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Perspective

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Genetic determinism, essentialism and reductionism: semantic clarity for contested science

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Abstract

Research linking genetic differences with human social and behavioural phenotypes has long been controversial. Frequently, debates about the ethical, social and legal implications of this area of research centre on questions about whether studies overtly or covertly perpetuate genetic determinism, genetic essentialism and/or genetic reductionism. Given the prominent role of the '-isms' in scientific discourse and criticism, it is important for there to be consensus and clarity about the meaning of these terms. Here, the author integrates scholarship from psychology, genetics and philosophy of science to provide accessible definitions of genetic determinism, genetic reductionism and genetic essentialism. The author provides linguistic and visual examples of determinism, reductionism and essentialism in science and popular culture, discusses common misconceptions and concludes with recommendations for science communication.

Sections

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Introduction

The scientific validity, ethical permissibility and practical utility of studies investigating the role of genes in human behaviour and disease are hotly debated, both within and outside academia. Studies focusing on genetic differences in relation to phenotypes that can be moralized (such as sexual behaviour and drug use) that show racialized and socioeconomic disparities (such as educational attainment and intelligence test scores) and that are more commonly understood as cultural practices (such as childbearing) are particularly contentious, although no field of human genetics is immune from controversy[1].

In the late twentieth and early twenty-first century, much of the controversy around the uses and misuses of human genetics centred on the subfield of behavioural genetics[2], which used twin and adoption studies to estimate the heritability of individual differences in behaviour and psychological characteristics, including cognitive abilities, personality and psychopathology[3]. Notoriously, results on the heritability of human individual differences were misused to advance the idea that economic and racial inequalities were immutable[4,5]. For example, "How much can we boost IQ and scholastic achievement?"[4] was psychologist Art Jensen's infamous rhetorical question, and he argued very much in the negative.

This interpretation of behavioural genetic results was widely condemned as not just politically and morally unpalatable but also as scientifically incorrect: (1) even highly heritable phenotypes can be modified via environmental change; (2) the heritability of individual differences within a group implies nothing about the source or even the direction of between-group differences; (3) there is far more genetic variation within socially defined racial groups than there is between them; and (4) heritabilities could arise, at least partly, via social processes (for example, bias against individuals with certain physical characteristics) rather than solely via 'inside-the-skin' cellular mechanisms. As will become clear in this Perspective, points (1) and (2) are arguments against 'genetic determinism', point (3) is an argument against 'genetic essentialism' and point (4) is an argument against 'genetic reductionism'.

Now, researchers investigating genetics in relation to human individual differences have moved beyond black-box estimates of heritability and are attempting to discover specific genetic variants associated with phenotypes of interest using genome-wide association studies (GWAS)[6]. Whereas the first years of GWAS research focused mostly on biomedical phenotypes, such as blood lipid levels or Crohn's disease[7], GWAS are increasingly used to study social and behavioural phenotypes, including educational attainment, cognitive abilities, sexual behaviour, childbearing, substance use and symptoms of mental disorders. This subfield of research, which has fuzzy boundaries, and which generally uses the same research methodologies as the larger field of complex trait genetics, has been termed social and behavioural genomics[8]. In contrast to earlier candidate gene research, social and behavioural genomics research has successfully identified replicable genetic associations with behavioural phenotypes, although the mechanisms that produce these associations remain largely unknown[9]. Moreover, for some phenotypes, the variance statistically accounted for by identified genetic variants now rivals the variance accounted for by variables more typically considered in social science[10,11].

As the pace of genetic discovery has accelerated, so too has the demand for researchers to communicate their results in ways that avoid the '-isms' — genetic determinism, genetic essentialism and genetic reductionism — that were characteristic of earlier misuses of behavioural genetic research[12]. To achieve this goal, it is necessary for there to be consensus and clarity about the meaning of these terms. Here, I give an accessible definition of genetic determinism, essentialism and reductionism, review psychological research on why the idea might be politically or socially consequential, provide examples from scientific papers and popular culture that imply (in)determinist, (anti-)essentialist or (anti-)reductionist ideas and conclude with recommendations for scientific communication and critique.

