

7. D. R. Weaver, *J. Biol. Rhythms* **13**, 100 (1998).
8. D. P. King *et al.*, *Cell* **89**, 641 (1997).
9. Z. S. Sun *et al.*, *Cell* **90**, 1003 (1997).
10. H. Tei *et al.*, *Nature* **389**, 512 (1997).
11. E. Nagoshi *et al.*, *Cell* **119**, 693 (2004).
12. D. K. Welsh, S. H. Yoo, A. C. Liu, J. S. Takahashi, S. A. Kay, *Curr. Biol.* **14**, 2289 (2004).
13. S. H. Yoo *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **101**, 5339 (2004).
14. S. M. Siepka, J. S. Takahashi, *Methods Enzymol.* **393**, 230 (2005).
15. C. S. Pittendrigh, S. Daan, *J. Comp. Physiol. A* **106**, 223 (1976).
16. M. H. Vitaterna *et al.*, *Science* **264**, 719 (1994).
17. K. T. Moortgat, T. H. Bullock, T. J. Sejnowski, *J. Neurophysiol.* **83**, 971 (2000).
18. M. H. Vitaterna, L. H. Pinto, J. S. Takahashi, *Trends Neurosci.* **29**, 233 (2006).
19. D. M. Bannerman, M. A. Good, S. P. Butcher, M. Ramsay, R. G. Morris, *Nature* **378**, 182 (1995).
20. M. Thomsen, S. B. Caine, *Behav. Genet.* **37**, 101 (2007).
21. E. A. Phelps, J. E. LeDoux, *Neuron* **48**, 175 (2005).
22. E. R. Kandel, *Science* **294**, 1030 (2001).
23. R. L. Davis, *Physiol. Rev.* **76**, 299 (1996).
24. P. L. Lowrey *et al.*, *Science* **288**, 483 (2000).
25. J. P. DeBruyne, D. R. Weaver, S. M. Reppert, *Nat. Neurosci.* **10**, 543 (2007).
26. Q. J. Meng *et al.*, *Neuron* **58**, 78 (2008).
27. D. P. King *et al.*, *Genetics* **146**, 1049 (1997).
28. The International Mouse Knockout Consortium, *Cell* **128**, 9 (2007).
29. Y. Gondo, *Nat. Rev. Genet.* **9**, 803 (2008).
30. A. Acevedo-Arozena *et al.*, *Annu. Rev. Genomics Hum. Genet.* **9**, 49 (2008).
31. B. T. Kile, D. J. Hilton, *Nat. Rev. Genet.* **6**, 557 (2005).
32. S. M. Siepka *et al.*, *Cell* **129**, 1011 (2007).
33. A. Matyina *et al.*, *PLoS One* **3**, e2121 (2008).
34. J. Flint, W. Valdar, S. Shifman, R. Mott, *Nat. Rev. Genet.* **6**, 271 (2005).
35. L. L. Peters *et al.*, *Nat. Rev. Genet.* **8**, 58 (2007).
36. W. F. Dietrich *et al.*, *Cell* **75**, 631 (1993).
37. K. E. Strunk, V. Amann, D. W. Threadgill, *Genetics* **167**, 1821 (2004).
38. K. Shimomura *et al.*, *Genome Res.* **11**, 959 (2001).
39. J. H. Nadeau, W. N. Frankel, *Nat. Genet.* **25**, 381 (2000).
40. K. A. Frazer *et al.*, *Nature* **448**, 1050 (2007).
41. D. R. Beier, *Mamm. Genome* **11**, 594 (2000).
42. E. R. Mardis, *Annu. Rev. Genomics Hum. Genet.* **9**, 387 (2008).
43. T. J. Albert *et al.*, *Nat. Methods* **4**, 903 (2007).
44. E. Hodges *et al.*, *Nat. Genet.* **39**, 1522 (2007).
45. Supported by NIH grants U01 MH61915, R01 MH078024, and P50 MH074924 (Silvio O. Conte Center) to J.S.T., Takeda Research grant 07-030R to K.S., and NIH National Research Service Award F32 DA024556 to V.K. J.S.T. is an Investigator in the Howard Hughes Medical Institute.

