ability to understand the importance of new molecular indicators of exposure.

Ethical, legal and social implications. It is recognized that the new knowledge and understanding of human disease risk emerging from the EGP is accompanied by a burden of responsibility to use that knowledge fairly and wisely. Therefore, the transformation of public health policy and healthcare in the light of the goals of the EGP is burdened with significant social, ethical and legal concerns[10]. For example, how will we deal with the fact that we may be able to predict risk for many common diseases long before effective and acceptable medical interventions are available to treat them? What are the ethical and economic implications for people who knowingly ignore a risk about which they have been informed? Personal compliance and responsibility will take on a whole new meaning. How do we protect research participants from discrimination, stigmatization and psychological stress? How will we deal with the concern that many, on learning that they carry a predisposing genotype, will develop a fatalistic attitude and assume that they can do nothing to prevent the disease? How do we deal with the issue of informed consent given that the risks and benefits cannot be fully anticipated at the outset of a particular study? And ultimately, how can a person be assured that their personal genetic information will remain private? Policies are urgently needed to ensure the appropriate and ethical use of susceptibility data.

Addressing these ethical, legal and social implications (ELSI), and developing safeguards that appropriately protect us in the future, will represent an important challenge for the EGP. So the EGP has made ELSI issues a priority topic. The EGP is promoting research projects and broad-based discussions on these issues, and will try to ensure that the public is adequately protected. This is essential even to allow the EGP to move forwards towards completion.

Although ELSI issues are one important challenge for the EGP, the knowledge of human disease susceptibility that may soon emerge will also raise scientific and technological challenges. For example, developing rapid screening to identify predisposing polymorphisms can be difficult; human genes are often large, carry many mutations, and may vary significantly from population to population. Therefore, the use of a single test may not be feasible. As more complex models of the genetic and exposure framework of disease are discovered, mathematical modelling and data management will have to be improved. Predictions on the basis of genetic polymorphisms will be far more complex than can be envisaged at the present time. Furthermore, improved understanding of disease susceptibility will intensify the need to identify the most beneficial and cost-effective intervention and prevention strategies.

Perhaps the biggest challenge for the EGP will be to manage its influence in the arena of public policy: how will those who formulate environmental and health policy accommodate the extraordinary new knowledge available to them? In the face of these challenges, we will need broader education and communications tools to find ways to make effective use of this knowledge and its enormous potential for biomedicine and human health.

Kenneth Olden and Samuel Wilson are at the National Institute of Environmental Health Sciences, National Institutes of Health, Department of Health and Human Services, Research Triangle Park, North Carolina 27709, USA.
Correspondence to K.O.
e-mail: olden@niehs.nih.gov

Links

FURTHER INFORMATION EGP | SNP catalogue | Center for Environmental Health Sciences | Coriell Institute for Medical Research | NHGRI | NIGMS | CDC

1. Kaiser, J. Environment institute lays plan for gene hunt. *Science* **278**, 569–570 (1997).
2. Guengerich, F. P. The environmental genome project: Functional analysis of polymorphisms. *Environ. Health Perspectives* **106**, 365–368 (1998).
3. Shalat, S. L., Hong, J. Y. & Gallo, M. The environmental genome project. *Epidemiology* **9**, 211–212 (1998).
4. Brown, P. O. & Hartwell, L. Genomics and human disease — variations on variation. *Nature Genet.* **18**, 91–93 (1998).
5. Schafer, A. J. & Hawkins, J. R. DNA variation and the future of human genetics. *Nature Biotechnol.* **16**, 33–39 (1998).
6. Wang, D. G. *et al.* Large-scale identification, mapping, and genotyping of single-nucleotide polymorphisms in the human genome. *Science* **280**, 1077–1082 (1998).
7. Taylor, J. A. *et al.* The role of *N*-acetylation polymorphisms in smoking-associated bladder cancer: evidence of a gene–gene exposure three way interaction. *Cancer Res.* **58**, 3603–3610 (1998).
8. Holtzman, N. A., & Marteau, T. M. Will genetics revolutionize medicine? *N. Engl. J. Med.* **343**, 141–144 (2000).
9. Hughes, T. R. *et al.* Functional discovery via a compendium of expression profiles. *Cell* **102**, 109–126 (2000).
10. Sharp, R. R. & Barrett, J. C. The environmental genome project: ethical, legal, and social implications. *Environ. Health Perspect.* **108**, 279–281 (2000).