Genetic determinism

Determinism is a philosophical term about the causal structure of the universe, and has been defined as follows: "The world is governed by determinism if and only if, given a specified way things are at time t, the ways things go thereafter is fixed as a matter of natural law."[13]. Carrying this forward, genetic determinism can therefore be defined as follows: a phenotype is governed by genetic determinism if, and only if, given a specified genotype, the way the phenotype develops thereafter is fixed as a matter of natural law.

A genetically determined phenotype, according to this definition, is a necessary occurrence: if one knows the genotype, then one can foretell the phenotype with a very high degree of certainty, regardless of social or environmental context. Using philosopher Ned Block's example of the number of fingers, having five fingers on each hand is genetically determined, because, if one has a specified genotype, then one will (almost) invariably develop five fingers on each hand as a matter of natural law[14]. In the case of the number of fingers, genes have a very high degree of what philosopher James Woodward called causal specificity: "the state of C [in this case, the genotype] exerts a fine-grained kind of control over which state of *E* [in this case, the phenotype] is realized"[15]. A normal *EVC1* gene produces the state of having five fingers; a mutation in the *EVC1* gene produces the state of having more than five fingers[16].

By contrast, specificity is low, and the conclusion that the phenotype is genetically determined is unsupported "if the same state of *C* leads to a number of different states of *E* or if there are many states of *E* that cannot be produced at all by realizing states of *C*"[15]. Educational attainment, for example, is not genetically determined, because people who have the same genotype can have numerous different educational outcomes, and there are many educational outcomes that cannot be produced by changing someone's genotype[11].

In addition to high causal specificity, genetic determinism also implies that there is high stability or non-contingency of the genotype–phenotype relationship across environmental contexts. A non-contingent relationship between genotype and phenotype has been defined as one that is "not dependent on other factors, particularly exposure to a specific environment or on the presence of other genes"[17]. I said previously that because the number of fingers is genetically determined, one will develop five fingers on each hand 'almost' invariably. The qualifier is necessary, because there are environmental exposures that might alter morphological development beyond one's genotype, for example, exposure to thalidomide in utero. Yet the existence of this exception does not do much to shake our intuition that the number of fingers is genetically determined, as exposure to teratogenic drugs is a rare event that is not part of the expectable environment for humans, regardless of time or place. Thus, as Woodward pointed out, "stability comes in degrees"[15].

What determinism is not

Genetic determinism, as a concept, does not map to heritability[18]. Some phenotypes, such as Huntington disease and other Mendelian disorders, are both genetically determined and are 100% heritable;

some, such as the number of fingers, are genetically determined but not at all heritable, because there is little to no variation in the relevant genes in the population being studied. Still other phenotypes, such as educational attainment, are heritable but not genetically determined, and heritability is contingent on the environmental context, historical time and social structure. For instance, the heritability of educational attainment in Norwegian men was 41%, but for men born after 1940, who experienced educational reforms introduced after World War II, heritability increased substantially (67–84%)[19]. Heritabilities can shift in response to even brief interventions, such as an online growth mindset intervention or an in-laboratory social stressor[20,21]. Because heritability does not imply determinism (and determinism does not imply heritability), attempts to ground definitions of genetic determinism in heritability, and to infer a scientist's beliefs about genetic determinism from their discussion of heritability, are mistaken.

Genetic determinism must also be distinguished from genetic causation[22]. In manipulationist, counterfactual and/or potential-outcomes understandings of causation, which are de rigueur across scientific fields, X is considered a (not the) cause of Y if a change in X would change the probability of Y occurring, even if the change in X is neither necessary nor sufficient to guarantee that Y occurs. For example, a randomized controlled trial of lithium versus placebo would conclude that lithium causally reduces manic symptoms if the probability of experiencing a manic episode was lower in the group randomly assigned to receive lithium, even if some individuals in the treatment group nonetheless did still experience a manic episode (and some in the placebo group did not). In the same way, the conclusion that genes are causally related to the phenotype is not synonymous with the claim that genes determine a phenotype.

Examples of genetic determinism and indeterminism

Genetic determinism is commonly implied — or claimed outright — in media coverage of genetic studies. For example, a news article in *Science* was titled 'Genes Don't Just Influence Your IQ — They Determine How Well You Do in School'[23], whereas an article in *MIT Technology Review* was titled 'Forecasts of Genetic Fate Just Got a Lot More Accurate'[24]. The language of 'genetic fate' implies that a person's phenotype is knowable given knowledge of their genotype, rather than — as is the case for any behavioural or psychological phenotype — being dynamically responsive to environmental conditions and subject to developmental variability.