## Supporting Online Material

www.sciencemag.org/cgi/content/full/322/5903/909/DC1 Table S1

10.1126/science.1158822

## PERSPECTIVE

# Biology, Politics, and the Emerging Science of Human Nature

James H. Fowler\* and Darren Schreiber

In the past 50 years, biologists have learned a tremendous amount about human brain function and its genetic basis. At the same time, political scientists have been intensively studying the effect of the social and institutional environment on mass political attitudes and behaviors. However, these separate fields of inquiry are subject to inherent limitations that may only be resolved through collaboration across disciplines. We describe recent advances and argue that biologists and political scientists must work together to advance a new science of human nature.

Aristotle is credited with being the first political scientist. In his work *The Politics* he carefully describes the constitutions of a number of different city-states, starting a science of political institutions that would last thousands of years. But he is also known for first asserting the biological uniqueness of human political behavior with his famous observation: “Man is, by nature, a political animal” (1).

It has not been easy for us to follow in his footsteps. In the past 50 years, biologists have learned a tremendous amount about human biology and its genetic basis. At the same time, political scientists have been intensively studying the effect of the social and institutional environment on political attitudes and behaviors. However, biologists and political scientists have been working largely in isolation of one another. Little cross-disciplinary work has been done.

This must change for two important reasons. First, recent evidence is making it increasingly clear that genetic variation plays an important

role in explaining variation in human political behavior. Second, additional evidence in neuroscience indicates that the human brain may be adapted particularly to solve social problems that are explicitly political. Much of this evidence is associational, and we therefore should be cautious in using it to build causal theories. However, if the need for sophisticated social cognition drove the evolution of the human brain (2), then a new science of human nature will require comprehending human biology in a sociopolitical context.

## Genes and Politics

Since at least the middle of last century, theories about political attitudes and behavior have focused almost exclusively on information about peer and parental socialization, socioeconomic factors, and political institutions. Although political scientists have made progress on important questions, their models have become burdened with dozens of ad hoc theories, and they usually fit poorly to the data (3). For example, one prominent model of voter participation includes 32 variables but accounts for only 31% of the variance in turnout behavior (4). Moreover, the theories underlying these empirical models typically

ignore genetic or biological factors that might be responsible for the remaining variation.

Unbeknownst to most political scientists, psychologists and behavioral geneticists began using twin studies in the 1980s to study variation in social attitudes, and these studies suggested that both genes and environment played a role (5). However, this early work did not specifically pursue the question of whether political orientations were heritable, and political scientists remained largely unaware of the heritability of social attitudes until 2005. In that year, the *American Political Science Review* published a reanalysis of political questions on a social attitude survey of twins that suggested that liberal and conservative ideologies are heritable (6). Follow-up studies showed that genes did not play a role in the choice of a political party (6, 7), thereby supporting a core finding in the study of American politics that the choice to be a Democrat or a Republican is largely shaped by parental socialization (8). However, other studies showed that the decision to affiliate with any political party (and the strength of this attachment) are significantly influenced by genes (9, 10).

These initial twin studies suggested that political ideas are heritable, but they said little about political behavior. That changed this year, when a study (11) examined the heritability of voter participation by matching publicly available voter registration records to a twin registry in Los Angeles (12), analyzing self-reported turnout in the National Longitudinal Study of Adolescent Health (Add Health), and analyzing other forms of political participation. In all three cases, both genes and environment contributed significantly to variation in political participation (Fig. 1).

Other scholars wondered whether there might be similar variation in basic economic behavior. For example, they administered a “trust” game to twins in the United States and Sweden in which one (anonymous) subject decides how much to “invest” in another subject, the amount invested

Department of Political Science, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA.