TIMELINE

Engineering American society: the lesson of eugenics

David Micklos and Elof Carlson‡*

We stand at the threshold of a new century, with the whole human genome stretched out before us. Messages from science, the popular media, and the stock market suggest a world of seemingly limitless opportunities to improve human health and productivity. But at the turn of the last century, science and society faced a similar rush to exploit human genetics. The story of eugenics — humankind's first venture into a 'gene age' — holds a cautionary lesson for our current preoccupation with genes.

Eugenics was the effort to apply the principles of genetics and agricultural breeding towards improving the human race. The term "eugenics" — meaning well born — was coined in 1883 by Francis Galton[1], a British scientist who used data from biographical dictionaries and alumni records at Oxford and Cambridge Universities to conclude that superior intelligence and abilities were traits that could be inherited[2].

Most people equate eugenics with atrocities that were committed in Nazi Germany for the sake of racial purity. In this context, eugenics is easy to dismiss as purely aberrant behaviour. However, the story of eugenics in the United States is, perhaps, more important than that of Nazi Germany as a cautionary tale to take with us into our new century. Here we describe the tale of the subtle ways in which the science of genetics was, by degrees, transformed from an agricultural experiment into a popular movement to engineer American society. The fact that eugenics flourished in the land of liberty, involved numerous prominent scientists and civic leaders, and made its intellectual home at the forerunner of the now prestigious Cold Spring Harbor Laboratory shows just how far America fell from grace during this period.

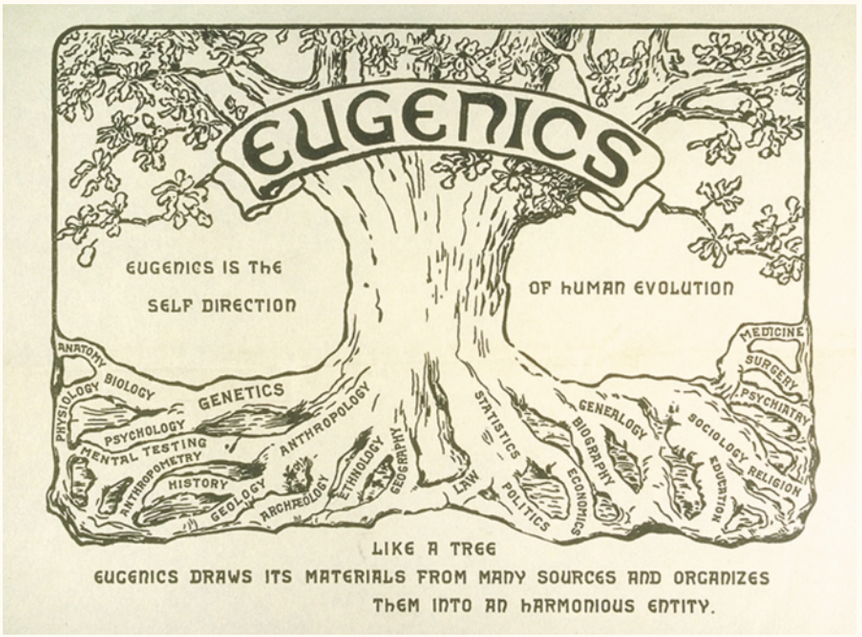


Figure 1 | **The eugenic tree.** This emblem, showing the far-flung roots of eugenics, was part of a certificate awarded to 'meritorious exhibits' at the Second International Congress of Eugenics, held in 1921 at the American Museum of Natural History in New York. (Image courtesy of the American Philosophical Society, Philadelphia, USA.)

The origins of American eugenics

Early in the twentieth century, eugenics was organized as a scientific field by the confluence of Mendelian genetics, experimental breeding and human biology (FIG. 1). This synthesis was embodied by Charles Benedict Davenport, who is considered to be the father of the American eugenics movement.

In 1898, Davenport assumed the directorship of The Biological Laboratory at Cold Spring Harbor, New York — a progressive 'summer camp' founded in 1890 for the study of marine biology and evolution. Although he had been trained in zoology and comparative morphology, Davenport became interested in testing evolution through controlled experiments using domestic plants and animals. He shared this interest with other biologists, including Thomas Hunt Morgan, whose studies in the fruitfly *Drosophila melanogaster* largely established the physical basis of genetics. Davenport secured funding from the Carnegie Institution of Washington to establish a Station for Experimental Evolution at Cold Spring Harbor in 1904. Davenport populated the Station with like-minded researchers, who increasingly used Mendel's laws to follow traits through their experimental crosses. For many, genetic analysis became an end in itself. The Station for Experimental Evolution was later renamed the Carnegie Department of Genetics, and many experimental evolutionists joined the first generation of geneticists.

