions? Should genetic interventions to alter human behaviour be developed? What effects might this research have upon how people and societies understand themselves and each other?

In determining ethical applications of this research, it is important that the nature and determinative significance of behavioural genetic information is taken into account. This paper draws upon existing discourse about the nature of genetic information and debates over genetic determinism to place behavioural genetic information in an appropriate context.<sup>2</sup>

For the purposes of this paper, 'behavioural genetic information' is defined as molecular genetic information that can be correlated with the development of a particular human behaviour.<sup>3</sup> This information could be general, such as a set of alleles correlated with a particular behaviour being published in a scientific journal; or specific, such as a person's result from a behavioural genetic test.

It is argued that behavioural genetic information can be viewed as a separate class of information, warranting separate policy consideration. It has a unique array of properties, and therefore is significantly different from either 'medical' genetic information or other 'non-genetic' information about behaviour. However, this property of distinctiveness does not mean genetic information should be conceived of as more important than other sources of information when considering the causes of people's behaviour.

### **Behavioural genetic research**

Currently, researchers are working to identify genes influencing the development of several human behaviours, including criminal tendency, homosexuality, cognitive ability, novelty seeking, mental disorder and addiction.<sup>4</sup> These traits are all 'complex traits', as the pattern of inheritance demonstrated cannot be explained by the involvement of only one or two genes. Any phenotype is the result of a combination of many genes interacting with the environment.

There is no denying that in addition to the social sensitivity of this research, it is shrouded in significant scientific controversy.<sup>5</sup> The inheritance of behavioural traits has been vehemently debated for over a century, with trends oscillating from ideas of environmentalism and genetic equalitarianism (people's behaviour and talents are purely a product of their environment) to considerations that our genes set the ultimate limits as to what we are able to achieve. However current dogma accepted by both behavioural geneticists and detractors of the research is that people's genes *and* the environment they are exposed to have an interactive effect on their development. So, genes can determine only the likelihood or probability of a particular behaviour, and do not represent the ultimate limits of what we can achieve.<sup>6</sup>

A variety of methodologies have been utilised in attempts to demonstrate a genetic contribution to human behaviour. Consider the example of cognitive ability.<sup>7</sup> Utilising psychometric definitions such as reasoning ability and mental processing speed, research papers about the inheritance of this trait have been consistently present throughout the history of behavioural genetics.<sup>8</sup> Most of these have utilised quantitative techniques, which investigate the proportion of differences in intelligence levels between individuals within a particular group that can be attributed to genetics.<sup>9</sup> The end-point of such studies is an entity termed *heritability*, which represents the genetic contribution to cognitive ability

expressed as a percentage of the overall population variation in intelligence. These studies have obtained heritability estimates of around 50%-70%<sup>10</sup> - that is, this percentage represents the amount of difference between people (in a particular environment at a particular time) attributable to genetic causes. However, there have been large inconsistencies between heritability studies<sup>11</sup> and they are often criticised.<sup>12</sup>

As quantitative genetic studies are not designed to identify specific genes, researchers are now using molecular genetic approaches to identify and characterise genes contributing to the development of intelligence.<sup>13</sup> One such study compared whether different alleles (or versions) of particular DNA markers occurred at a higher frequency in children of 'high intelligence' than those of 'low intelligence' (disputes over definitions of these states aside). If a difference was observed in the frequency of a particular DNA marker between the two groups (as it initially was), this could indicate the presence of a gene influencing intelligence in the region of the marker. However a subsequent study has failed to replicate this finding.<sup>14</sup>

### **Is behavioural genetic information different?**

Although providing meaningful behavioural genetic information to individuals is not yet possible, it seems reasonable to suggest that this won't always be so – and the ethical considerations raised earlier will come to the fore. In considering the implications of this research, it is important to consider how *distinctive* this type of information will be. First, whether or not this information is distinguishable as a class of genetic information could influence how legislative or policy responses should be made to the various issues raised by the research. Should there be special policies or laws for behavioural genetics?<sup>15</sup> Second, an answer to this question might help explain the apparent inconsistency in our attitudes to information about ourselves. Why is it that we are often likely to be interested in (at least some of) our medical genetic information and our psychological profiles, but balk at the spectre of knowing about genetic influences on our behaviour?

According to Murray, if special treatment of genetic information were to be warranted, it would 'have to be distinctive and especially sensitive'.<sup>16</sup> He argues that in the medical context, genetic information does not meet such a requirement. What happens when this test is applied to genetic information about behaviour?

It seems obvious that behavioural genetic information will be *sensitive* – the considerable media coverage and public discourse about this research are testimony to this. However, to determine whether behavioural genetic information is *distinctive*, two comparisons must be made. First, we must ask whether behavioural genetic information is distinguishable from other non-genetic information about behaviour (an analysis that also draws upon the more general question of whether genetic information *per se* is distinctive).<sup>17</sup> Second, we need to question whether behavioural genetic information is different from medical genetic information. It is argued here that the answer is 'yes', on both counts.

*Is behavioural genetic information distinctive when compared to non-genetic information about behaviour?*

In a recent commentary, Benjamin argued that:

In principle there seems to me little difference between information about a person's genes, and how it is treated, and information about his or her intellectual abilities, psychological qualities, appearance, and past medical history, and how these are treated.<sup>18</sup>

Yet contrary to this view, it is possible to make a distinction between ‘genetic’ and ‘non-genetic’ information about behaviour. This can be illustrated by examining some of the features of *medical* genetic information which may render it as distinct, and examining how these apply to behavioural genetics. Common features about genetic information in general that have been suggested as reasons to consider it as distinct from non-genetic information are that it:

- Uniquely identifies particular people;<sup>19</sup>
- Is ubiquitous: genetic information is potentially all around us; it can be obtained from a small amount of material (perhaps even without the person being present) and lasts for life;<sup>20</sup>
- Has predictive properties - the results of a genetic test can give people information about their future health before symptoms develop;
- Can be obtained before people are born;
- May indicate a risk for other genetically related family members or future offspring;
- May be of relevance to third parties, such as insurers and employers; and
- Can be shared by members of larger communities beyond the individual or family, as is the case with Tay Sachs disease in populations of Ashkenazi Jewish descent.<sup>21</sup>

However, there are also many who do not consider medical genetic information to be special. Interestingly, this includes both proponents and detractors of genetic testing and research.<sup>22</sup> Several claims are made in advocating this position. First, the ‘predictiveness’ of genetic information is not a compelling reason to render genetic information special – many other types of information can also provide us with glimpses of our future health, such as measurements of cholesterol levels in blood. Additionally, other factors affecting people’s lives (such as social class) are transmissible between generations. Moreover, medical conditions not caused by the presence or absence of a gene are also shared within families, as is the case with communicable diseases such as tuberculosis.