\*To whom correspondence should be addressed. E-mail: jhfowler@ucsd.edu

is tripled by the researcher, and the recipient decides how much to return to the investor. They found that the behavior of both the investor and the recipient was significantly heritable, which suggests that genetic variation contributes to variation in cooperative behavior in the laboratory (13). Similar behavioral economics experiments have also indicated that altruism (14), bargaining (15), and attitudes toward risk (14) are heritable, and that variation in these traits plays an important role in political behavior (16, 17).

These studies suggest that heritable factors are involved in political behavior and cooperation more generally, but they say nothing about which genes might play a role. Scholars therefore have turned their attention to specific genes that might be associated with political behaviors and attitudes, particularly those that affect the regulation of neurotransmitters. Dopamine and serotonin have been studied for several years and have been shown to influence social behavior in both animals and humans, so early work on politics has been directed at genes that affect their regulation (18, 19). A direct association was recently established between voter turnout and the monoamine oxidase A (*MAOA*) gene, as well as a gene-environment interaction between turnout and the serotonin transporter (*5HTT*) gene, among those who frequently participated in religious activities (18). In other research, scholars have also found an association between voter turnout and a dopamine receptor (*DRD2*) gene that is mediated by a significant association between that gene and the tendency to affiliate with a political party (19). This work is preliminary and replication will be crucial, but it suggests that neurotransmitter function has an effect on political behavior. Future studies will also need to investigate whether genes influence political behavior predominantly through neurotransmitters and other cellular-level processes; through larger-scale differences in brain structure, function, or connectivity; through broader psychological constructs such as personality (20); or through a complex mix of all three (21).

### Neurobiology and Politics

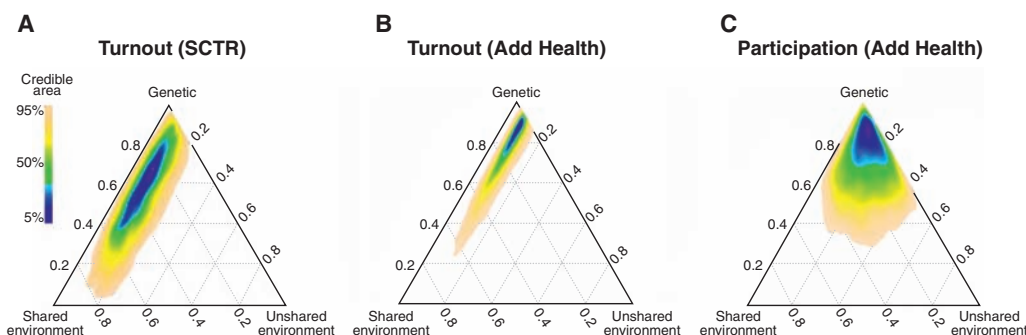
The genetic evidence so far has been about variation in political behavior, but there is also a stable core to this behavior that differentiates humans from other species. Synthesizing five decades of research, psychologists have recently identified a motivational basis for the stable, definitional core of conservative ideology, claiming that it is adopted in part to satisfy a variety of social, cognitive, and psychological needs (22).

Like our primate cousins, we are naturally adept at a variety of skills needed to navigate the everyday politics of our social species. However, although young humans appear to perform at a level similar to orangutans and chimpanzees in tasks involving technical problem solving, humans are far more sophisticated when it comes to social tasks (23).

It is easy to imagine that politics is just a cognitive exercise, like learning math or history in elementary school. However, neuroimaging evidence suggests that politics is not like subjects taught in the classroom. Instead, politics may be

parietal cortex and posterior cingulate, is active while we implicitly evaluate the social environment around us and is also implicated in emotional processing.

