The democracy of the genes

Matt McGue

The genetic heritability of IQ remains highly contentious. A new analysis shows that genetic influences may be weaker, and prenatal environmental influences greater, than previously appreciated.

Sir Francis Galton's contributions in 1869 alone were enough to ensure that his scientific legacy would be a lasting one. In that year, he not only helped in founding this journal, but also published the first empirical investigation of the inheritance of human achievement[1], a study that is generally credited with framing the modern nature–nurture debate. On page 468 of this issue[2], Devlin, Daniels and Roeder report a statistical analysis of more than 200 familial IQ correlations, the most recent in a long line of empirical investigations aimed at resolving issues that were raised by Galton.

Because it is associated with a wide range of social effects, including educational and occupational success, poverty and even delinquency[3], IQ has long been of interest to behavioural and social scientists. But these associations have also challenged cherished beliefs about the nature of social achievement. If social status is influenced by IQ, which is in turn substantially inherited, then social standing will, in part, be a function of one's genetic endowment. Hard work may be no guarantee of success, unless one has also received a lucky draw in the genetic lottery.

The general uneasiness over IQ reached new heights with the publication of *The Bell Curve*[4], by Herrnstein and Murray, in 1994. The authors described declines in the population's genetic potential for high IQ (that is, dysgenic trends), because of higher fecundity among the poorly educated relative to the well educated; and they also forecast the establishment of a caste-like cognitive élite, which would be maintained through intermarriage and the (genetic) transmission of high IQs from parents to offspring. In short, they argued that Western (and in particular US) society was becoming a two-class system, where the cognitively limited masses would be ruled by a relatively small and reproductively isolated cognitive élite.

Devlin and colleagues' findings will lead to a reconsideration of these most dire conclusions from *The Bell Curve*. The likelihood of dysgenic trends occurring, as well as the ability of parents genetically to reproduce desired traits in their children, both depend on the strength of parent–offspring transmission, which in turn depends on the narrow-sense, rather than the broad-sense (total) heritability. Quantitative geneticists distinguish additive gene effects, which are independent of genetic background and thus shared by parents and their offspring, from non-additive gene effects, which are dependent on genetic background and thus not shared by parents and offspring. Narrow-sense heritability is the proportion of a trait's variance that is attributable to additive gene effects; broad-sense heritability is the proportion attributable to both additive and non-additive gene effects.

Herrnstein and Murray[4] based their arguments on an IQ heritability of 60%; Devlin *et al.* report a broad-sense heritability estimate of 48% and a narrow-sense heritability of only 34%. Although a narrow-sense heritability of this magnitude does not preclude dysgenic trends (albeit at a slower rate than Herrnstein and Murray projected), it is certainly too low to support the establishment of a high-IQ caste. Over the long term, unless both the narrow-sense heritability and the rate of intermarriage is very high, genes for quantitative traits such as IQ are essentially democratic; by the third or fourth generation, descendants of gifted individuals are not much more likely to be gifted than are descendants of ordinary people.

Although their paper is entitled "The heritability of IQ", Devlin and colleagues' most important finding probably concerns the nurture rather than nature of IQ. Behavioural geneticists had previously pointed out an inconsistency in the familial IQ correlations. From data on twins that have been reared together, the heritability of IQ is estimated to be about 50%; but from twins reared apart, it is estimated at about 70% (ref. 5). Because IQ correlations for twins reared together are based primarily on adolescents or children, whereas correlations for twins reared apart are based primarily on middle-aged adults, the discrepancy had been thought to reflect age-related increases in the heritability of IQ. This hypothesis is supported by research on octogenarian twins published earlier this year[6], as well as by studies of other familial pairings[7].

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Devlin *et al.* offer, and provide statistical support for, an alternative account of this anomaly. Specifically, they hypothesize that failure to consider the shared prenatal environment of twins results in an overestimation of IQ heritability in studies of twins reared apart, but would not bias heritability estimates in studies of twins reared together, where shared prenatal effects are cancelled out in the comparison of monozygotic and dizygotic twin similarity. When shared prenatal environments were included in the statistical model that Devlin *et al.* fitted to the IQ correlations, they accounted for 20% of IQ similarity among twins but only 5% among non-twin siblings. The former estimate is particularly remarkable given that twins, and especially monozygotic twins, can experience radically different intrauterine environments even though they share the womb at the same time[8].