So why is genetic information considered as distinctive by the public and the media, and can these claims be substantiated? Murray has explained the public’s intuition about genetic information being distinctive or special as because it carries with it a peculiar ‘technologization’ or ‘mystery’ that has developed since the introduction of recombinant DNA techniques, not because it is actually substantively different from any other kind of information.<sup>23</sup> However, there remains an intuition that there is *something* about genetic information making it different.

A better explanation of the intuition behind the belief in so-called ‘genetic exceptionalism’ can be made by examining an important quality of medical genetic information overlooked to date. It may be true that none of the above properties of genetic information are unique to genetics when each is considered *individually*. However, the distinctiveness of genetic information – the quality that allows it to be set apart from other types of information – is the fact that for most genetic information, all of the above properties are present *together*. Very few other kinds of health information will possess a combination such as this.<sup>24</sup> In the very least, it seems clear that the notable features of genetic information cannot be ignored, though of course it would also be a mistake to consider genetic information in pure isolation from other relevant health and social information.<sup>25</sup>

These claims about the distinctiveness of genetic information are also true for behavioural genetic information. Presuming it can be identified and made applicable to individuals, behavioural genetic information is capable of being:

- Uniquely identifying;<sup>26</sup>
- Obtainable from a small tissue sample (perhaps before birth);
- Capable of predicting tendencies towards certain future behaviours;
- Indicative of behavioural probabilities for other family members or offspring;
- Of potential interest to third parties such as educators and the State; and
- Shared by members of larger communities beyond the individual or family.

It is difficult to think of a personality or psychological test (or any other non-genetic information about behaviour) that would possess this combination of properties.

In addition to these properties, behavioural genetic information is also likely to be pleiotropic. Pleiotropy occurs where a single gene has effects on multiple unrelated phenotypes as a gene influencing one biochemical pathway will also be involved with others.<sup>27</sup> Pleiotropy has already been observed for several complex genetic diseases, such as the relationship between coronary heart disease and Alzheimer's disease, where variant alleles of the *ApoE4* gene can provide risk information for both conditions. This may give rise to ethical difficulties, as recommendations for testing for one condition (or people's attitudes to one test) may differ significantly depending on the phenotype under examination. How should society respond if genes involved with intelligence were also found to be associated with something like anxiety or an antisocial personality? The moral difficulties are likely to be significant. Although I might be quite interested in genes influencing my propensity to undertake novelty-seeking behaviour, I might not want to know whether I am at risk of developing alcoholism, were such a link to be found.<sup>28</sup> However, although the pleiotropic effect of complex genetic information is a 'special ethical issue'<sup>29</sup> it may not be one which distinguishes genetic from non-genetic information about behaviour. That is, something like the measurement of neurotransmitter levels may also provide indications for more than one apparently unrelated human behaviour.<sup>30</sup> Yet despite this, the properties of behavioural genetic information discussed above still serve to distinguish it from non-genetic information.

#### *Is behavioural genetic information distinct from medical genetic information?*

Although it has been argued that genetic and non-genetic information can be distinguished, nothing has been said about whether behavioural genetic and medical genetic information can be distinguished from each other. Given the somewhat fuzzy boundaries between considerations of what is commonly considered as 'health' and what may be described as 'behavioural' in Western society, many are likely to argue that such a distinction is impossible.

Despite this potential problem, behavioural genetic information is distinguishable from medical genetic information in numerous ways, suggesting a need for at least a degree of separate policy recognition.

Some behavioural genetic researchers have already articulated their view on this issue. For example, McGuffin, Riley and Plomin have argued that:

Although in many ways behavior presents geneticists with the same challenges as other complex psychological and medical traits, behavior is unique in that it is the product of our most complicated organ, the brain.<sup>31</sup>

There are other reasons why behavioural and medical genetic information can be distinguished. Contrary to medical genetic information, genetic information about a range of behaviours has a much greater potential to affect how individuals perceive their personality and attributes, significantly influencing self-perception. These broad reflections on personality and ability may form a much greater component of who we are (our 'identity') than our medical history does.<sup>32</sup> Consider again the example of intelligence. Bearing in mind the social value placed upon intelligence within Western cultures, it is likely that any genetic information about it would be relevant for a vast majority of the population, and that this type of information could have a huge effect upon people's self-image.

A third way in which behavioural genetic information can be distinguished from medical genetic information is its potential relevance to everyone. Whilst almost all of us will carry some risk for one or two particular genetic conditions in a post-genomic world, the difference with behavioural traits is that we are likely to be able to obtain meaningful (a greater than zero-risk) profiles for *any* behavioural trait we choose. It is hard to think of one example of medical genetic information that could potentially affect such a broad range of people in such a way – a genetic risk for heart disease will be relevant for many people, as will cancer susceptibility information, yet information about behaviours will unequivocally affect all of us.

Fourth, the majority of behavioural genetic information would be of relevance over a much broader temporal range of people's lives. To be sure, medical genetic information for some conditions such as heart disease will be relevant for much of our lives (and potentially the lives of our children), to enable us to live a particular lifestyle to minimise disease risk. Yet behavioural genetic information is going to be of much greater relevance to our life's autobiographical narrative; the way we make sense of things over time. Particularly as we age, we are more likely to be interested in behavioural genetic information than we are medical genetic information.<sup>33</sup> If I was 80 and had never had heart trouble, there would be no need for me to obtain genetic information about this condition to make sense of my health status. In contrast, our autobiographical narratives are greatly informed by our behavioural experiences and tendencies and so this information is more likely to attract a special relevance.

Finally, as mentioned above, behavioural genetic information is much more *sensitive* than medical genetic information, especially when social groups are concerned. Again this is obvious where intelligence is considered, as debate over the relationship between intelligence and ethnicity has raged for over a century.