In scholarly work and science communication, researchers can avoid implying genetic determinism with text and visual displays that highlight unpredictability or uncertainty in the prediction of an individual's phenotype from their genotype and that highlight instability or contingency of genotype–phenotype relationships. For example, one study highlighted the contingency of genotype–phenotype associations by examining how polygenic score associations with educational attainment differed by gender and year. The study's abstract concluded with specific language about genetic indeterminism: "genetic influence must be understood through the lens of historical change, the life course, and social structures like gender"[25].

As a visual example, Fig. 1 presents two ways of graphing the same association with a polygenic score[26]. Figure 1a, by showing the full range of individual variability around a given value of the polygenic score, conveys more uncertainty in the genotype–phenotype relationship than Fig. 1b, which focuses on average outcomes by deciles of the polygenic score. In some cases, focusing on extreme subgroups with very different expected values for the phenotype might be useful clinically and/or scientifically. But even in these cases, researchers should still be mindful that presentations of individual-level data might be helpful in combating deterministic biases. Presenting individual-level data also answers more general calls for greater transparency in data visualization[27].

Why determinism matters

In the twentieth century, the idea of genetic determinism was used to justify state-sponsored violence, including involuntary sterilizations and genocide[28]. More recently, belief in genetic determinism was evident in the writings of a mass shooter who targeted Black victims[29]. Also, genetic determinism continues to be invoked in support of the idea that social and economic inequalities between people are fixed and immutable, that environmental interventions, social policies or structural changes will be ineffective and that people, therefore, have no moral or political responsibilities to address inequalities[2,5].

In addition to concerns about genetic determinism being used to justify violence and perpetuate inequalities, determinism might also raise "fears about our own status as free agents in the world"[13]. That is, debates about genetic determinism can become a stand-in for larger concerns about agency, free will and moral responsibility in a deterministic universe. Such concerns about the existence of free will, although they can attach themselves to conversations about genetics, typically have very little to do with genetics per se.

Among the general public, the relationships between genetics knowledge, belief in genetic determinism and political ideology are complicated. In the United States, there is actually little ideological or demographic polarization in beliefs about genetic determinism[30]. In a nationally representative US sample, white people, socio-economically advantaged people and political conservatives were no more or less likely than other groups to believe that genetics are important for health and social phenotypes[31]. Similarly, a Gallup survey found that people who described themselves as opponents of President Trump were actually more likely to give bio-deterministic explanations of income inequality ('the rich are born with greater abilities') than were self-described supporters of President Trump[32]. Another study also found no relationship between belief in genetic determinism and political ideology (liberal versus conservative), although there was a modest positive correlation with authoritarianism, that is, with holding attitudes deferential to existing authorities, supporting of traditional morality and supportive of strict or punitive forms of social control[33]. Also, perhaps surprisingly, people with greater knowledge about genetics and genomics are not less likely to believe in genetic determinism[34].

Finally, similar to genetic determinism, environmental determinism might also have pernicious consequences. For example, the 'refrigerator mother' theory, which was prevalent in the mid-twentieth century, blamed mothers who were alleged to be cold and rejecting for the development of autism and schizophrenia in their children. This stigmatizing theory began to be questioned in response to twin and children-of-twin studies suggesting that autism and schizophrenia were genetically influenced.

Genetic essentialism

Essentialism is the belief that things have essences — one or more deep, underlying characteristics, without which the thing or person would not be what it is — and that these essences explain why certain individual things or people are appropriately considered members of the same category[35,36]. That is, essentialism is a theory that structures how

