Explore the ways in which contemporary genetics both challenges and underpins notions of human freedom, value and identity

The discovery of DNA and genes has revolutionised our understanding of human evolution, yet it is far from the ultimate 'secret of life' as James Watson once suggested[1]. What makes modern humans is a far more complex process than some kind of passive obedience of adaptive genetic code by our bodies. With each advance in genetic science, including the publication of the complete human genome in 2003[2], we understand more and more about our evolutionary history and find that it has implications for everything from medicine and psychology to crime and gender relations. On the other hand, it is becoming apparent, through new fields such as epigenetics, that genes are not simply prescriptive, but inextricably linked to our interactions with the environment.

The 'blueprint' for an individual is contained within every cell they have[3]. That person's unique DNA sequence codes for all the amino acids that combine to form their body, including developmental changes and the basic set-up of their mind[4]. Throughout life, development can be shaped by diet, stress, mental and physical exercise, climate, experience, other people, and random mutations. Research into non-coding DNA[5] and copy number variation[6] shows that the story is not as simple as inheriting DNA, having it transcribed into RNA, and translating the code tidily into the proteins it encodes.

Lamarck has often been mocked[7] for his theory of acquired characteristics, but new research suggests that, in some instances, the genome may in fact 'remember' environmental influences and become changed by them. The classic example is a study conducted in Overkalix, Sweden[8], which found that the grandsons of men who grew up during periods of high food availability were more likely to die of heart disease, while those whose grandfathers experienced famine were more likely to have diabetes. In the

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[1] Watson JD, and Berry A (2003). 'DNA: The Secret of Life'. New York: Random House.
[2] http://www.sanger.ac.uk/about/press/2003/030414.html
[3] Dawkins R (2006). 'The Selfish Gene'. Oxford: University Press.
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[5] Gerstein MB, et al (2007). 'What is a gene, post-ENCODE? History and updated definition'. Genome Research 17, pp. 669-681.
[6] Hurles M, Lee C, et al (2006). 'Global variation in copy number in the human genome'. Nature 444, pp. 444-454.
[7] Williams GC (1966). 'Adaptation and Natural Selection: A critique of some current evolutionary thought'. Princeton: University Press.
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paternal line at least, it seemed that changes occurring during someone's lifetime could alter the way their descendents' genes are expressed, as the effect lasted for two generations. This is in contrast to studies of factors like smoking during pregnancy[9], which are known to affect the way a baby develops but not necessarily their DNA. Epigenetics leaves room for our genes to be flexible, and demonstrates how we are not simply slaves to our DNA.

Freedom

"Nothing in biology makes sense except in the light of evolution"[10], but that does not mean evolution can explain everything about biology. Because our genes have been produced through natural selection, it is very easy to 'reverse-engineer' human behaviour, and describe it as a product of our evolutionary history. 'Selfish' genes[11] are more likely to survive through many generations if they confer some advantage to whoever carries them in terms of reproductive success, perhaps prompting this individual to act in their own interests through behaviour such as adultery, rape, or infanticide. These horrors all make sense in terms of natural selection, but explaining them sometimes strays close to justifying them. The very fact that not everyone uses these reproductive strategies (in fact most of us regularly hamper our own reproductive success by using contraception), suggests that we are not so single-minded in our quest to pass on genes to the next generation. It could be argued that humans have evolved beyond the basic goals of survival and mating and found, in culture, new goals such as art and humour. The pleasure we derive from these past-times is a byproduct of adaptive biological rewards, like hormone release, for creativity and social bonding[12].

It is always difficult, and sometimes impossible, to separate the twin forces of nature and nurture. Behaviours from aggression[13] to homosexuality[14] have been linked to genes. However, when people grow up in very similar circumstances we cannot be certain that

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[9] Milberger S, et al (1996). 'Is maternal smoking during pregnancy a risk factor for attention deficit hyperactivity disorder in children?'. American Journal of Psychiatry 153(9), pp. 1138-1142.
[10] Dobzhansky T (1973). 'Nothing in biology makes sense except in the light of evolution'. American Biology Teacher 35, pp. 125-129.
[11] Dawkins R (2006). 'The Selfish Gene'. Oxford: University Press.
[12] Diamond J (1991). 'The Rise and Fall of the Third Chimpanzee'. London: Vintage.
[13] Caspi A, et al (2002). 'Role of genotype in the cycle of violence in maltreated children'. Science 297, pp. 851-854.

their shared environment is not what determines the observed trait. Intelligence, for example, is certainly affected by genes, but if someone has intelligent parents they are more likely to get a good education with lots of support and a stimulating home environment. The primary methodology for calculating heritability is a twin study; if monozygotic twins are more similar to each other for a certain trait than dizygotic twins, and dizygotic twins are more similar than unrelated individuals, that trait probably has a genetic component.