Thus there are several reasons why behavioural genetic information can be distinguished from medical genetic information. However, a potential objection to this distinction arises if we consider the exact boundary between that which is medical and which is behavioural. As most behavioural traits have a 'continuous' distribution within the population (there are not discrete classifications of behaviour) and some extremes of this distribution may have a pathological component, it is often not possible to 'draw a line' between what is medical and what is not. Nor is it possible to draw lines between the various manifestations or classes of a particular trait within the population. Mental retardation, for example, is usually considered as more a medical condition than a behavioural one. Alcoholism and aggression are more contentiously 'medical', as people inflicted with these conditions often respond to therapeutic interventions. So, whether behavioural genetic information is distinctive might depend on whether lines can be drawn along this continuum between medicine and health, and between various categories of the particular behaviour.

Buchanan *et al* note that currently, things the community would be compelled to treat are generally considered as medical; this would probably include several behavioural extremes.<sup>34</sup> Although this concept allows for mere social values (as opposed to more objective measures) to define what disease is, *prima facie* it does make sense. This reflects Jonathan Glover's point that even though the distinction between night and day is problematic, this is not reason for abandoning the distinction altogether.<sup>35</sup> The distinction between what is medical and what is behavioural may be problematic, but this does not mean that such a distinction can never be drawn.

Therefore, as summarised in the following table, behavioural genetic information is different; distinguishable from both non-genetic and medical genetic information.

<b>Table 1: How behavioural genetic information is different</b>	
<p><i>Compared to non-genetic information</i></p> <ul style="list-style-type: none"> <li>• Distinct individual tailoring, information unique for particular people</li> <li>• May be obtained prior to condition developing</li> <li>• May be obtained about those yet to be born</li> <li>• A unique combination of properties</li> </ul>	<p><i>Compared to medical genetic Information</i></p> <ul style="list-style-type: none"> <li>• Sheer volume of Information</li> <li>• Will provide information about a very broad range of traits and thus will infiltrate people's lives more</li> <li>• Relevant at broader temporal range of people's lives</li> <li>• Particularly sensitive information</li> </ul>

### **What is the significance of genes influencing human behaviour?**

Although behavioural genetic information may be distinct from both medical genetic and non-genetic information about behaviour, this tells us little about how significant genes may be to the determination of human behaviour. This is an important consideration, given the widespread concern about this information ever being made available for public consumption.<sup>36</sup> There is a:

... dark feeling that biology is destiny, that what was thought to make up human dignity, free will, self-determination, is determined by blind molecular and physiological mechanisms.<sup>37</sup>

Are these fears about the limiting properties of behavioural genetic information likely to be realised? Answering this question necessitates this next phase of analysis – a consideration of the way in which behavioural genetic information should be construed as an influence on the development of human behaviour. The validity of this 'dark feeling' is questioned through an examination of the significance of genetic information from two perspectives: those undertaking behavioural genetic research and their critics. What emerges is that researchers do not support such notions of complete genetic determinism, but that critics of genetic research still claim an over-emphasis of the significance of genetic information. A more moderate position about the significance of genetic information is then advocated, namely that behavioural genetic information can be an acceptable first 'port of call' in researcher's quests to understand human behaviour. However, this information certainly should not be the only information sought when seeking to explain human behaviour – it will only be valid if represented within a context of other causal factors.

### *Genetic determinism*

'Genetic Determinism' is a term broadly used to describe the view that the way we look and act is primarily due to the sequences of DNA we possess, with our environment playing only a minimally modifying role.<sup>38</sup> That is, our traits, diseases and capabilities can be solely attributed to the additive effects of genetics and environmental stimuli. This view sits in virtual opposition to 'environmentalism', supporters of which claim that the various environments people are exposed to during their development are a major determinant of their behaviour, with genes playing only a secondary role.

Questions examining how and to what extent genetic information influences human behaviour have been debated throughout history – enthusiasm for genetic explanations of behaviour first peaked in the nineteenth century, when Francis Galton proposed that intelligence was predominantly inherited.<sup>39</sup> This research was subsequently linked with eugenic acts such as using IQ tests (in English) to limit immigration to North America after the First World War,<sup>40</sup> and acts of genocide based upon genetic origins during the Second World War. In the 1950s, cultural and environmental explanations of behaviour became popular. Yet with the advent firstly of quantitative, and now molecular techniques (and the recent completion of the Human Genome sequencing Project), genetic explanations of behaviour have again resurfaced for public consideration.

What is clear within this current enthusiasm for genetic explanations of behaviour is that behavioural geneticists do not support 'hard' genetic determinism – they do not believe that if one inherits a certain set of genes linked to a particular trait, they will develop that trait in almost all environments. For example, two prominent behavioural geneticists recently stated that:

'Some of the fears [about the research] derive from misunderstandings about what genetics can and cannot do. The main misunderstanding is to think that genes determine outcomes in a hardwired, there's-nothing-anyone-can-do-about-it way... behavioural dimensions (and their extremes and disorders) are complex traits influenced by many genes as well as by many environmental factors.'<sup>41</sup>

In another commentary, one of the same authors argued:

There is the assumption that genes are directly determinative such that if you have a particular gene, you will inevitably get the disorder with which it is associated... But the vast majority of medical conditions are not like that at all. Instead, they are multifactorially determined, meaning that they arise from the interplay among a mixture of genetic and environmental risk and protective factors... Accordingly, genetic effects are probabilistic rather than deterministic in their effects.<sup>42</sup>

However, examples of strong support for genetic explanations of behaviour (by those not actively involved in the research) can still be found in the literature:

It is genes that determine the extent to which behaviour may be expressed and the environment that creates either limited or full opportunities for expression... it is necessary to understand that each of us carries into this world from birth genetically ordained behaviours, some of which may be uplifting and life-fulfilling and other detrimental to the human condition.<sup>43</sup>

Although researchers and critics alike view the development of behaviour as involving both genetic and environmental influences, critics claim that in focussing upon genetic factors, behavioural geneticists see these as more important than others.<sup>44</sup>

The genetic determinism debate therefore seems to have closed in one sense only. It is clear that hard determinism is unsupported, yet there is no agreement upon how we should conceive the importance of genetic factors in influencing human behavioural traits.

*What is the view supporting the significance of genetic information?*

As discussed, no recent papers by behavioural geneticists advocate 'hard' genetic determinism. Those undertaking this research do not believe there is a 'volitional power' in genes, directly compelling a particular behaviour. Any human behavioural trait will manifest via the interaction of a complex of social, biological and psychological factors.