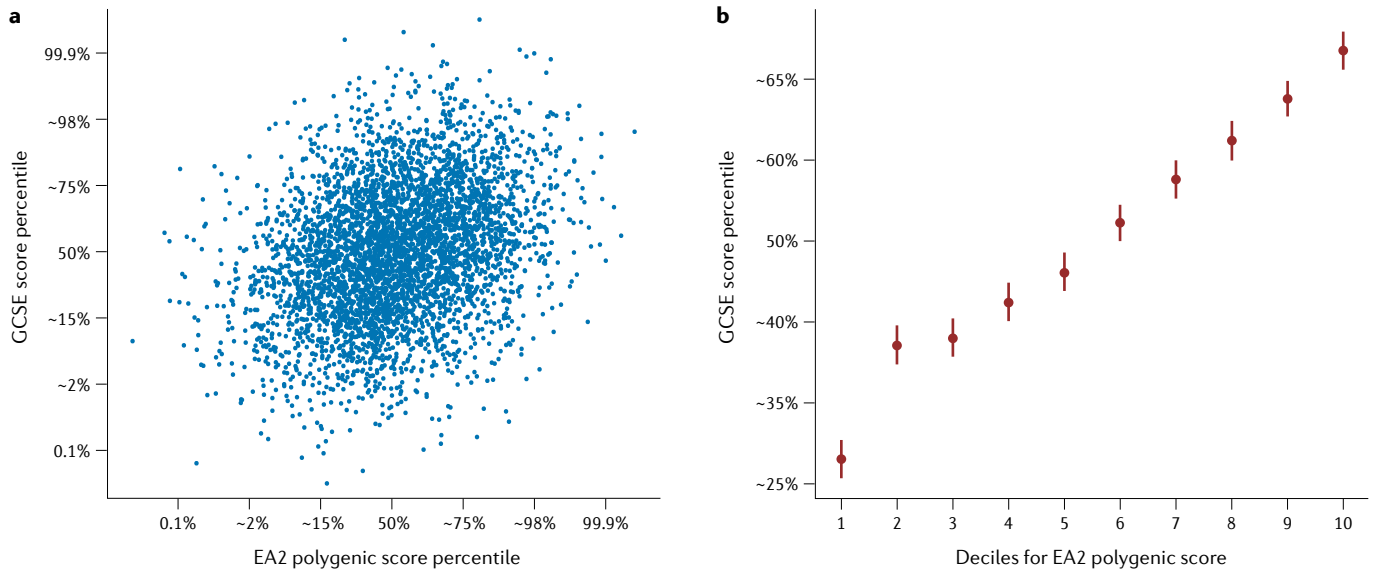

Fig. 1 | Alternative visualization of the same data implies less or more genetic determinism. Association between GCSE scores in a sample of British adolescents and a polygenic score calculated from results of a genome-wide association study of educational attainment[32]. **a**, Representation of each individual in the sample and the entire range of possible outcomes (0.1 percentile to 99.9 percentile). **b**, Average GCSE score for each decile of the polygenic score, with confidence bands representing the standard error around the estimate of the mean. Part **a**, representing more of the phenotypic variability among people who have similar polygenic scores, implies less genetic determinism than part **b**. Figure reprinted from ref.[26], Springer Nature Limited.

concepts and categories are organized, including social categories such as gender or race. Thus, whereas determinism is a belief about why something comes to be, essentialism is a belief about what makes that thing similar to (or unlike) another thing. For example, one holding a determinist belief will overlook environmental influences such as sun exposure and believe that skin tone is genetically determined. One holding an essentialist belief will believe that people who have a similarly dark skin tone share an underlying essence, such that their superficial similarity reflects a deeper property that explains what they are all 'really' like.

Research in developmental psychology suggests that essentialist thinking is a cognitive bias that emerges very early in development; even preschool-aged children construct categories based on folk theories about essences, rather than simply on learning associative rules[37]. Genetic essentialism, then, is a particular type of essentialist thinking, where the essence that constitutes what a thing or person 'really' is or that links various particulars to a single category is some real or imagined DNA sequence.

Psychological studies have identified two major dimensions of essentialism[38]: naturalness and entitativity. The first dimension, naturalness, is most relevant to genetics, and encompasses the beliefs that a group is biological (versus artificial), discrete (versus having fuzzy, ambiguous boundaries) and stable (versus changing or disappearing across historical time and context), and that group membership is immutable (versus members being able to change or leave groups) and requires necessary characteristics (that is, there is something that a member must have to be appropriately considered part of the group). The second dimension, entitativity, encompasses the beliefs that groups are highly similar or uniform (versus group members being heterogeneous or variable), exclusive (versus being able to be part of more than one group) and inherent (having similarities that are 'deep' versus being similar only superficially), and that knowledge of group membership is informative about many characteristics of group members (having high versus low inductive potential).