As an example of natural selection and genetics being used to explain behaviour, it has been shown that children living with a stepfather are at greater risk of abuse[15], apparently because they do not carry the man's DNA and so he has no genetic investment in them. This theory does a huge disservice to the many step-parents who show love and affection for children *despite* not being biologically related, and fails to acknowledge that in most families with step-parents there are additional strains and complications imposed by divorce and separation, which may confound the statistics. Clearly, people are not genetically programmed to neglect their stepchildren.

In a similar way, we seem to have the power to choose to behave altruistically, even if the cost of helping others outweighs the benefits and thus seems evolutionarily illogical. The theory of kin selection[16], whereby we help our relatives because they share our genes, still cannot explain why we would ever offer assistance to strangers. Perhaps the human brain has evolved such that we appreciate how cooperation benefits us all more than the alternative, or maybe the emotional and hormonal rewards associated with helping family members have extended to unrelated individuals. Either way, the phenomenon of altruism seems to demonstrate 'free will', the contentious notion that 'we' - not our biology – make our own decisions.

That notion is especially important in the context of crime. Biological causes, from schizophrenia to pre-menstrual syndrome[17], have been used successfully as a defence for crimes, suggesting that the perpetrators lost some free will to their own bodies. People

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[14] Hamer D, Hu S, Magnuson V, Hu N, and Pattatucci A (1993). 'A linkage between DNA markers on the X chromosome and male sexual orientation'. Science 261(5119), pp. 321-327.
[15] Daly M, and Wilson M (1998). 'The truth about Cinderella: A Darwinian view of parental love'. London: Weidenfeld & Nicolson.
[16] Hamilton WD (1963). 'The evolution of altruistic behaviour'. American Naturalist 97(896), pp. 354-356.
[17] Lewis JW (1990). 'Premenstrual syndrome as a criminal defense'. Archive of Sexual Behaviour 19(5), pp. 425-441.

are routinely excused from jail sentences on the grounds of diminished responsibility due to mental illness, which implies that the illness itself is the guilty party. It could be argued that murderers, by violating the social convention of *not* committing murder, must by definition suffer from some kind of mental disorder, whether related or not to their genetic make-up. Brain tumours have been linked to crime - for instance, one in the urge-suppressing prefrontal cortex implicated in a case of paedophilia[18] - and it is well known that alcohol and drugs lead people to decisions that are 'out of character', and therefore potentially not their fault. The question is, how much of behaviour is left to be explained by personal decisions after accounting for genetic differences and biology? Maybe there is in fact no such thing as a personal decision; logically, of course, it must be determined by the biological processes in our mind which are partly defined by genetics. Maybe these processes are exactly what a personal decision is. Maybe the justice system should not seek to 'punish' at all, but instead to reform criminals whose actions can be explained, but not justified, by experience and genetics.

It has been established that some violent tendencies have a genetic component, as they are more similar between monozygotic than dizygotic twins, and between adopted children and their biological parents rather than their adopted parents[19]. In an attempt to explain why people commit violence, psychologists have cited a number of different genes. Certain genetic features are thought to make men more aggressive: for instance, higher testosterone levels are found in criminals, especially violent criminals[20]. However, the differences are small, and testosterone fluctuates throughout life rather than being pre-determined by genes. Another culprit is the gene controlling production of enzyme MAOA, which breaks down the hormone serotonin. Men with a gene which produces less of the enzyme tend to display more violence and aggression, but only if mistreated as children[21]. This finding is a good example of genetics interacting with the environment, and still leaves room to help those with this gene variant, rather than automatically labeling them dangerous.

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[19] Mason DA, and Frick PJ (1994). 'The heritability of antisocial behavior: A meta-analysis of twin and adoption studies'. Journal of Psychopathology and Behavioral Assessment 16, pp. 301-323.

[20] Brooke JH, and Reddon JR (1996). 'Serum testosterone in violent and nonviolent young offenders'. Journal of Clinical Psychology 52, pp. 475-483.

On the other side of the law, genetics can also help in bringing criminals to justice. Genetic fingerprinting, pioneered by Alec Jeffreys in 1984[22], has been used to identify many high-profile murderers including Colin Pitchfork in 1987, and equally helped to establish the innocence of people who turned out to have left no DNA at a crime scene. Since 2003, the UK Criminal Justice Act has allowed DNA to be kept from anybody convicted of an offence, with the aim of building up a database which can be used to quickly identify DNA samples. However, contamination is an important issue[23]. Cells can be transferred between individuals by handshakes or even on door handles, and DNA from innocent third parties may also be found at a crime scene. Genetic fingerprints can only provide circumstantial evidence; they should not be treated as conclusive, especially by lawyers or jurors with only a basic grasp of the science. It has been argued that keeping records of so many people's DNA, even if they are never charged or convicted of any crime, is an invasion of privacy, a threat to their freedom, and a very dangerous idea given the potential for miscarriages of justice.