However, researchers obviously support a role for genes in *influencing* the probability of a particular behavioural trait developing. They are enthusiastic about genetic information – if it were otherwise it is unlikely they would be doing this kind of research. Generally, genes are perceived to be a primary causal factor in the development of human behavioural traits (a view termed 'ontogenic primacy'). Researchers believe that behavioural genetic research will be relevant to explanations of particular behaviours and abilities that people may have, and that as more behavioural genetic research is carried out, more will be understood about human development.

Further, researchers claim that not only are genes a primary causal factor in the development of human behaviour, in future it will also become legitimate to access genetic information as a first 'port of call' for research, or when seeking to explain or predict a particular individual's behaviour. This is due to the 'explanatory primacy' or 'informational primacy' of genetic information over any other factors relevant to how a person develops. In a recent paper, Plomin and Crabbe declared that in a few years, psychology will be 'awash in specific genes responsible for the widespread influence of genetics on behaviour'.<sup>45</sup> Further, they claim that behavioural genetic information will drastically alter clinical practice in psychology and will be valid enough to use in diagnosis.

Despite this enthusiasm, these statements are flagged with an important caveat. Plomin and Crabbe state that in identifying genes associated with behaviour:

These advances will need to be integrated with corresponding advances in understanding the multiple, interactive environmental influences as well... [H]igher levels of analysis are increasingly needed to understand the pathways between genes and behaviour.<sup>46</sup>

These researchers recognise that although finding genes at the molecular level is important, the results will be meaningless unless integrated with an understanding of processes at neurological and psychological levels. However, even in the absence of genetic determinism, they believe genetic information is capable of predicting the probability of a specific human behaviour will become available.

Other behavioural geneticists have been noticeably absent from debates on genetic determinism. Rather than engage in this kind of discourse, they have preferred to justify molecular genetic research by referring back to quantitative experiments indicating a high heritability of the trait they are investigating. Yet, this stance should not be used to promote the stereotypical notion of a socially insensitive, ill-informed behavioural geneticist, as very few of these actually exist.<sup>47</sup>

An inconsistency in the literature arises when we turn to the claims of those critical of the significance of genetic information. Most literature in this area represents genetic researchers as holding deterministic views and failing to recognise the importance of other complex causal factors in the development of behavioural traits. Yet, as has been seen here, this is not so.<sup>48</sup> The views of these critics are now discussed.

### *What do critics of genetic research believe?*

There is a plethora of literature by both scientists not involved in behavioural genetic research and philosophers of science, which adopts a strong 'anti-deterministic stance'.<sup>49</sup> These critics do not agree that genetic information can have ontogenic or informational priority, as they deny that genes have any primacy over other developmental influences in behaviour. They claim that viewing genetic information as significant in these ways is an over-simplification of complex developmental processes, in which a phenotype is not an end-point but a continually evolving entity. Instead, they adopt what is termed an interactionist view, and state that rather than emphasising either genetic or non-genetic information, the interaction between the two should instead be focussed upon.<sup>50</sup>

However as most researchers in behavioural genetics now also refer to themselves as interactionists, a more structured theory in disagreement with the significance of genetic information has emerged. Termed *Developmental Systems theory*, proponents of this view claim that the effects of genes and environment can never be separated, as they have an essential and continuous interdependence.<sup>51</sup> Rather, they emphasise causal complexity. Individual processes involved in the development of behaviour cannot be isolated, and development is significantly influenced by other factors such as spontaneous mutations (Table 2). Central to this view is the concept of *parity*, the view that the genome should be considered as equal with all other factors relevant to development. Singling out genes for separate analysis is therefore misleading, as their influence is inherently linked with all other factors that are excluded from genetic studies.

Thus in contrast to the views of behavioural geneticists, proponents of Developmental Systems Theory refute the idea that predictability in behavioural genetics will be possible, even if all environments were known. Further, they argue that DNA sequence information has no fixed meaning, but is interpretable only in a particular context. Genetic information does influence the development of behaviour, but there are many other factors that can promote its development, often in unpredictable ways.

Proponents of Developmental Systems theory therefore seem to differ with the views of researchers in the significance placed upon both 'ontogenic' and 'informational' priority of genetic information in the development of behaviour. Thus they would claim that genetic information cannot be used for clinical diagnosis or prediction of behaviour, as such an approach fails to take account of the vast complexity involved. Can these two views be reconciled?

#### *A more moderate view*

As behavioural genetics is yet to provide us with large numbers of results, how can we evaluate these conflicting claims? The determinative significance of behavioural genetic information will have strong repercussions for the permissibility of this research. At first, it seems clear that there is no basis to any claim that 'biology is destiny'. However, the intricacies of the significance of genetic information, both causally and in its potential use as one of the first 'ports of call' for explanations of behaviour, require further analysis.

As Schaffner claims, proponents of Developmental Systems Theory are correct in emphasising the roles of numerous causal factors in the development of behaviour.<sup>52</sup> Thus the 'ontological priority' ascribed by researchers may be too great an interpretation of the power of genes to direct development. However, the 'informational priority' of genetic information may still be acceptable. Genes could be the first 'port of call' for information about behaviour, but that this should not be the only type of information worth obtaining and analysing. Genes can have a unique informational role in research upon behaviour, as when contrasted with other intracellular and extracellular information, they are easily

characterisable, and can be investigated using well-developed research methods.<sup>53</sup> Other information will be inherently more complex to investigate.

Thus, when considering the role of genes in behaviour, there is a need to recognize the likelihood that there will be a variety of different factors involved, but that genetic information may legitimately be sought before any other information, as long as it is interpreted within a context of other causal factors. Kitcher rightly points out that research teams cannot investigate every factor relevant to the development of behaviour at once,<sup>54</sup> and just because genes do not act alone in the development of behaviour does not mean that they cannot be investigated at all.<sup>55</sup> Indeed, if research into behaviour is left merely to general terms, what will result is mere 'explanatory spread',<sup>56</sup> which will not achieve much in explaining behaviour. Additionally, genetic research can actually be carried out at the same time as higher-order functional studies, so that the two can then inform each other.<sup>57</sup> The following table summarises this moderate view:

<b>Table 2: A framework for interpreting behavioural genetic information</b>
<p><i>It is important to recognise that:</i></p> <ul style="list-style-type: none"> <li>• Genes associated with behaviour must be interpreted within the context of other genes and the environment (cellular, extracellular and extraorganismic), and that there exists a complex web of causes of behaviour. Genes can be singled out for analysis, but this does not mean that they are all that should be considered as relevant.</li> <li>• There are factors which complicate DNA expression: <ul style="list-style-type: none"> <li>- Spontaneous Mutations</li> <li>- Pleiotropy</li> <li>- Variable penetrance – just because a gene is there does not mean that it will be expressed within a complex system</li> <li>- Variable expressivity – genetic makeup cannot tell us how mild or severe the expression of a trait will be.</li> </ul> </li> <li>• A genetic component to a behavioural trait does not mean that the behaviour cannot be altered</li> <li>• There will only be rare circumstances where a single gene type is closely tied to a single type of behaviour</li> <li>• Behavioural phenotypes will not be entirely predictable from genetic information</li> </ul>

Therefore, the significance of behavioural genetic information lies in its tangibility to researchers and the relative ease with which it can be investigated. However, this explanation does not lend itself to mean that behavioural genetic information is solely predictive of how a person's behaviour, personality or talents will develop. This will be achieved through a vast interactive network of causes at biological, psychological and environmental levels.