During this period, Davenport began to focus on heredity in human beings. He conducted early studies on the genetics of epilepsy[3], Huntington disease[4], neurofibromatosis[5] and albinism[6]. He also became interested in eugenics, and was actively involved in the American Breeders Association (ABA). Established in 1903, the ABA was one of the first scientific organizations in the United States to recognize the importance of Mendel's laws. The ABA's committee on eugenics (1906) was the first scientific body to actively support eugenic research[7]. The subtitle of Davenport's first eugenics text[8], 'The science of human improvement by better breeding', made the eugenic movement's connection to agriculture clear.

In 1910, Davenport convinced a wealthy widow, Mrs Edward H. Harriman, to contribute $10,000, and a later endowment, to set up a Eugenics Record Office (ERO) on property adjacent to the Station for Experimental Evolution. Davenport recruited Harry Laughlin as the superintendent of the ERO and together (FIG. 2), with almost religious zeal, they set out to popularize eugenics. A series of ERO bulletins, including Davenport's *Trait Book*[9] and *Making a Family Pedigree*[10], helped to standardize the methods and nomenclature for pedigree studies. *Eugenical News*, published by the ERO from 1920–1938, was the dominant mouthpiece for the racist and anti-immigration agenda of eugenics research. The ERO also published several forms to simplify data collection. Many families proudly submitted their pedigrees to competitions at State fairs (FIG. 3), while others sought advice on the eugenic fitness of proposed marriages. Budding eugenics researchers convened at Cold Spring Harbor each summer to learn how to conduct field work, such as interviewing subjects, taking medical histories, and constructing pedigrees. During its years of operation, 1910–1939, the ERO amassed hundreds of thousands of family records, pedigrees and articles on eugenics[11].

Positive and negative eugenics

Galton's primary interest in improving the human race through voluntary selective breeding became known as 'positive eugenics'. However, the American eugenics movement independently had its roots in degeneracy theory, which was advanced in the eighteenth century in texts such as the *Onania*[12]. Degeneracy theory propounded the idea that unfit people arose from bad environments that damaged heredity and perpetuated degenerate offspring[13]. The American Richard Dugdale followed in this

Figure 2 | **Leaders of the American eugenics movement.** Harry Laughlin (left) and Charles Davenport (right) photographed outside the Eugenics Record Office at Cold Spring Harbor, circa 1912. (Photograph courtesy of Truman State University, Missouri, USA.)

vein with his 1877 study of the Jukes family, a clan of 700 petty criminals, prostitutes and paupers who were descended from 'Margaret, the Mother of Criminals', in Ulster County, New York[14].

Although Dugdale's work predated the American eugenics movement by 30 years, it was the model for early twentieth-century studies of degenerate families or tribes[15–17]. The American eugenicists proposed that degeneracy was caused by faulty genes, and they coined the term cacogenics to describe the deterioration of a genetic stock over time. This emphasis on 'bad' heredity, and the accompanying attempts to halt it, became known as 'negative eugenics'. Both positive and negative eugenics had supporters on either side of the Atlantic. However, British eugenicists tended to look for ways to perpetuate the privileged classes, whereas American eugenicists tried to slow down the supposedly corrupting influence of the degenerate classes.

Eugenics researchers attempted to trace the inheritance of dysgenic traits through a family tree, and constructed pedigrees by interviewing living family members and by scrutinizing the records of poorhouses, prisons and insane asylums. Then, they attempted to discern one of three basic modes of Mendelian inheritance — dominant, recessive or sex-limited (X-linked). The implication of these studies was that a constellation of degenerate behaviours — including alcoholism, pauperism, social dependency, shiftlessness, nomadism and 'lack of moral control' — were caused by single-gene defects inherited in a simple Mendelian fashion.

'Feeblemindedness' became an increasingly important concern of American eugenicists after 1910, when intelligence testing provided a means to 'quantify' several grades of mental retardation. In addition to low scores on IQ tests, 'feeblemindedness' was also frequently linked to abnormal behaviour, promiscuity, criminality, and social dependency. Eugenicists especially feared the 'high-grade feebleminded', or 'morons,' because they could potentially seem to be normal and, so, reproduce with unaffected people.