Value

Taken literally, genetic determinism can get dangerously close to making value judgements about people, sometimes before they are even born. In the past it has been seriously suggested that the disabled, the poor, or certain racial groups should be eliminated in the cause of creating a fitter society. Social Darwinists like Herbert Spencer and Francis Galton misappropriated evolutionary theory to support the idea of selective breeding, or eugenics, to improve mankind[24]. It was apparently an affront to natural selection that richer individuals in society had fewer children, while the least civilised or least fit bred freely. Now, it is clear that this sort of venture would be pointless as genes are far from being the only factors involved. Foreign “savages” were not actually unfit; they just did not conform to Western ideas about how society should work. Disability, and

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[21] Caspi A, et al (2002). ‘Role of genotype in the cycle of violence in maltreated children’. Science 297, pp. 851-854.
[22] Jeffreys A, Wilson V, Thein S (1985). ‘Individual-specific “fingerprints” of human DNA’. Nature 316(6023), pp. 76-79.
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mental health, are more complicated issues, and challenge our beliefs about a person's value.

The development of pre-implantation genetic diagnosis (PGD) in the 1990s[25] led to popular concern about "designer babies". In PGD, embryos from in-vitro fertilisation are screened before being transferred into the womb, and can be chosen on the basis of viability, or to prevent genetic disorders. For instance, potential parents may choose only female embryos to avoid conceiving a son with an X-linked condition like Duchenne muscular dystrophy, or eliminate embryos found to carry autosomal disorders such as cystic fibrosis.

The trouble with this kind of technology is where we draw the line. Discarding embryos due to their genetic defects could be seen as insulting to those who have already been born with them. It implies they should not have been allowed to live; ostensibly to avoid their own personal suffering, but perhaps also to protect their parents from the burden of caring for a disabled child. It is theoretically possible to prevent the births of children with congenital deafness, but this suggestion has been met with outrage from the deaf community. In fact, in the UK it is illegal not only to select an embryo's sex based on preference rather than the risk of disease, but also to deliberately select for deaf children even if both parents are deaf[26].

Although "designing" babies with optimal intelligence and physical fitness, as in science fiction like the film *Gattaca*, is beyond the capability of today's technology, the whole business brings eugenics uncomfortably to mind, evoking the notion of children as commodities of variable value rather than independent human beings. This is further provoked by the existence of 'saviour siblings' - children born to donate tissues to siblings with diseases like leukaemia[27]. While this process has saved or significantly improved lives, it raises interesting questions of who owns the tissues in question, whether the healthy child is obliged to become a donor, and which child is more important, or valuable, to their parents.

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[25] Sermon K, van Steirteghem A, and Liebaers I (2004). 'Preimplantation genetic diagnosis'. The Lancet 363, pp. 1633-1641.

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[27] Liu CK (2007). '"Saviour Siblings"? The distinction between PGD with HLA tissue typing and preimplantation HLA tissue typing'. Journal of Bioethical Inquiry 4(1), pp. 65-70.

The value we attach to human life is further questioned by new advances like stem cell technology and gene therapy. Embryonic stem cells are pluripotent, with the potential to mature into any type of adult cell and potentially to be used as a replacement, for instance as a dopamine neuron in treatment for Parkinson's disease[28]. Though this technology could potentially save many lives it is the subject of ongoing controversy, as it uses cells from embryos and many religious groups believe this amounts to destroying human life. More recently, induced pluripotent stem cells have been made from adult cells[29], although the virus used to genetically modify them may cause cancer.

Gene therapy involves infecting body cells with a virus carrying a healthy copy of the faulty gene, like the one causing Severe Combined Immune Deficiency disorder (SCID). This is literally changing someone's DNA in order to cure their disease – a strange thought which could be interpreted as playing God. Theoretically the procedure could be used before birth, in germline gene therapy, but this would mean controversially manipulating someone's genes without their consent, using a technique that does not always work and carries some risks.