Devlin and colleagues' report supports the view that the main environmental influences on IQ occur early in life. If indeed they do, improved cognitive functioning might be an unexpected benefit of public health initiatives aimed at improving maternal nutrition and reducing prenatal exposure to toxins. Nonetheless, it is important to recognize that the evidence of Devlin *et al.*, like that supporting the influence of early intellectual stimulation on synapse formation and subsequent human intellectual performance, is indirect and as yet unreplicated.

Caution is certainly warranted. In large-scale studies where pre- or perinatal influences on IQ have been assessed directly, little evidence for any strong effect has been found[9]. Perhaps this early work lacked precise assessments of prenatal exposures, or perhaps the effect of any single prenatal factor is relatively minor and thus difficult to detect. Even though it does not establish the effect of any specific prenatal factor, Devlin and colleagues' statistical analysis implies that a relatively sizable portion of IQ variability can be attributed to the aggregate effect of the prenatal environment, and so provides a rationale for reconsidering these earlier studies.

That the IQ debate now centres on whether IQ is 50% or 70% heritable is a remarkable indication of how the nature–nurture debate has shifted over the past two decades. The anti-hereditarian position that there are no genetic influences on IQ has crumbled for want of any empirical data that would support such a radical view. Equally remarkable is the increasingly dominant view that the major environmental influences on IQ occur within the first few years of life, or in the womb, and directly affect the development of the brain. Research on the nature and nurture of IQ is converging on the view that human intellectual ability has a strong, but malleable, biological basis — a convergence that Galton would, no doubt, have found quite congenial. □

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Palaeoclimatology

A warm future in the past

William R. Howard

To understand the impact of a possibly warmer future climate, geologists are searching the past for warmer-than-present interglacial intervals — examples of what we may expect in a world with more greenhouse gases than ours[1]. A common tactic is to look at the last interglacial (around 120,000 years ago), but a period 423,000 to 362,000 years ago may fit the bill better, because the Earth's orbital geometry has been similar during the Holocene (the present interglacial period) to what it was then. This period is known to palaeoclimatologists as stage 11 or 'MIS 11', according to a numbering system for glacial advances and retreats marked in the marine oxygen isotope record (Fig. 1). At a recent symposium*, evidence emerged of extreme climatic variation and peculiar interplays between ocean temperature, thermohaline circulation, plankton ecology, sea level and reef growth during MIS 11, all of which may provide insight into the response of the natural carbon cycle to future climate change.

Changes in the Earth's orbital geometry explain the strong 41,000-year and 23,000-year rhythms in climate over the past five million years (due to changes in axial tilt and orbital precession, respectively). During the past 600,000 years, however, the dominant rhythm has been a 100,000-year cycle. Although this climate cycle is at a similar frequency to orbital eccentricity variation, the radiative impact of that orbital cycle is too small — at least in linear climate models[2] — to produce the large swings in the climate record.

MIS 11 is the warm peak of one such '100k' cycle, with two intriguing features. First, climate change at the 12–11 transition is nearly the most severe of the past half-million years (Fig. 1), yet it comes at a time of low orbital eccentricity, thus of low precessional amplitude. Second, interglacial conditions last longer. Subsequent interglacials (stages 9, 7, and 5) show short periods of warmth followed by early returns to glacial conditions (Fig. 1).

Many other aspects of the climate were strange. In deep-sea records of MIS 11, subpolar waters in both hemispheres were at their warmest (L. Burckle, Lamont-Doherty Earth Obs.), following one of the coldest glacial stages of the past 500,000 years (Fig. 1c, d). Deep-ocean carbon isotope data show a maximum in the production of North Atlantic Deep Water (D. Hodell, Univ. Florida). Tracers of downward particle flux in the equatorial Pacific show that biological productivity was at a minimum in MIS 11 (R. Murray, Boston Univ.). Calcium carbonate production peaked in subpolar and subtropical oceans (R. Schneider, Univ. Bremen), reflecting a temperature-related shift in plankton ecology from diatoms to calcareous plankton.