'Feeblemindedness' and other dysgenic traits were closely associated with poverty. So to many observers today, the eugenicists' pedigrees of faulty genes are striking examples of lack of education and opportunity. However, most American eugenicists placed themselves squarely on one side of the nature versus nurture debate, and sought genetic explanations of human behaviour to the near exclusion of environmental influences. Dugdale, whose study of the Jukes had helped to launch the eugenics movement, held the Lamarckian view that the environment actually induced heritable changes in traits and that degenerate traits could be reversed by moving people into a good social environment. However, most eugenicists adopted August Weismann's germ-plasm theory, which propounded that specialized sex cells are inherited without influence from environmental changes in somatic cells[18].

> "The science of genetics was, by degrees, transformed from an agricultural experiment into a popular movement to engineer American society."

The eugenic social agenda and law

Eugenics arose in the wake of the industrial revolution, when the fruits of science and technology were improving public and private life. During this time, a growing professional middle class believed that scientific progress could be used to cure all social ills, and many educated people accepted that humans, like all animals, were subject to natural selection. Social interpretations of Darwinian evolution viewed humans as a flawed species that required pruning to maintain its health[19]. Therefore negative eugenics seemed to offer a rational solution to certain age-old social problems.

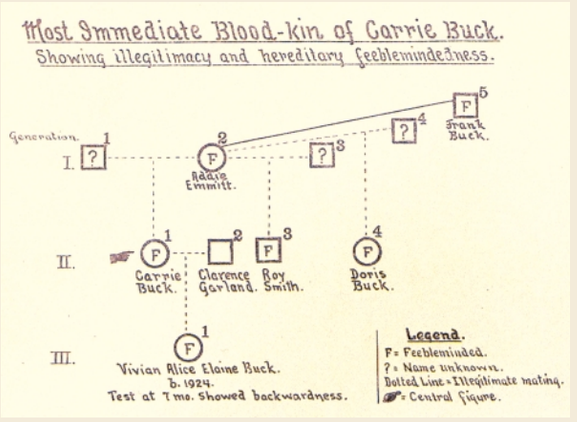
American eugenicists were largely successful in lobbying for eugenic social legislation on three fronts: to restrict European immigration; to prevent racial mixing; and to sterilize the 'genetically unfit'.

Immigration restriction. At the same time that Mendel's laws were revolutionizing biology, a tide of immigration was rolling into the United States. During the first two decades of the twentieth century, 600,000–1,250,000 immigrants per year entered the United States through New York (except during World War I). During this period, the origin of most immigrants shifted from northern and western Europe — the regions that had been the source of most immigrants during the Colonial, Federal and Victorian eras — to southern and eastern Europe, from where came large numbers of displaced Jews[20].

Many Americans believed they had reason to resent the influx of new immigrants. Labour organizations fanned fears that native workers would be displaced from their jobs by an oversupply of cheap immigrant labour. Anti-Communist factions predicted a 'red

Figure 3 | **Eugenics Pavillion at Texas State Free Fair, 1920.** During the 1920s, the American Eugenics Society used state fairs as venues for popular education. The placard on top of the building to the left announces 'Fitter Families for Future Firesides', a contest that judged the eugenic fitness of competing families. (Photograph courtesy of the Image Archive on the American Eugenics Movement, Cold Spring Harbor, New York, USA.)

Box 1 | The pedigree of Carrie Buck



Carrie Buck, the subject of the test of eugenic sterilization in the United States Supreme Court case, Buck versus Bell, and her mother, Addie Emmit, were both inmates of the Virginia Colony for the Epileptic and the Feebleminded. Carrie and Addie were both judged to be 'feebleminded' and promiscuous. It is impossible to judge whether or not Carrie was feebleminded by the standards of her time, but the child Carrie bore out of wedlock was the result of her rape by a relative of her foster parents. Although Carrie's infant daughter, Vivian, was judged to be "not quite normal", her first-grade report later showed her to be a solid 'B' student, who received an 'A' in deportment[34,35]. (Image courtesy of Truman State University, Missouri, USA.)

tide' entering the United States from Russia and Eastern Europe. Sentimental Anglophiles bemoaned the diminishing influence of their founding settler stock[21]. Eugenicists — overwhelmingly educated people of northern and western European extraction — provided a scientific veneer for these anti-immigration sentiments. According to their interpretation, immigration was a problem of 'bad genes', which were rapidly 'polluting' the national gene pool.