When people who are knowledgeable about national politics are asked for judgments of political issues or to attend to faces of national political figures, they increase the level of activity in the default state network above the resting baseline; such findings suggest that political thinking is akin to social cognition (Fig. 2) (24, 28). Politically sophisticated subjects—both Republicans and Democrats—are using the same brain



**Fig. 1.** Political participation is heritable. Ternary plots show estimates from a twin study model of (A) voter turnout among subjects in the Southern California Twin Registry (SCTR), (B) voter turnout among subjects in the National Longitudinal Study of Adolescent Health (Add Health), and (C) political participation among subjects in Add Health (an index that includes contributing money to a campaign, contacting a public official, running for office, or attending a rally or march). An additive genetic model uses identical and fraternal twin covariances to decompose the variance of a trait with respect to genetics, shared environment, and unshared environment factors. Colors indicate probabilities. The blue areas indicate the regions that are most likely to contain the true estimates; the beige areas indicate the region of 95% confidence (i.e., the probability that the true coefficients lie outside the colored regions is  $P = 0.05$ ). Mean contribution of the genetic factor is estimated to be 53% for SCTR turnout, 72% for Add Health turnout, and 60% for Add Health participation (11).

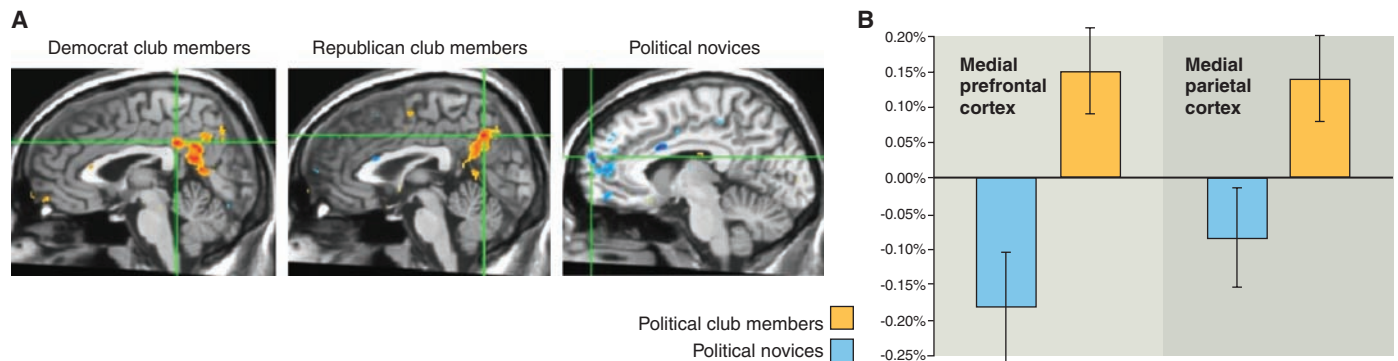
a form of social cognition that we have called “playground cognition” (24). On the playground, we are figuring out whom to cooperate with and whom to avoid; we are cognizant of social hierarchy; and we engage in coalitional cognition, knowing that an alliance with one group will entail exclusion from another. Even at rest on the playground, we are constantly monitoring our social environment and our place in it.

Neuroscientists have been studying a network of brain regions that diminishes in activity when subjects are engaged in a wide variety of technical cognitive tasks (25). One puzzle with this resting or “default state” network is that it consumes a large portion of the brain’s metabolic budget and yet appears to deactivate under many conditions of active cognition. Meanwhile, when people make personal moral judgments (26) or observe social interactions (27), this network of brain regions increases in activity above the resting baseline. One component of this network, the medial prefrontal cortex, appears to be involved in thinking about the mental states of others. Another region, the medial

regions when they think about national politics. However, people who do not know much about national politics actually deactivate this set of brain regions, as if they had to treat these political questions as a form of technical cognition. We would not expect political novices to have some fundamental impairment on the playground. Instead, they appear to be merely unfamiliar with the specific domain of national politics. In contrast, people with autism spectrum disorders do appear to be generally unable to use their default state network properly (29, 30), and although some of them are able to perform very well in the classroom, they struggle with the social cognition skills demanded on the playground.