### **Where to from here?**

The claims advanced in this paper have been twofold. First, behavioural genetic information is distinct from either medical genetic or other non-technological information.

Second, despite this distinctiveness, society should refrain from causally prioritising it over other types of information about human behaviour, as it cannot be interpreted without additional contexts.

This analysis is important as it establishes the best context for a reasoned analysis of the ethical and social implications of this research. It has been important to consider what behavioural genetic information is and what its significance may be, but the next and perhaps even more important step is to decide how it should be used. Such an analysis is beyond the scope of this paper, but an initial question has already been posed above – are current public and political responses to the prospect of this information (namely that the research should either not be undertaken in the first place; or if it is, that results should not be used) rational?

Without wanting to detract from the purpose of this paper, it can be stated that some negative attitudes towards this research may be unfounded. Behavioural genetic research may make a valuable contribution to existing psychological knowledge, and it will not shed light on people's destiny or ultimate limits in life. Yet it is also important to recognise that if people are given access to this information, appropriate mechanisms need to be in place to insure that it is not interpreted out of context. However, these are obviously questions that do require future debate, in addition to issues surrounding the allocation of resources to behavioural genetics within the current economic climate.

## **Conclusion**

In response to the challenge of understanding the significance of behavioural genetic information to assess the permissibility or otherwise of such research, the central questions of this paper have been 'Is behavioural genetic information different?' and 'What is its significance?'

It has been claimed that behavioural genetic information is distinct when compared to both medical genetic and 'non-genetic' information about behaviour. However, the determinative significance of behavioural genetic information should be interpreted contextually as one of many factors considered relevant to the development of human behaviour. Thus behavioural genetic information may be sought in preference to other information (due to the relative ease with which it will be able to be procured and analysed) so long as this does not lead to other information relevant to explaining human behaviour being ignored.

Obviously questions about the value that this information may have for individuals and how this information should be handled socially require further exploration. However at the very least, this discussion has called into question strong objections to behavioural genetics based upon fatalistic or semi-fatalistic views. Although this may appear to be the mere defeat of a straw man, arguments against behavioural genetics underpinned by fatalism are often advocated, particularly in the media. It is clear that fears about the limiting properties of behavioural genetic information are very unlikely to be realised by the research.

The next but no less significant challenge that researchers and policy-makers will face is to facilitate how the sheer complexity of this information can be accurately relayed to the public, the media and policy-makers.<sup>58</sup>

## Acknowledgments

The author acknowledges the contributions of Dr Richard Ashcroft, Professor Julian Savulescu, Professor Bob Williamson, Dr Marilyns Guillemin and Dr Craig Olsson for helpful discussions during the drafting of this paper. Staff and students at the Key Centre for Women's Health and the Centre for the Study of Health and Society at the University of Melbourne also provided valuable feedback, as did two anonymous referees.

## Notes and References

1. For any particular behavioural trait under investigation, quantitative genetic research leads to a statistical measure of the differences between people within a group that can be attributed to genetic factors. For a recent review of this research, see: Bouchard T.J. and McGue M. "Genetic and Environmental Influences on Human Psychological Differences." *Journal of Neurobiology* 54 (2003): 4-45.
2. The importance of contextualising genetic information has recently been highlighted by the Australian Law Reform Commission: Australian Law Reform Commission and Australian Health Ethics Committee. "Coming to Terms with Genetic Information" in: *Essentially Yours: The Protection Of Human Genetic Information In Australia*. ALRC Report No 96, (2003): 129-46.
3. I say 'molecular' information, to distinguish it from the more traditional statistical information that is usually the subject of discussions about behavioural genetics, such as measures of heritability. Throughout this paper whenever behavioural genetic information is discussed, it should be taken as an implicit reference to the kind of genetic data derived from molecular genetic research. It is important to recognise, however, that at present this information doesn't exist.
4. Drew A.P. "Genes and Human Behavior: The Emerging Paradigm." *Zygon* 32 (1997): 41-50.
5. For a review, see: Alper J.S. and Beckwith J. "Genetic Fatalism and Social Policy: The Implications of Behavior Genetics Research." *Yale Journal of Biology and Medicine* 66 (1993): 511-24.
6. Gottesman I.I. "Twins: En Route to QTLs for Cognition." *Science* 276 (1997): 1522-23: 1522. Gottesman represents behavioural geneticists as striving to be seen as 'probabilists' rather than determinists.
7. Assuming it is possible to define what 'intelligence' is.
8. See, eg: McClearn G.E., et al. "Substantial Genetic Influence on Cognitive Abilities in Twins 80 or More Years Old." *Science* 276 (1997): 1560-3; and Petrill S.A., et al. "Exploring the Genetic and Environmental Etiology of High General Cognitive Ability in Fourteen- to Thirty-Six-Month-Old Twins." *Child Development* 69 (1998): 68-74.
9. There are three main quantitative techniques: comparisons of identical and non-identical twins, comparisons of twins who have been raised apart, and comparisons of adopted people with their natural and adopted parents. See: Plomin R. DeFries J.C. McClearn G.E. and McGuffin P. *Behavioral Genetics* (New York: Worth Publishers, 4th ed. 2001).
10. Devlin B. Daniels M. and Roeder K. "The Heritability of IQ." *Nature* 388 (1997): 468-71; Bouchard and McGue, n 1 above: 12.
11. Maddox J. "Genetics and Heritable IQ." *Nature* 309 (1984): 579.