So Albert Johnson, chairman of the Committee on Immigration and Naturalisation, welcomed the involvement of the eugenics movement in his crusade to curb immigration. ERO Superintendent Harry Laughlin became the anti-immigration movement's most ardent scientific lobbyist. Between 1920 and 1924 he testified three times before the House Committee, becoming its 'expert eugenics agent'. In his testimonies, Laughlin used flawed data to show that southern and eastern European countries were purportedly 'exporting' genetic defectives, who had disproportionately high rates of mental illness, 'feeblemindedness', crime and social dependency[22–24]. The Immigration Restriction Act of 1924 did everything that Johnson and Laughlin had hoped for. It limited total annual immigration to 165,000 — about 15–20% that of peak years — and it restricted immigration from southern and eastern European countries to only 9% of the total[24]. This change in the complexion of American immigration was accomplished by a cunning use of statistics. The Johnson Act limited immigrants from each country according to their proportion in the United States population in 1890 — a time before the main waves of southern and eastern European immigration. Immigration to the United States did not regain pre-Johnson Act levels until the late 1980s (REF. 25).

Race mixing. Laws against interracial marriage had existed in some states since colonial times, but their number increased after the Civil War. The idea that race mixing, or miscegenation, causes genetic deterioration was proposed by Joseph Arthur Gobineau and other anthropologists in the late nineteenth century[26]. It is worth noting that eugenicists' conception of race included the classic divisions by skin colour, as well as differences in national origin. Most lay-eugenicists subscribed to the Biblical idea of 'like with like' and that the 'half-breed' offspring of parents from two different races were genetically inferior to the parental stock. Davenport's compilation in 1913 showed that 29 states had laws forbidding mixed-race marriages[27]. Although these laws were not always enforced, heavy fines and long prison terms showed how seriously American society considered miscegenation to be at that time.

"Of all the United States legislation enacted during the early twentieth century, the sterilization laws . . . most clearly bear the stamp of the eugenics lobby."

As in the case of immigration restriction, eugenicists were more than willing to provide a supposed scientific rationale for existing racial prejudice. In his influential book, *The Passing of the Great Race*, Madison Grant warned that racial mixing was a social crime that would lead to the demise of white civilization[28]. Eugenicists actively supported strengthening pre-existing laws and enacting of new ones, including the Virginia Racial Integrity Act of 1924 (REF. 29). The Virginia Act and all other similar state laws were struck down by the United States Supreme Court in 1967 in *Loving versus Commonwealth of Virginia*[30].

Eugenic sterilization. Of all the United States legislation enacted during the early twentieth century, the sterilization laws, which were adopted by 30 states, most clearly bear the stamp of the eugenics lobby. The first eugenic sterilization law was passed in Indiana, in 1907, at the urging of the prison physician Harry Clay Sharp[31]. Speaking at meetings of the American Medical Association, Sharp convinced fellow physicians to lobby their legislatures for laws to allow the involuntary sterilization of sex offenders, habitual criminals, epileptics, the 'feebleminded' and 'hereditary defectives'. The intent was to prevent alleged degenerates from breeding with each other or from contaminating 'good genetic stock' by reproducing with normal people. By contrast, even though Britain had its share of advocates for negative eugenics, the British parliament did not enact laws to allow compulsory sterilization[32].

Many of the early sterilization laws were legally flawed and were not upheld in the state courts. To address this problem, Laughlin designed a model eugenic law that was reviewed by legal experts. The use of this law by the State of the Virginia was tested in *Buck versus Bell*, in the Supreme Court in 1927 (BOX 1). Oliver Wendell Holmes, Jr delivered the Court's decision to uphold the legality of eugenic sterilization, which included the infamous phrase "Three generations of imbeciles are enough!"[33,34] The Buck case was never overturned, and sterilization of the mentally ill in the United States continued into the 1970s, by which time around 60,000 Americans had been sterilized without their consent or that of a legal guardian[35].

The downfall of eugenics

It is clear that growing knowledge of the Nazi 'final solution' to achieve racial purity

led to a wholesale abandonment of popular eugenics in the United States, and the ERO was closed on 31 December 1939. Less clear, however, is the extent to which the science behind the American eugenics programme had been discredited among geneticists before the Nazis' rise to power. In retrospect, one can detect several lines of evidence that refuted key eugenic tenets, from as early as 1908. However, many sophisticated geneticists — including some who provided refuting evidence — supported some form of eugenic programme at one point or another.