Factor analyses indicate that naturalness and entitativity beliefs are relatively independent. For instance, a study of a sample of US undergraduates (from a predominantly white college) found that, on average, they tended to think of white racial identity as being very natural but not very entitative[38]. That is, they saw whiteness as being stable, discrete, immutable and biological, but did not see white people as being highly uniform or believe that one could tell a lot about an individual by knowing they were white. By contrast, political groups (for example, 'liberal' or 'Republican') were perceived as highly entitative but not as natural kinds. That is, even though 'Republicanism' was not seen as biological, Republicans were perceived as being similar to each other, 'Republicanism' was seen as a deep property of a person rather than a superficial characteristic, and it was thought that you could infer a lot about a person just from knowing that they were a Republican.

In addition to essentialist beliefs about categories or groups, genetic essentialism can also characterize thinking about an individual identity or self. Essentialism about the self can be considered a special case of categorization: the feelings, experiences, preferences, interests, attitudes, values and motivations that describe 'me' at any one point in time can shift from moment to moment, from year to year, but despite the differences between 20-year-old Paige and 40-year-old Paige, I nonetheless perceive these variable psychological states to be reflective of a single, coherent 'I' rather than as a disparate constellation of unlike things. What constitutes this 'I'? In genetic essentialism, "the individual's genome is taken not only to cause characteristics and typical behaviors, but to represent the very essence of the individual's identity"[39].

What essentialism is not

Genetic essentialism is related to, but distinct from, genetic determinism. Essentialist thinking involves beliefs that category membership is stable, immutable and based on biology. Accordingly, determinist thinking about the effects of genes might contribute to more essentialist thinking. Nonetheless, these concepts are not synonymous: one might think, for instance, that musical ability is genetically determined without thinking about the category of 'musician' as a natural kind, or one might have entitative beliefs about the group 'Catholics' without believing that religiosity is genetically determined.

There are also important differences between determinist and essentialist beliefs with regards to how genetic information is used in moral judgements[39]. Determinist thinking conceptualizes the genome as a constraint on one's ability to be or to have done otherwise, which might lead to diminished judgements of blameworthiness. As Dar-Nimrod and Heine conclude, "behaviors with moral implications lose their moral force if people view those behaviors as beyond the individual's volition"[40], for example, owing to being genetically determined. Essentialist thinking, by contrast, conceptualizes the genome not as limiting what a person can do or become but, rather, as constituting who a person 'really' is. People are judged as more morally blameworthy or praiseworthy when their actions are perceived to be in line with who they 'really' are, that is, in line with their 'true self'[39]. Thus, genetic information might reduce judgements of blameworthiness or praiseworthiness if that information is understood through the lens of determinism, but increase those judgements if genetic information is understood through the lens of essentialism.

Examples of genetic essentialism and anti-essentialism

Genetic essentialist thinking about the self is evident, for example, in the slogan that the direct-to-consumer genetic testing company 23andMe uses to advertise its DNA testing kits: 'Welcome to you'. This slogan could be understood by consumers to mean that they will meet or reveal their 'real' or 'true' self on the basis of genome testing results. Genetic essentialism about groups involves, as I have described, beliefs that (among other things) groups are discrete, exclusive, uniform and have high inductive potential. Accordingly, anti-essentialist text or visual representations of data are ones that emphasize continuous variation, fuzzy boundaries, overlapping distributions, variation within groups and uncertainty around the prediction of individual characteristics given group membership (Fig. 2).

Why essentialism matters

Social theorists have long suspected that essentialist beliefs about social groups might engender prejudice (negative attitudes), stereotyping (negative beliefs) and discrimination (negative actions) towards group members[41]. The empirical evidence, however, is more complicated.