12. See, eg: Bailey R.C. "Hereditarian Scientific Fallacies." *Genetica* 99 (1997): 125-33.
13. Plomin R et al. "DNA Markers Associated with High Versus Low IQ: the IQ Quantitative Trait Loci (QTL) Project." *Behavior Genetics* 24 (1994): 107-18; Chorney M.J. et al. "A Quantitative Trait Locus Associated with Cognitive Ability in Children." *Psychological Science* 9 (1998): 159-66; Fisher P.J. et al. "DNA Pooling Identifies QTLs on Chromosome 4 for General Cognitive Ability in Children." *Human Molecular Genetics* 8 (1999): 915-22.
14. Hill L. Chorney M.J. Lubinski D. Thompson L.A. and Plomin R. "A Quantitative Trait Locus Not Associated With Cognitive Ability in Children: A Failure to Replicate." *Psychological Science* 13 (2002): 561-2.
15. This is a timely question, given current debates in academe and elsewhere. The Nuffield Council on Bioethics has recently completed an inquiry into behavioural genetics: Nuffield Council on Bioethics. *Genetics and Human Behaviour: The Ethical Context*. London, 2002. Available at: <http://www.nuffieldbioethics.org>. Additionally, the celebrated debate between Stock and Fukuyama centres strongly upon the theme of future modifications of human behaviour using genetic information: Fukuyama F. *Our Posthuman Future: Consequences of the Biotechnology Revolution* (New York: Farrar Straus & Giroux, 2002); contra Stock G. *Redesigning Humans: Our Inevitable Genetic Future* (New York: Houghton Mifflin, 2002).
16. Murray T.H. "Genetic Exceptionalism and 'Future Diaries': is Genetic Information Different from Other Medical Information?" In Rothstein M.A., ed. *Genetic Secrets: Protecting Privacy and Confidentiality in the Genetic Era* (Yale: Yale University Press, 1997), 60-73: 64.
17. 'Genetic' information can be envisaged via imagery of lots of DNA bases in a row, or bands on an electrophoresis gel. On the other hand, 'non-genetic' information incorporates information such as the results of a psychometric test. The results of an IQ test are a typical kind of 'non-genetic' information, however a description of factors in a person's environment could also provide 'non-genetic' information (whether explanatory or predictive) about her intelligence.
18. Benjamin J. "Genes for Human Personality Traits." *Science in Context*: 11 (1998):357-62, 366.
19. This, of course, does not apply in the context of monozygotic (identical) twins.
20. The so-called 'ubiquity dimension': Australian Law Reform Commission; cited in n. 2 above: [3.17-3.21].
21. Annas G.J. "Privacy Rules for DNA Databanks: Protecting Coded Future Diaries." *JAMA* 270 (1993): 2346-50; Annas G.J. Glantz L.H. and Roche P.A. "Drafting the Genetic Privacy Act: Science, Policy and Practical Considerations." *Journal of Law, Medicine and Ethics* 23 (1995): 360, 65; Bayertz K. "What's Special about Molecular Genetic Diagnostics?" *Journal of Medicine and Philosophy* 23 (1998): 247-54; Green R.M. Thomas A.M. "DNA: Five Distinguishing Features for Policy Analysis." *Harvard Journal of Law and Technology* 11 (1998): 571-91; Richards M. "How Distinctive is Genetic Information?" *Studies in History and Philosophy of Biological and Biomedical Sciences* 32C (2001): 663-87.
22. See, eg: Beckwith J. Alper J.S. "Reconsidering Genetic Antidiscrimination Legislation." *Journal of Law, Medicine and Ethics* 26 (1998): 205-10; Alper J.S. "Genes, Free Will, and Criminal Responsibility." *Social Science and Medicine* 46 (1998): 1599-611; Holm S. "There is Nothing Special about Genetic Information." In Thompson A.K. and Chadwick R.F., eds. *Genetic Information: Acquisition, Access and Control*. (New York: Kluwer Academic, 1999): 97-103.; Murray, cited in n. 16 above; Gostin L.O. and Hodge J.G.

“Genetic Privacy and the Law: An End to Genetic Exceptionalism.” *Jurimetrics* 40 (1999): 21-58.

23. Murray, cited in n. 16 above.
24. HIV status is one example of information that may have all of these properties, however this too is treated as distinctive information.
25. For example, the Australian Law Reform Commission had adopted an exceptionalist approach, but changed its position in its final report to a more contextual view: Australian Law Reform Commission, cited in n. 2 above: [3.56-3.63].
26. ...so long as the information obtained is of a significant enough quantity that it will contain information capable of identifying the individual being tested. The assertion of the uniqueness of genetic information is more applicable to genetic information (and behavioural genetic information) as a whole, rather than a specific piece of genetic information. Each specific ‘piece’ of genetic information, or a combination of pieces, will not necessarily be uniquely identifying of the individual – they will be shared by many people in the population. However, a ‘behavioural genetic profile’ is likely to be uniquely identifying.
27. Wachbroit R.. “The Question Not Asked: The Challenge of Pleiotropic Genetic Tests.” *Kennedy Institute of Ethics Journal* 8 (1998): 131-44, 131.
28. For example, if a person were to be tested for one particular trait, should they be informed about any roles that the relevant genes may play in other traits or diseases? What if contributions or links with other traits are found after the test has already taken place? In consenting to a genetic test, a person may be consenting to a much greater amount of information than they had initially anticipated as even if they elect not to receive further results, media reports of studies may render this impossible. The significant complexities and potential psychological risks in exploring our behavioural genetic constitutions will be compounded if we are given more than we bargained for.
29. Wachbroit, cited in n. 27 above: 132.
30. I thank one of the referees for drawing this point to my attention.
31. McGuffin, P., Riley, B., and Plomin, R., “Genomics and Behavior: Toward Behavioral Genomics.” *Science* 291 (2001): 1232-49, 1232.
32. This is not, of course, to say that our health status does not impact upon our sense of identity. However, our personal identity is arguably shaped much more by our attributes and abilities than it is by health status.
33. Apart from instances where this information will assist other family members; but this will be rarer than for behavioural genetic information. For most of us, health information will become relevant at isolated times throughout our lives.
34. Buchanan A. Brock D.W. Daniels N. and Wikler D. *From Chance to Choice: Genetics and Justice* (Cambridge: Cambridge University Press, 2000): 108. They add that it would not include the boundary between what is permissible and what is impermissible.
35. *Ibid*: 110.
36. Numerous public awareness campaigns have been undertaken in opposition to genetic research, a notable one being that of the *Campaign for Real Intelligence*, which staged a consistent campaign to prevent funding for projects investigating the genetic influences on intelligence.