Mathematical models of population genetics provided evidence against the simplistic claim that degenerate families were increasing the societal load of dysgenic genes. The equilibrium model of Godfrey N. Hardy and Wilhelm Weinberg[36] showed that, although the absolute number of dysgenic family members might increase over time, their frequency did not increase relative to the normal population.

At the same time, the Hardy–Weinberg equation created a quandary for the eugenic control of mental illnesses, which were thought by most to be recessively inherited. Geneticists almost universally agreed that the feebleminded or mentally defective should be prevented from reproducing. However, the Hardy–Weinberg equation showed that sterilization or the social segregation of affected people would not appreciably reduce the percentage of mental defectives in society. Only a massive programme of sterilization or segregation of the many heterozygous carriers predicted by the equation would appreciably reduce the incidence of mental illness. Despite this, feeblemindedness was thought to be so rampant that many geneticists believed reproductive control could still prevent the birth of tens of thousands of affected people per generation[37].

Work by several scientists also countered the eugenicists' simplistic assertions that complex behavioural traits are governed by single genes. Herman Muller's survey of mutations in *Drosophila* and other organisms, from 1914–1923, showed variation in the 'gene to character' relation that defied simple Mendelian analysis. He found that many genes are highly variable in their expression, and a single gene might affect several characters (traits) at one time. Conversely, mutations in many different genes can affect the same trait in similar ways. Moreover, the expression of a gene can be altered significantly by the environment[38,39]. Although Muller remained committed to a personal brand of positive eugenics that was based on individual worth, during the 1930s he denounced the American eugenics movement and called for a halt to applied genetics[40].

"Eugenics seemed to offer a rational solution to certain age-old social problems."

Twin studies — conducted in the 1930s by Horatio Newman, Frank Freeman and Karl Holzinger — also showed that identical twins raised apart after birth had different IQs[41]. Lionel Penrose, in particular, railed against the simplistic Mendelian analysis of mental illnesses. He found that most cases of mental illness at a state-run institution in Colchester, England, resulted from a combination of genetic, environmental and pathological causes[42]. The geneticist, Raymond Pearl, was forthright in his 1928 critique of the eugenics movement[43]:

> "In preaching, as they do, that 'like produces like', and that therefore superior people will necessarily have superior children, and inferior people inferior children, the orthodox eugenicists are going contrary to the best established facts of genetical science."

A visiting committee, convened by the Carnegie Institution in 1935, concluded that the work collected at the ERO was without scientific merit and recommended that it "cease from engaging in all forms of propaganda and the urging or sponsoring of programs for social reform or race betterment, such as sterilisation, birth control, inculcation of race or national consciousness, restriction of immigration…" and so on[11].

Lesson for the future

American eugenicists sought an almost exclusively genetic explanation of human development, and neglected the important contributions of the environment. They managed to inculcate this belief into a generation of educated Americans. Today, biological progress could seem to be measured in terms of genes sequenced, and there is a danger that genes will, once again, be misconstrued as the sole determinants of human life.

At first sight, the Human Genome Project's objective to identify disease genes emphasizes the genetic contribution to health, and also entails value judgements about what is normal *versus* what is abnormal. The social and legal acceptance of such judgements may create a pressure for genetic conformity that is difficult to predict today. What will it be like when we have a precise catalogue of all the 'good, bad and middling genes' — and the wherewithal to determine who has which? In the face of such knowledge, will society continue to acquiesce to those who prefer to let nature take its course? Will only the wealthy be able to afford preimplantation genetic selection, further widening the gap between the rich and the poor?

For better or worse, we will move into the gene age. James D. Watson, one of the discoverers of the structure of DNA, has said that the greatest future danger will not be the misuse of genetics but, rather, its disuse. Over-regulation and blind fear may discourage people from making the best use of genetic technology. In this view, knowledge that we are taking conscientious actions to avoid the abuses of the past can allow us to move with greater confidence into our future.

Viewed in the light of the worst abuses of eugenics, it may seem that only a strict, and amoral, interpretation of scientific data will protect us from future disasters. However, the past also tells us that many of the first crop of human geneticists loaded their data and models with their own aspirations for society. So it is imperative that we build a critical mass of scientists and citizens who understand that the interpretation of genetic data about human beings is rarely free from value judgement.