Several studies have found that holding essentialist beliefs about race, gender, religious groups or sexual orientation is correlated with greater stereotyping, prejudice, dehumanization and support for discriminatory policies (see ref.[42] for a review). Particularly relevant for social and behavioural genomics research, one study examined entitativity beliefs separately from two kinds of naturalness beliefs: 'bio-somatic' essentialism versus 'bio-behavioural' essentialism. Both bio-somatic and bio-behavioural essentialism see racial groups as natural kinds predicated on a shared biological essence, but differ in whether the ostensible biological origin of group membership links members to certain physical characteristics (for example, blond hair and blue eyes) or, instead, links them to certain character traits (for example, intelligence and criminality). That is, bio-somatic and bio-behavioural essentialism differ in which traits (somatic versus behavioural) group membership is informative about. Compared with bio-somatic essentialism, bio-behavioural essentialism about race was found to be more strongly correlated with anti-Black prejudice[43].

A few studies have even found evidence for a causal relationship, such that priming or manipulating essentialist beliefs can change stereotypes, attitudes and/or behaviour[44,45]. One notable study examined the effects of a high school genetics curriculum specifically designed to undermine essentialist thinking by, for example, presenting evidence about the extent of genetic variance within racial groups (challenging uniformity) and the extent of genetic overlap across racial groups (challenging exclusivity)[46]. Compared with students randomly assigned to education about an unrelated topic (climate change), students who received an anti-essentialist genetics education agreed less with negative racial stereotypes. Other studies, however, have suggested that the causal arrow points in the opposite direction: people strategically invoke essentialist ideas to justify existing social hierarchies[47].

Some experimental studies that manipulated essentialist thinking have failed to find causal effects on stereotyping or prejudice[48]. An alternative hypothesis is that essentialism and bias are not linked causally or by logical necessity but, rather, are two sets of beliefs that have come to be correlated with each other because they have been 'packaged' together by historical events and cultural narratives. Consistent with that idea, participants who were briefly exposed to information that supported biological essentialism but that was packaged with an anti-bias message no longer showed the expected positive correlation between essentialist thinking and endorsement of stereotypes[48].

Finally, essentialist beliefs can also be destigmatizing: the correlation between essentialism and stereotyping and prejudice is sometimes negative, depending on the measure of essentialism used, on the presence of other psychological beliefs (such as belief in the acceptability of inequality) and/or on the group being evaluated[42]. For instance, biological essentialism about sexual orientation is correlated with less, rather than more, anti-gay prejudice[49]. Similarly, some people seem to reject essentialist ideas to justify prejudice (for example, insisting that a group could change but refuses to). On the basis of these results, one author concluded that "essentialism is not by definition oppressive and that de-essentialism is not by definition progressive. The discursive power of (de-)essentialist group beliefs depends on the way they are used and the context in which they appear."[50]

Understanding the relationship between genetic essentialism and social bias is a particularly important area of study, because it informs our understanding of scientists' ethical responsibilities. Researchers are tasked with minimizing potential social risks of their work and with disseminating research in a socially responsible manner. This task is particularly salient for researchers who work in behaviour genetics and population genetics, as results from these subfields have been invoked to justify white supremacy and violent political extremism[51]. If genetic essentialism is directly and causally related to prejudicial attitudes towards social groups, particularly towards racial minorities, then this suggests that researchers linking genetics with phenotypes that are involved in group-based stereotypes (as well as editors, funders, journalists and others involved in scientific knowledge production and dissemination) have a particular responsibility to justify the benefits of their research as outweighing its social risks, and to describe results in ways that do not support beliefs about the naturalness or entitativity of social groups. However, if genetic essentialism does not actually cause