37. de Jong HL. "Genetic Determinism: How not to Interpret Behavioral Genetics." *Theory and Psychology* 10 (2000): 615-37: 616.
38. There are many varying theories of genetic determinism – the discussion of which is beyond the scope of this paper.
39. Galton F. *Hereditary Genius*. (London: Macmillan and Co., 1869).
40. Rothstein M.A. "Behavioral Genetic Determinism: Its Effects on Culture and Law." In Carson R.A. and Rothstein M.A., eds. *Behavioral Genetics: the Clash of Culture and Biology* (Baltimore: Johns Hopkins University Press, 1999): 89-115.
41. Plomin R. and Crabbe J. "DNA." *Psychological Bulletin* 126 (2000): 806-28, 823.
42. Rutter M. and Plomin R. "Opportunities for Psychiatry from Genetic Findings." *British Journal of Psychiatry* 171 (1997): 209-19, 210.
43. Drew, cited in n. 4 above: 45.
44. Kitcher P. "Battling the Undead: How (and How Not) to Resist Genetic Determinism." In Singh R, et al., eds. *Thinking about Evolution: Historical, Philosophical and Political Perspectives* (Cambridge: Cambridge University Press, 2001): 397. Kitcher claims that researchers hold largely the correct view, but that they misapply it.
45. Plomin & Crabbe, cited in n. 41 above, 806.
46. Ibid.
47. Kitcher, cited in n. 44 above, note 11.
48. See, eg: Lewontin R.C. *The Doctrine of DNA: Biology as Ideology* (London: Penguin, 1993); Wolf U. "The Genetic Contribution to the Phenotype." *Human Genetics* 95 (1995): 127-48; Schouten M.K.D., *Memory Genes Knocked Out: Gene Manipulation as a Reduction Tool in Cognitive Neurobiology* (paper presented at the Society for Applied Philosophy Annual Conference, Manchester, United Kingdom, 2000).
49. See, eg: Kitcher, cited in n. 44 above; Schaffner K.F. "Genes, Behavior and Developmental Emergentism. One Process, Indivisible?" *Philosophy of Science* 65 (1998): 209-52; Griffiths P.E. and Knight R.D. "What is the Developmentalist Challenge?" *Philosophy of Science* 65 (1998): 253-58; Strohmman RC. The Coming Kuhnian Revolution in Biology. *Nature Biotechnology* 1997; 15: 194-200; Wolf, cited in n. 48 above; Griffiths P.E. and Gray R.D. "Developmental Systems Theory and Evolutionary Explanation." *Journal of Philosophy* 91 (1994): 277-304; Lewontin, cited in n. 48 above; Oyama S. *The Ontogeny of Information* (Cambridge: Cambridge University Press, 1985).
50. Fogle T. "Information Metaphors and The Human Genome Project." *Perspectives in Biology and Medicine* 38 (1995): 535-47; Johnston T. "The Persistence of Dichotomies in the Study of Behavioral Development." *Developmental Review* 7 (1987): 149-82, cited by Schaffner n. 49 above at 211.
51. Griffiths & Gray, cited in n.49 above; Oyama, cited in n. 49 above.
52. Schaffner, cited in n. 49 above.
53. Schouten, cited in n. 48 above.
54. Kitcher, cited in n. 44 above, 409.
55. However, he also points to a need for behavioural geneticists to be aware that their findings *will* be applied, often by those who 'do not grasp the nuances of their positions': Kitcher, 411.

56. de Jong, cited in n. 37 above: 625-6. de Jong cites Wheeler M. and Clark A. "Genetic Representation: Reconciling Content and Causal Complexity." *British Journal for the Philosophy of Science* 50 (1999): 103-135.
57. See, eg: Plomin and Crabbe, cited at n. 41 above.
58. Initiatives such as that being undertaken by the Hastings Center (in conjunction with the American Association for the Advancement of Science) are to be welcomed and encouraged. This joint collaboration, entitled 'crafting tools for public conversation about behavioural genetics' is to provide resources for public discussion about behavioural genetics. The group aims to clarify concepts and distinctions essential for a meaningful debate.

## Bibliography

- Alper J.S. "Genes, Free Will, and Criminal Responsibility." *Social Science and Medicine* 46 (1998): 1599-611.
- Alper J.S. and Beckwith J. "Genetic Fatalism and Social Policy: The Implications of Behavior Genetics Research." *Yale Journal of Biology and Medicine* 66 (1993): 511-24.
- Annas G.J. "Privacy Rules For DNA Databanks: Protecting Coded Future Diaries." *JAMA* 270 (1993): 2346-50.
- Annas G.J. Glantz L.H. and Roche P.A. "Drafting the Genetic Privacy Act: Science, Policy and Practical Considerations." *Journal of Law, Medicine and Ethics* 23 (1995): 360,65.
- Australian Law Reform Commission & Australian Health Ethics Committee. "Coming to Terms with Genetic Information." In: *Essentially yours: the protection of human genetic information in Australia*. ALRC Report No 96, (2003): 129-46.
- Bailey R.C. "Hereditarian Scientific Fallacies." *Genetica* 99 (1997): 125-33.
- Bayertz K. "What's Special about Molecular Genetic Diagnostics?" *Journal of Medicine and Philosophy* 23 (1998): 247-54.
- Beckwith J. and Alper J.S. "Reconsidering Genetic Antidiscrimination Legislation." *Journal of Law, Medicine and Ethics* 26 (1998): 205-10.
- Benjamin J. "Genes for Human Personality Traits." *Science in Context*: 11 (1998): 357-62, 366.
- Bouchard T.J. and McGue M. "Genetic and Environmental Influences on Human Psychological Differences." *Journal of Neurobiology* 54 (2003): 4-45.
- Buchanan A. Brock D.W. Daniels N. and Wikler D. *From Chance to Choice: Genetics and Justice* (Cambridge: Cambridge University Press, 2000).
- Chorney M.J. Chorney K. Seese N. Owen M.J. Daniels J. McGuffin P. Thompson L.A. Detterman D.K. Benbow C. Lubinski D. Eley T. and Plomin R. "A Quantitative Trait Locus Associated with Cognitive Ability in Children." *Psychological Science* 9 (1998): 159-66.
- de Jong H.L. "Genetic Determinism: How Not to Interpret Behavioral Genetics." *Theory and Psychology* 10 (2000): 615-37.
- Devlin B. Daniels M. and Roeder K. "The Heritability of IQ." *Nature* 388 (1997): 468-71.
- Drew A.P. "Genes and Human Behavior: The Emerging Paradigm." *Zygon* 32 (1997): 41-50.
- Fisher P.J. Turic D. Williams N.M. McGuffin P. Asherson P. Ball D. Craig I. Eley T. Hill L. Chorney K. Chorney M.J. Benbow C.P. Lubinski D. Plomin R. and Owen M.J. "DNA Pooling Identifies QTLs on Chromosome 4 for General Cognitive Ability in Children." *Human Molecular Genetics* 8 (1999): 915-22.
- Fogle T. "Information Metaphors and the Human Genome Project." *Perspectives in Biology and Medicine* 38 (1995): 535-47.
- Fukuyama F. *Our Posthuman Future: Consequences of the Biotechnology Revolution* (New York: Farrar Straus & Giroux, 2002).
- Galton F. *Hereditary Genius* (London: Macmillan and Co., 1869).
- Gostin L.O. and Hodge J.G. "Genetic Privacy and the Law: An End to Genetic Exceptionalism." *Jurimetrics* 40 (1999): 21-58.