The real lesson of American eugenics is that it was practised by well-intentioned people and bigots alike, and, apart from the most obvious excesses, there was often no sharp line between them. Certain forms of behaviour that pass for eugenics are still with us today. Every parent's longing for healthy, happy children, who can continue the flow of their family heritage, is an expression of the best aspirations of 'positive eugenics'. And the killing fields of Cambodia, Central Africa and the Balkans differ only in method and degree from the Nazi regime of 'negative eugenics'. So, rather than dismissing eugenics out-of-hand, it is far better that each of us attempt to discover where we — and the technologies we are using — stand in its continuum. Only by reminding ourselves that we, indeed, dwell on the slope between positive and negative eugenics can we guard against slipping too far.

*David Micklos is at the *DNA Learning Centre, Cold Spring Harbor Laboratory, Cold Spring Harbour, New York, USA. Elof Carlson is at the ‡State University of New York, Stony Brook, New York, USA.*
e-mails: micklos@cshl.org; ecarlson@notes.cc.sunysb.edu

Links

FURTHER INFORMATION Principles of the Hardy–Weinberg law | Image Archive on the American Eugenics Movement | The DNA Learning Center at Cold Spring Harbour Laboratories | Galton — Biography and works

1. Galton, F. *Inquiries into Human Faculty and its Development* (Dent, London, 1883).
2. Galton, F. *Hereditary Genius: An Inquiry into its Laws and Consequences* (MacMillan, London and New York, 1869).
3. Davenport, C. B. First study of inheritance of epilepsy. *J. Nerv. Ment. Dis.* **38**, 641–670 (1911).
4. Davenport, C. B. Huntington's chorea in relation to heredity and eugenics. *Proc. Natl Acad. Sci. USA* **1**, 283–285 (1915).
5. Presser, S. A. & Davenport, C. B. Mutlitple neurofibromatosis (Von Recklinghausen's disease) and its inheritance: With description of a case. *Am. J. Med. Sci.* **156**, 506–541 (1918).
6. Davenport, C. B. Heredity of albinism. *J. Heredity* **7**, 221–223 (1916).
7. Selden, S. *Inheriting Shame: The Story of Eugenics and Racism in America* (Teachers College, New York, 1999).
8. Davenport, C. B. *Eugenics: The Science of Human Improvement by Better Breeding* (Holt, New York, 1912).
9. Davenport, C. B. *Eugenics Record Office Bulletin Number 6: The Trait Book* (Eugenics Record Office, Cold Spring Harbor, New York, 1912).
10. Davenport, C. B. & Laughlin, H. H. *Eugenics Record Office Bulletin Number 13: How to Make a Eugenical Family Study* (Eugenics Record Office, Cold Spring Harbor, New York, 1915).
11. Allen, G. E. The Eugenics Record Office at Cold Spring Harbor, 1910–1940: An essay on institutional history. *Osiris* **2**, 225–264 (1986).
12. Anonymous. *Onania, Or the Heinous Sin of Self–Pollution and All Its Frightful Consequences in Both Sexes, Considered* (Corbett, London, circa 1710).
13. Carlson, E. A. *The Unfit: A History of a Bad Idea* (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, 2001.)
14. Dugdale, R. *The Jukes: A Study in Crime, Pauperism, Disease, and Heredity* (Putnam, New York, 1877).
15. Davenport, C. B. & Estabrook, A. H. *Eugenics Record Office Memoir #2: The Nam Family. A Study of Cacogenics* (Eugenics Record Office, Cold Spring Harbor, New York, 1912)
16. Goddard, H. H. *The Kallikak Family: A Study in the Heredity of Feeblemindedness* (Macmillan, New York, 1912).
17. Estabrook, A. H. in *Eugenics, Genetics, and the Family* Vol I, 398–404 (Williams and Wilkins, Baltimore, 1923).
18. Weismann, A. in *Essays Upon Hereditary and Kindred Biological Problems* 67–106 (Oxford Univ. Press, Oxford, 1891).
19. Chase, A. *The Legacy of Malthus: The Social Costs of the New Scientific Racism* (Knopf, New York, 1977).
20. Tift, W. S. *Ellis Island* (Contemporary Books, Chicago, 1989).
21. Adams, G. *The Age of Industrial Violence* (Columbia Univ. Press, New York, 1967).
22. United States House of Representatives. *Hearings before the Committee on Immigration and Naturalization: Biological Aspects of Immigration, 66th Congress, Second Session, April 16–17, 1920* (Government Printing Office, Washington, DC, 1921).