In shallow-water environments, the evolution of several major reef systems (such as the Great Barrier Reef) accompanied increased reef carbonate production (A. Droxler, Rice Univ.; P. Davies, Sydney Univ.). The production of carbonate in continental shelves and in mid-latitude open-ocean environments may partly explain the extreme dissolution of carbonate sediments during MIS 11 throughout ocean basins such as the Indian and Pacific[3]. (In the oceans' carbonate cycle, biological formation of hard body parts from carbonate outstrips river input of the component ions, and dissolution from the seabed makes up the difference. In other words, to produce more carbonate in one place you must dissolve more elsewhere.)

Perhaps barrier-reef tracts were established during stage 11 because tropical continental shelves were flooded (A. Droxler; C. Kievman, Kean Coll.). How high did the seas rise? Beach deposits in Alaska, Bermuda and the Bahamas (P. Hearty, Bahamas) and uplifted reef terraces in Indonesia[4] seem to imply that the ocean stood as much as twenty metres above its present level. But this is uncertain: estimating sea level for MIS 11 is complicated by the fact that dating beaches

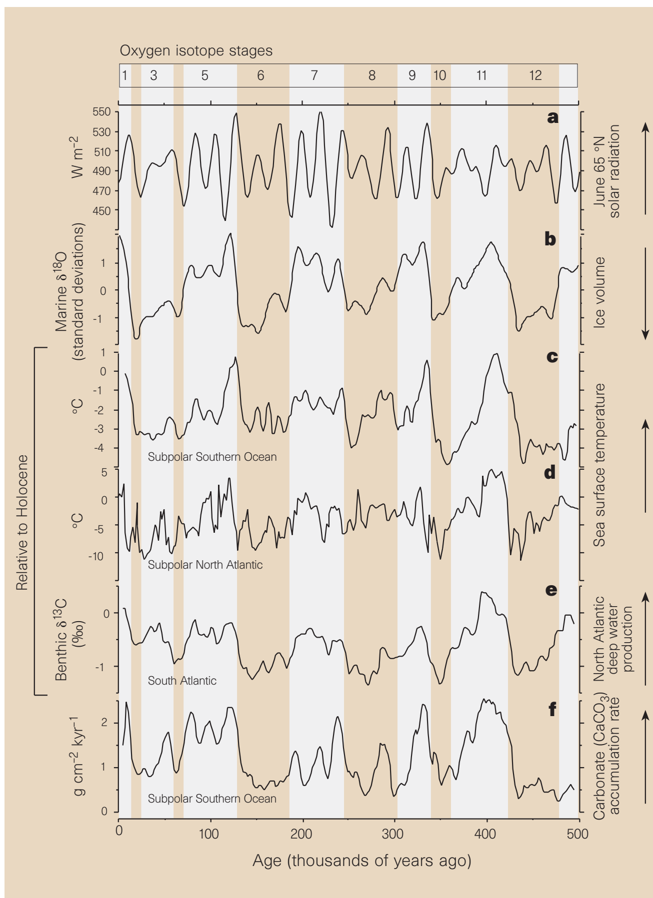

Figure 1 **Climate and chemistry of the past 500,000 years. All the climatic variables** b **to** f **(refs 2, 8–11, respectively) are related to solar forcing,** a **(ref. 12), determined by changes in the Earth's orbit** (c, d **and** e **relative to average over the Holocene — the past 10,000 years or so). The long, hot interglacial of stage 11 occurred under similar orbital conditions to those we have now — so is it a model for our own time?**

**Carbonate Marine System During Oxygen Isotope Stage 11, American Geophysical Union Spring Meeting,* Baltimore, Maryland, USA, 27–30 May 1997.