- Gottesman I.I. "Twins: En route to QTLs for Cognition." *Science* 276 (1997): 1522-23.
- Green R.M. and Thomas A.M. "DNA: Five Distinguishing Features for Policy Analysis." *Harvard Journal of Law and Technology* 11 (1998): 571-91.
- Griffiths P.E. and Gray R.D. "Developmental Systems Theory and Evolutionary Explanation." *Journal of Philosophy* 91 (1994): 277-304.
- Griffiths P.E. and Knight R.D. "What is the Developmentalist Challenge?" *Philosophy of Science* 65 (1998): 253-58.
- Hill L. Chorney M.J. Lubinski D. Thompson L.A. and Plomin R. "A Quantitative Trait Locus Not Associated With Cognitive Ability in Children: A Failure to Replicate." *Psychological Science* 13 (2002): 561-2.
- Holm S. "There is Nothing Special About Genetic Information." In Thompson A.K and Chadwick RF, eds. *Genetic Information: Acquisition, Access and Control* (New York: Kluwer Academic, 1999), 97-103.
- Johnston T. "The Persistence of Dichotomies in the Study of Behavioral Development." *Developmental Review* 7 (1987): 149-82.
- Kitcher P. "Battling the Undead: How (and How Not) to Resist Genetic Determinism." In Singh R Krimbas C.B Paul D and Beatty J, eds. *Thinking about Evolution: Historical, Philosophical and Political Perspectives* (Cambridge: Cambridge University Press, 2001).
- Lewontin R.C. *The Doctrine of DNA: Biology as Ideology* (London: Penguin, 1993).
- Maddox J. "Genetics and Heritable IQ." *Nature* 309 (1984): 579.
- McClearn G.E. et al. "Substantial Genetic Influence on Cognitive Abilities in Twins 80 or More Years Old." *Science* 276 (1997): 1560-3
- Murray T.H. "Genetic Exceptionalism and 'Future Diaries': Is Genetic Information Different from Other Medical Information?" In Rothstein MA, ed. *Genetic Secrets: Protecting Privacy and Confidentiality in the Genetic Era*. (Yale: Yale University Press, 1997), 60-73.
- Nuffield Council on Bioethics. *Genetics and Human Behaviour: The Ethical Context* (London, 2002). Available at: <http://www.nuffieldbioethics.org>.
- Oyama S. *The Ontogeny of Information* (Cambridge: Cambridge University Press, 1985).
- Petrill S.A. et al. "Exploring the Genetic and Environmental Etiology of High General Cognitive Ability in Fourteen- to Thirty-Six-Month-Old Twins." *Child Development* 69 (1998): 68-74.
- Plomin R. and Crabbe J. "DNA." *Psychological Bulletin* 126 (2000): 806-28.
- Plomin R. McClearn G.E. Smith D.L. Vignetti S. Chorney M.J. Chorney K. Venditti C.P. Kasarda S. Thompson L.A. and Detterman D.K. et al "DNA Markers Associated with High Versus Low IQ: The IQ Quantitative Trait Loci (QTL) Project." *Behavior Genetics* 24 (1994): 107-18.
- Plomin R. DeFries J.C. McClearn G.E. and McGuffin P. *Behavioral Genetics* (New York: Worth Publishers, 4th ed. 2001).
- Richards M. "How Distinctive is Genetic Information?" *Studies in History and Philosophy of Biological and Biomedical Sciences* 32C (2001): 663-87.
- Robertson J.A. *Children of Choice: Freedom and the New Reproductive Technologies* (Princeton: Princeton University Press, 1994).

- Rothstein M.A. "Behavioral Genetic Determinism: its Effects on Culture and Law." In Carson R.A and Rothstein M.A, eds. *Behavioral Genetics: the Clash of Culture and Biology*. (Baltimore: Johns Hopkins University Press, 1999), 89-115.
- Rutter M. and Plomin R. "Opportunities for Psychiatry from Genetic Findings." *British Journal of Psychiatry* 171 (1997): 209-19.
- Schaffner K.F. "Genes, Behavior and Developmental Emergentism. One Process, Indivisible?" *Philosophy of Science* 65 (1998): 209-52.
- Schouten M.K.D. *Memory Genes Knocked Out: Gene Manipulation as a Reduction Tool in Cognitive Neurobiology*. Paper presented at the Society for Applied Philosophy Annual Conference, Manchester, United Kingdom 2000.
- Strohman R.C. "The Coming Kuhnian Revolution in Biology." *Nature Biotechnology* 15 (1998): 194-200.
- Stock G. *Redesigning Humans: Our Inevitable Genetic Future* (New York: Houghton Mifflin, 2002).
- Wachbroit R. "The Question Not Asked: The Challenge of Pleiotropic Genetic Tests." *Kennedy Institute of Ethics Journal* 8 (1998): 131-44.
- Wheeler M. and Clark A. "Genetic Representation: Reconciling Content and Causal Complexity." *British Journal for the Philosophy of Science* 50 (1999): 103-135.
- Wolf U. "The Genetic Contribution to the Phenotype." *Human Genetics* 95 (1995): 127-48.