23. United States House of Representatives. *Hearings before the Committee on Immigration and Naturalization: Analysis of America's Modern Melting Pot, 67th Congress, Third Session, November 21, 1922* (Government Printing Office, Washington, DC, 1923).
24. United States House of Representatives. *Hearings before the Committee on Immigration and Naturalization: Europe as an Emigrant-Exporting Continent and the United States as an Immigrant–Receiving Nation, 68th Congress, First Session, March 8, 1924* (Government Printing Office, Washington, DC, 1924).
25. United States Department of Justice. Legal immigration, fiscal year 1998. *US Immigration and Naturalization Service Annu. Report* **2**, 1–11 (1999).
26. Gobineau, J. A. *The Inequality of Races* (New York: Fertig, New York, 1853).
27. Davenport, C. B. *Eugenics Record Office Bulletin Number 9: State Laws Limiting Marriage Selection in Light of Eugenics* (Eugenics Record Office, Cold Spring Harbor, New York, 1913).
28. Grant, M. *The Passing of the Great Race or the Racial Basis of European History* (Scribners, New York, 1921).
29. Reilly, P. R. The Virginia Racial Integrity Act revisited: the Plecker–Laughlin correspondence: 1928–1930. *Am. J. Med. Genet.* **16**, 483–492 (1983).
30. Lombardo, P. A. Miscegenation, eugenics and racism: Historical footnotes to Loving v. Virginia. *Univ. Calif. Davis Law Review* **21**, 421–452 (1988).
31. Sharp, H. C. The severing of the vasa deferentia and its relation to the neuropsychopathic constitution. *NY Med. J.* **75**, 411–414 (1902).
32. Ridley, M. Eugenics and liberty. *Prospect* August /September, 44–47 (1998).
33. Lombardo, P. A. Three generations, no imbeciles: New light on Buck v. Bell. *NY University Law Review* **60**, 30–62 (1985).
34. Gould, S. J. in *The Flamingo's Smile: Reflections on Natural History* 306–318 (Morton, New York, 1987).
35. Reilly, P. R. *The Surgical Solution* (Johns Hopkins Univ. Press, Baltimore, 1991).
36. Hardy, G. N. Mendelian proportions in a mixed population. *Science* **28**, 49–50 (1908).
37. Paul, D. B. & Spencer, H. G. The hidden science of eugenics. *Nature* **374**, 302–304 (1995).
38. Muller, H. J. Genetic variability, twin hybrids, and constant hybrids, in the case of balanced lethal factors. *Genetics* **3**, 422–499 (1918).
39. Altenburg, E. & Muller, H. J. The genetic basis of truncate wing: An inconstant and modifiable character in *Drosophila*. *Genetics* **5**, 1–59 (1920).
40. Muller, H. J. in *A Decade of Progress in Eugenics*, 138–144 (Williams and Wilkins, Baltimore,1934).
41. Newman, H. H., Freeman, F. N. & Holzinger, K. J. *Twins: A Study of Heredity and Environment* (Univ. of Chicago Press, Chicago, 1937).
42. Kevles, D. *In the Name of Eugenics: Genetics and the Uses of Human Heredity* (Knopf, New York, 1985).
43. Pearl, R. *The Present Status of Eugenics* (Sociological Press, Hanover, Minneapolis, Liverpool, 1928).

Further reading

There are several excellent and highly readable books on the eugenics movement, including: Gould, S. J. *The Mismeasure of Man* (Norton, New York, 1981) | Kevles, D. *In the Name of Eugenics: Genetics and the Uses of Human Heredity* (Knopf, New York, 1985) | Paul, D. *Controlling Human Heredity: 1865 to the Present* (Humanities, Atlantic Highlands, New Jersey, 1995) | Selden, S. *Inheriting Shame: The Story of Eugenics and Racism in America* (Teachers College, New York, 1999).

Acknowledgements

This article was inspired by original documents and photographs from the collection of the Image Archive on the American Eugenics Movement, of which the authors are the editor (D.M.) and editorial advisor (E.C.). The Image Archive is supported by a grant from the Ethical, Legal, and Social Issues (ELSI) Program of the United States National Human Genome Research Institute.

We welcome correspondence

Has something in the journal caught your attention?

If so, please write to us about it by sending an email to: naturereviews@nature.com and flag it for the attention of the *Nature Reviews Genetics* editors.

Correspondence to the journal will be selected by the editors for publication on the *Nature Reviews Genetics* website at http://www.nature.com/reviews/genetics/ where it will be linked to the relevant article.