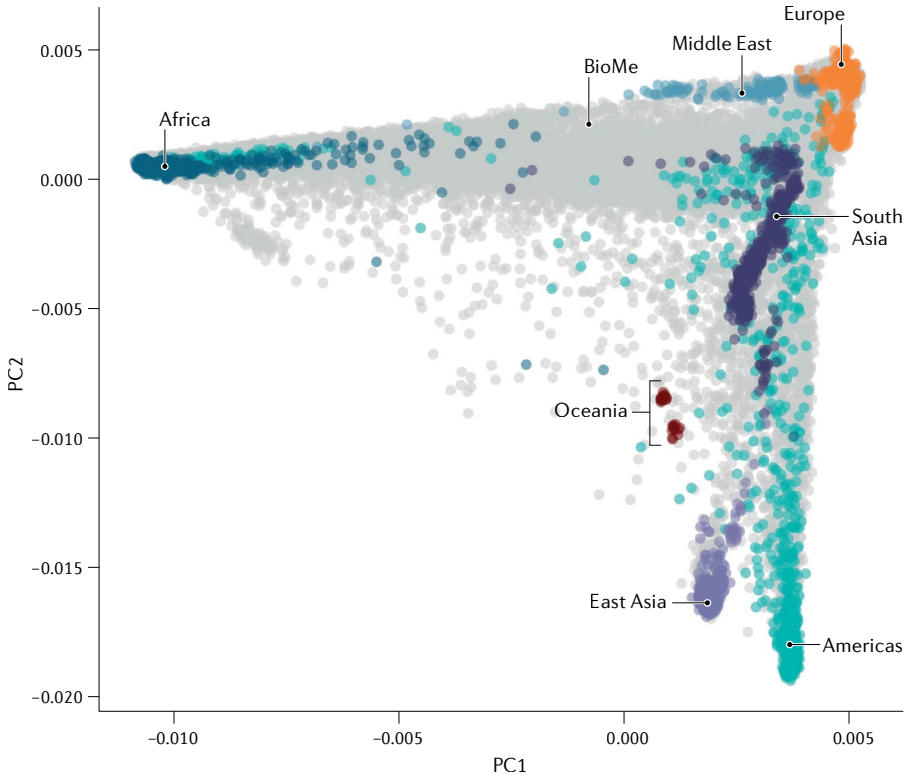

Fig. 2 | Anti-essentialist representation of genetic variation. Individuals drawn from a diverse New York-based biobank (BioMe) (grey dots) projected onto the first two principal components of genetic similarity, emphasizing that genetic similarity and dissimilarity are clinal rather than discontinuous. By contrast, coloured dots represent reference panel individuals deliberately sampled from different continental and subcontinental regions, visually suggesting the existence of discrete groups with clearer-cut boundaries. Figure adapted with permission from ref.[65], Elsevier.

social bias but is merely correlated with it by virtue of the historical events and cultural narratives or is invoked as a post hoc justification for existing prejudices, explanations of why research does not support essentialist beliefs, or curtailing the research altogether, might have limited or no benefits to reducing stereotyping and prejudice. This is, of course, an area of active enquiry and debate among scholars and other stakeholders[29].

Genetic reductionism

"Reductionism is a metaphysical thesis, a claim about explanations, and a research program."[52] The metaphysical thesis is materialism: people, and their minds and their behaviour, ultimately consist of physical states and processes; there is no extra-material or spiritual realm. This thesis is not an object of serious debate among scientists. Rather, scientific debates centre on the latter two components of reductionism: the claim that higher-level phenomena can, in theory, be entirely explained by knowledge about lower-level parts and processes, and that, accordingly, phenomena are more fruitfully investigated at those lower levels. An objection to genetic reductionism, then, is an objection to the idea that knowledge about genes and genetic processes could ever be sufficient to explain a higher-level phenomenon, such as psychotic experiences or depression, or that these phenomena are best studied using genetic tools and methods.

Debates about genetic reductionism can produce a dichotomy between two extreme positions. One extreme position is the idea that genetics (or biology more generally) can, in principle, fully explain all facts about human behaviour, making higher-level psychological or social theories entirely dispensable. The other extreme position is that the social sciences' theories of human behaviour are fully autonomous, such that lower-level biological facts or theories are in no way beneficial to scientific understanding at the higher level. Although it is possible to find scholars who seem to endorse either the extreme reductionist[53] or the extreme anti-reductionist[54] position regarding the relationship between biology and behaviour, most scientists who study human behaviour concede the middle ground of explanatory pluralism, at least in principle. Explanatory pluralism holds that a complex phenomenon, such as human behaviour, can be understood from multiple, overlapping perspectives, and scientific studies that differ in their level of analysis (ranging from the actions of molecules within cells to the actions of governments within nations) can provide complementary information[55–57].