It is now possible to test for a number of heritable diseases, including risk factors for cancer[30]. These tests can be tremendously useful, allowing for 'tailor-made' medicine particularly suited to the individual's genetic situation. But they might instead be devastating if, say, a person discovers s/he carries the mutation for untreatable Huntington's disease. Moreover, there is always a possibility of reading too much into our genes, as a huge number of factors contribute to the risk of cancer, or to be lazy and decide that if we are 'genetically predisposed' to something like obesity then there is no point making healthy lifestyle choices. Testing also gives insurance companies an excuse to deny someone health cover, literally attaching different values to different people purely because of their DNA, and discriminating against potential clients based on data that should, arguably, remain private.

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[28] Thomson JA, et al (1998). 'Embryonic stem cells derived from human blastocysts'. Science 282(5391), pp. 1145-1147.

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Identity

Genetics is the cornerstone of an individual's personal identity, as well as the identity of the human race as a whole species. At both of these levels, the effect of our genes is elaborated upon by development, either as the person matures or as the species evolves culture. Perhaps the most important – certainly the most readily noticed[31] – aspects of our identity are sex and skin colour, both dictated by our genes and easy to use as an excuse for prejudice. A slightly more complex problem is that of intelligence, which depends on a number of variables, both biological and environmental.

Obviously, there are fundamental genetic differences between men and women. The basic theory for disparities in sexual behaviour[32] is that men invest a minimum of one ejaculation into each offspring, and can potentially sire dozens of children in the time it takes a woman to carry one pregnancy to term. Because they invest so much more, in the gestational period and the relative energetic expense of an egg, women are typically 'coy' and seek out males who are more likely to supply her with resources and help with raising babies, whereas men look for more casual sexual partners. This generalisation is supported by much evidence but, as always, things are not so simple. Reducing the small differences to determinist theories can perpetuate stereotypes like gold-diggers and players, while promoting double standards in sexual relationships.

Sex differences like typically male "systemising" and typically female "empathising"[33] are fascinating, but have been somewhat exaggerated and explained away by the dichotomy of hunter and gatherer roles in prehistoric communities. Thus, men evolved strength and cleverness to provide meat for the family, while women concentrated on forming bonds with each other, keeping the community and the household in order. Sex and sexuality certainly influence psychology beyond the realm of actual sexual behaviour, but there are always exceptions to the rule which do and should defy stereotypes. Variation within each sex is greater than the average differences between men and women.

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[30] Broadstock M, Michie S, and Marteau T (2000). 'Psychological consequences of predictive genetic testing: a systematic review'. European Journal of Human Genetics 8(10), pp. 731-738.
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Homosexuality has long puzzled scientists: it seems to make no evolutionary sense. Most gay people feel that they were born gay, rather than became that way as the result of development or social context, but if there were a gene for homosexuality then surely it would have been bred out of the population. The story is not so simple. Factors on the X chromosome of gay men seem to promote increased fecundity in their female relatives[34]. This reproductive advantage in the maternal line might explain how a homosexuality gene could persist, although obviously there must be many other influences involved. It has been established that men with older brothers are more likely to be gay. This is thought to be a maternal immune response which strengthens with each successive pregnancy, as male-specific antigens cause the mother's immune system to produce a response to each genetically foreign male foetus[35]. Perhaps the genes of large families have developed a strategy of allowing younger brothers to be homosexual, so they are not only removed from the competition for women, but also freed up to help raise closely-related nieces and nephews. This sort of research (although it has generally proved inconclusive about, or just completely ignored, women) may help to eliminate prejudice by establishing homosexuality as a biologically determined facet of identity, but not something to be feared or persecuted.

Race is another basic facet of our identity, and research in this area has been highly controversial. In 1994, *The Bell Curve*[36] made sweeping claims about differences in intelligence between different groups, reporting that African Americans have lower IQs than Caucasians, who in turn score lower than Asians and Ashkenazi Jews. It is suggested that different selection pressures work in each group, just as African marathon runners are thought to have more efficient slow-twitch muscle fibres thanks to a simplified ancestral stereotype of running on the African savannah[37]. In the case of intelligence, intelligent Ashkenazi Jews were supposedly more brutally selected for by a history of

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[34] Camperio-Ciani A, Corna F, and Capiluppi C (2004). 'Evidence for maternally inherited factors favouring male homosexuality and promoting female fecundity'. Proceedings of the Royal Society 271(1554), pp. 2217-2221.

[35] Bogaert A, Blanchard R, and Crothswait L (2007). 'Interaction of birth order, handedness, and sexual orientation in the Kinsey Interview Data'. Behavioral Neuroscience 121(5), pp. 845-853.