### The New Science of Human Nature

Large-scale political behavior is an extremely recent phenomenon in the span of human evolution, but the initial evidence suggests that it relies on genetic and neural mechanisms that evolved to solve basic social problems. These problems are inherently political because they involve decisions about the organization of humans to achieve group goals and the distribution



**Fig. 2.** Politics is a form of playground cognition. **(A and B)** When both college Democrat club members [(A), top left; cross-hairs at (2, -42, 33) with  $z = 3.94$ ] and college Republican club members [(A), top right; cross-hairs at (1, -65, 37) with  $z = 3.90$ ] answer questions about national politics, they demonstrate increases (colored orange and red) in the blood oxygen level–dependent functional magnetic resonance imaging (BOLD fMRI) signal above a resting baseline in the medial prefrontal cortex [(B), left; 4-mm spherical region of interest (ROI) centered at (-8,

59, 21)] and the medial parietal cortex [(B), right; 4-mm spherical ROI centered at (2, -64, 30)], brain regions that are part of a resting state network that has been shown to be active during social cognition. In contrast, college students with little knowledge of national politics [(A), bottom; cross-hairs at (-7, 61, 26) with  $z = -3.55$ ] have a pattern of decreases (colored blue) in the same regions [(B), left and right]. Deactivations in this network typically occur during the kinds of technical cognition tasks performed in the classroom (24).

of resources within a group. But they are also inherently biological. For example, one of the most fundamental unanswered questions in evolutionary biology is how cooperative behavior evolved (31). If natural selection favors fit individuals, why do some individuals voluntarily reduce their fitness in order to enhance the fitness of others? Meanwhile, in political science we are focused on the nearly identical problem of collective action (32). In large-scale societies, why do people join political groups, participate in elections, and engage in other kinds of mass behavior when they know their efforts will not alter the political outcome?

Although simple forms of cooperation can be found far back in our evolutionary history, more sophisticated forms are quite recent. Evidence of political behavior in chimpanzees (33), capuchins (34), and early human societies (35) suggests that we may have, in part, evolved in ways that maximize our capabilities for small-scale interactions. But what are the biological mechanisms that enable us to cope with these small-scale interactions? And were new adaptations necessary for the development of large-scale political attitudes, behaviors, and institutions, or are we merely conserving other older tools for a new purpose?

Like Aristotle, we believe that the study of human nature should lie at the intersection of politics and biology. Whereas physiological studies on the correlation between political attitudes and biological factors can be rigorously performed on small numbers of subjects (36), political scientists are particularly adept at testing the implications of their theories in large populations (e.g., with surveys, natural experiments, and field experiments). Similarly, puzzles that arise at the population level can drive the kind of laboratory work that neuroscientists are more familiar with (37).

When Aristotle wanted to understand how humans govern themselves, he started by cataloging political institutions. Today, the study of institutions has improved our understanding of political outcomes because they help us understand how legislatures, courts, and other bodies are constrained in their behavior. Similarly, the study of genes potentially promises a better understanding of the constraints imposed on basic political psychology. The new science of human nature demands that we recognize that genes are the institutions of the human body. They regulate the neurological processes that drive social and political behavior. And we cannot fully appreciate their function in humans without understanding their role in the very complex social and political interactions that characterize our species.