This approach to understanding human behaviour has been illustrated with the analogy of 'physics of carpets'[58]: understanding physics might inform one's understanding of fibre strength and colour saturation, which are essential dimensions for manufacturing carpets, but what makes something a carpet — and not, say, a wall-hanging or a throw blanket — is defined by social conventions, not the laws of physics. Similarly, understanding genetics or neurobiology might inform one's understanding of information processing or emotion regulation, which are essential dimensions of mental health and cognitive

ability, but what makes something an 'ability' is measured at the level of behaviour and defined by social conventions.

Examples of genetic reductionism and anti-reductionism

Media coverage of genetics studies often uses reductionist language. For example, a headline in the *Washington Post* claimed that "Our politics are in our DNA"[59], whereas an article in *The Atlantic* referred to "Genetic intelligence tests"[60]. Stating that a higher-level social or behavioural phenomenon is 'in' DNA, or can be measured entirely with genetic information, is reductionist, because it implies that the phenomenon can be entirely understood, or is best understood, at a lower level of genetic analysis. Even headlines critical of genetic studies can still imply genetic reductionism if the language inappropriately collapses across levels of analysis (for example, 'genetic intelligence tests').

What reductionism is not

As with genetic determinism, genetic reductionism is not genetic causation. The disjuncture between causal claims and reductionist claims is more obvious when all of the relevant phenomena are behavioural: the claim that social media use increases depression[61] implies that, all other things being equal, increasing the number of hours per day that people spend on social media will, on average, make a difference to their probability of experiencing depression, not that depression is always most fruitfully investigated by measuring social media activity or that theories and knowledge about depression can be reduced or recapitulated by theories and knowledge about social media.

Causal claims are more readily misinterpreted as reductionistic when genes are involved, but the distinction between causation and reduction still applies. In the classic hypothetical scenario proposed by Jencks, if red-headed children were prohibited from going to school, then inheriting a certain genetic variant might 'cause' one to have worse literacy, because the genetic variant codes for a physical characteristic (red hair) that then makes one subject to culturally and historically specific social biases[62]. In an empirical example, we have observed a genetic correlation between 'non-cognitive' variance in educational attainment and chronotype, specifically, with being a 'morning lark' rather than a 'night owl'[63]. However, if school start times were pushed to the afternoon rather than the early morning, this genetic correlation might disappear or even reverse direction. In these examples, genes are difference-makers for education relative to a given causal context, but understanding the biology of chronotype or hair colour will not give a satisfactory explanation of why some children go further in school than other children.

Given the potential for miscommunication, particularly across disciplinary boundaries, researchers should be clear in their written and oral presentations that they are not using causal language to imply any sort of explanatory reduction.

Why reductionism matters

Theoretical debates regarding the best level of analysis by which to understand a phenomenon do not remain in the realm of the theoretical but are reflected in funders' decisions about how to allocate finite resources: claims about explanations guide research programmes. Accordingly, genetic reductionism (particularly regarding psychological and medical phenotypes) has perhaps been most heavily criticized on the grounds that it redirects resources disproportionately to genetic or other biological research, at the expense of understanding and ameliorating the social determinants of poor health and psychopathology[1,64].

Conclusion

Human genetics is contested science. The sometimes bitter debates about the utility and ethics of linking genetics with human behaviour are complicated by semantic differences in how different academic disciplines use the same words (consider, for example, the different meaning(s) of the word 'population' for a demographer and an evolutionary geneticist), and in how the lay public interprets academic jargon. Anyone who has attempted to explain the concept of heritability to college freshmen or to a science journalist has likely experienced this semantic difficulty first hand.

Here, I have attempted to provide greater semantic clarity regarding the terms genetic determinism, genetic essentialism and genetic reductionism, with the aim of improving, even modestly, the quality of scientific discourse about contested areas of scientific research and of scientific communication with the lay public. As described in this Perspective, these terms capture well-specified concepts that have been the subject of much philosophical and psychological scholarship, but they are also often used as interchangeable, expandable and emotionally charged ethical terms that both presuppose and provoke a negative value judgement. This semantic muddiness regarding what does and does not constitute determinism, essentialism and reductionism can contribute to lack of scientific progress and to rancour and miscommunication in vital scientific and ethical debates. Geneticists are encouraged to be careful and precise in their use of the words 'determinism', 'reductionism' and 'essentialism', and to avoid language and data visualizations that might unwittingly imply support for these ideas.

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