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persecution which killed off all but the most cunning[38]. It is difficult to separate any effect of this kind from the influence of culture: Jewish communities tend to promote scholarship and to favour careers in trade, but did these traditions emerge as a result of genetic characteristics, or contribute towards them? Similarly, lower IQ scores in African-Americans may not be genetic as such[39], but due to generally poorer living conditions, fewer educational opportunities, and the terrible self-perpetuating stereotype that leads poor black children to believe they will never amount to anything.

Quite apart from the question as to whether IQ tests do in fact measure what they are designed to measure, it is dangerous to simplify a genetic explanation in this way because, like with sexual behaviours, average differences within groups are greater than those between them. Racial categories are useful guidelines in medicine; for instance, sickle-cell anaemia is more prevalent in African populations[40], so the idea of race may not quite be scientifically insignificant, but racial identities are the product of both genetic and cultural history and the perceived average differences between them are no excuse for prejudice. Predictions of diverging ethnic groups resulting in new species[41] are unfounded; the trend may well have been for widening differences between pre-industrialised populations, but today globalisation and air travel allow for an unprecedented level of interaction between different races[42]. This has made our social experiences much more enriched and varied, helping us to understand that we are all share some mysterious human identity despite our superficial differences.

Genetic testing on fossils and modern humans has provided clues to the story of human evolution. Specimens such as Lucy have established that our oldest ancestors lived in Africa, having diverged from chimpanzees[43]. The Multiregional Hypothesis[44] postulates that separate *Homo erectus* proto-human populations moved away from Africa and

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[38] Cochran G, Hardy J, and Harpending H (2006). 'Natural History of Ashkenazi Intelligence'. Journal of Biosocial Science 38(5), pp. 659-693.
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[41] Hawks J, Wang ET, Cochran GM, Harpending HC, and Moyzis RK (2007). 'Recent acceleration of human adaptive evolution'. Proceedings of the National Academy of Sciences 104(52), pp. 20753-20758.
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[43] Johanson D, and Edey M (1981). 'Lucy: The Beginnings of Humankind'. New York: Simon and Schuster.
[44] Eckhardt RB, Wolproff MH, and Thorne AG (1993). 'Multiregional Evolution'. Science 262(5136), pp. 973-974.

evolved concurrently in different parts of the world due to extensive interbreeding with other populations. However, the dominant model of our evolutionary journey is the Out of Africa Hypothesis[45], contending that modern humans evolved once, then migrated in waves to other continents, displacing other populations including, eventually, the Neanderthals. This is supported by evidence that genetic diversity decreases the further the population in question is from Africa[46], suggesting they settled there more recently. The true story may be much more complicated[47], with complex interactions between populations over tens of thousands of years. It may even be that Neanderthals are not so different as we thought[48].

The other really intriguing question is what made modern humans so different from other great apes, allowing us to out-compete all other similar primates. While our genomes show differences in the immune system and gene regulation between humans and chimps[49], most of our staggering uniqueness among the world's species is attributed to our brains. Our HAR1 gene, for example, differs from that of chimps in 18 places, and is thought to have driven the rapid increase in human brain size compared to other apes[50]. Larger brains granted humans the intelligence needed to make tools, build things, cook, trade and, above all, use language. Often cited as one of the genes that make us human, our version of FOXP2 is thought to contribute to linguistic ability along with syntax and complex grammatical rules[51]. Meanwhile, possessing a version with only two amino acids' difference, apes struggle to learn single words or symbols[52].

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Conclusion

We would all like to think that our personality is something personal and almost spiritual – a sort of elusive 'self', encompassing free will, which does all the thinking and controlling of our behaviour[53]. This is the same kind of intuitive reasoning that makes us treat the thought of cloning humans with horror[54]. The response makes no sense, as monozygotic twins are technically clones and they are not considered unnatural, and in fact they turn out far from identical by the time slightly different uterine conditions and variable factors in the home environment have exerted their influence. Nonetheless, this feeling persists that our genes and identity are something special and almost sacred.

However, patients with brain damage have shown how our personalities can change dramatically, and it seems that the intuition about possessing free will is part of a delusion we maintain to avoid facing the fact that we are nothing but a configuration of chemicals[55]. Scientifically, there can be no such spiritual force in control. As depressing as it may seem, we are our genes, but we are also the biological product of memories, experiences and goals.

It is an exciting but critical time for the science of genetics. Recent research holds the promise of amazing medical advances, unprecedented understanding of how our genes work, and inevitable controversy over issues like sex differences, legal responsibility, and biological determinism. We must take care not to simplify our genetic explanations, lest mass media and the general public fail to appreciate the details in epigenetic change, variation or the role of the environment. As long as the science is presented clearly and accessibly, this research will continue to provide fascinating insights into various puzzles and phenomena, all the while refining and redefining our idea of what it means to be human.

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