#### References

- Aristotle, in *Cambridge Texts in the History of Political Thought*, S. Everson, Ed. (Cambridge Univ. Press, Cambridge, 1996).
- R. W. Byrne, A. Whiten, *Machiavellian Intelligence: Social Expertise and the Evolution of Intellect in Monkeys, Apes, and Humans* (Oxford Univ. Press, Oxford, 1988).
- J. G. Matsusaka, F. Palda, *Public Choice* **98**, 431 (1999).
- E. Plutzer, *Am. Polit. Sci. Rev.* **96**, 41 (2002).
- N. G. Martin *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **83**, 4364 (1986).
- J. R. Alford, C. L. Funk, J. R. Hibbing, *Am. Polit. Sci. Rev.* **99**, 153 (2008).
- P. K. Hatemi, S. E. Medland, K. I. Morley, A. C. Heath, N. G. Martin, *Behav. Genet.* **37**, 435 (2007).
- A. Campbell, P. E. Converse, W. E. Miller, D. E. Stokes, *The American Voter* (Univ. of Chicago Press, Chicago, 1960).
- J. E. Settle, C. T. Dawes, J. H. Fowler, *Polit. Res. Q.*, in press.
- P. K. Hatemi, J. Hibbing, J. Alford, N. Martin, L. Eaves, *Polit. Res. Q.*, in press.
- J. H. Fowler, L. A. Baker, C. T. Dawes, *Am. Polit. Sci. Rev.* **102**, 233 (2008).
- L. A. Baker, M. Barton, A. Raine, J. H. Fowler, *Twin Res. Hum. Genet.* **9**, 933 (2006).
- D. Cesarini *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **105**, 3721 (2008).
- D. Cesarini, C. T. Dawes, M. Johannesson, P. Lichtenstein, B. Wallace, Q. J. Econ., in press.
- B. Wallace, D. Cesarini, P. Lichtenstein, M. Johannesson, *Proc. Natl. Acad. Sci. U.S.A.* **104**, 15631 (2007).
- J. H. Fowler, *J. Polit.* **68**, 674 (2006).
- J. H. Fowler, C. D. Kam, *J. Polit.* **69**, 813 (2007).
- J. H. Fowler, C. T. Dawes, *J. Polit.* **70**, 579 (2008).
- C. T. Dawes, J. H. Fowler, *J. Polit.*, in press.
- J. M. Olson, P. A. Vernon, J. A. Harris, K. L. Jang, *J. Pers. Soc. Psychol.* **80**, 845 (2001).
- N. I. Eisenberger, B. M. Way, S. E. Taylor, W. T. Welch, M. D. Lieberman, *Biol. Psychiatry* **61**, 1100 (2007).
- J. Jost, *Am. Psychol.* **61**, 651 (2006).
- E. Herrmann, J. Call, M. V. Hernández-Lloreda, B. Hare, M. Tomasello, *Science* **317**, 1360 (2007).
- D. Schreiber, in *The Affect Effect: Dynamics of Emotion in Political Thinking and Behavior*, A. Crigler, M. MacKuen, G. E. Marcus, W. R. Neuman, Eds. (Univ. of Chicago Press, Chicago, 2007), pp. 48–70.
- M. E. Raichle *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **98**, 676 (2001).
- J. D. Greene, R. B. Sommerville, L. E. Nystrom, J. M. Darley, J. D. Cohen, *Science* **293**, 2105 (2001).
- M. Iacoboni *et al.*, *Neuroimage* **21**, 1167 (2004).
- D. Westen, P. Blagov, K. Harenski, C. Kiltz, S. Hamann, *J. Cogn. Neurosci.* **18**, 1947 (2006).
- M. Iacoboni, *Trends Cognit. Sci.* **10**, 431 (2006).
- D. P. Kennedy, E. Redcay, E. Courchesne, *Proc. Natl. Acad. Sci. U.S.A.* **103**, 8275 (2006).
- R. M. May, in A. M. Colman, *Nature* **440**, 744 (2006).
- E. Ostrom, *Am. Polit. Sci. Rev.* **92**, 1 (1998).
- F. B. M. de Waal, *Chimpanzee Politics: Power and Sex Among Apes* (Johns Hopkins Univ. Press, Baltimore, 1982).
- S. F. Brosnan, C. Freeman, F. B. M. de Waal, *Am. J. Primatol.* **68**, 713 (2006).
- C. Boehm, *Hierarchy in the Forest: The Evolution of Egalitarian Behavior* (Harvard Univ. Press, Cambridge, MA, 1999).
- D. M. Amodio, J. T. Jost, S. L. Master, C. M. Yee, *Nat. Neurosci.* **10**, 1246 (2007).
- M. Lieberman, D. Schreiber, K. Ochsner, *Polit. Psychol.* **24**, 681 (2003).

10.1126/science.1158188