

## Plasticity, plasticity, plasticity...and the rigid problem of sex

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Why is popular understanding of female–male differences still based on rigid models of development, even though contemporary developmental sciences emphasize plasticity? Is it because the science of sex differences still works from the same rigid models?

In recent months, a new book co-authored by best-selling author John Gray hit the shelves that, like his many other books, claims there are ‘hardwired’ differences in the brains of females and males [1]. In the news media, continuing commentary on the causes of the global financial crisis point to a testosterone-fueled finance industry that would benefit from more women, whose lower levels of testosterone make them intrinsically more risk averse (e.g., [2]). Meanwhile, on the website of the popular magazine *Psychology Today*, several evolutionary psychology blogs draw on the familiar theme of the brains of cavemen, and cavewomen, to explain contemporary gender relations (e.g., *Homo consumericus* and *Evolutionary Entertainment*, accessible from <http://www.psychologytoday.com/topics/evolutionary-psychology>).

Curiously, the scientific ideas implicit in these popular understandings have long been left in the dust: assumptions that brain circuitry is largely fixed by a genetic blueprint, that there is a unidirectional, causal pathway from genes to behavior via hormones and brains, and that evolution has left us with brains and mental processes strongly reminiscent of our Paleolithic ancestors, have been widely rejected following conceptual and empirical upheavals in the relevant scientific fields.

It is now clear that the functional and even structural organization of the human nervous system is a continuous and dynamic process that persists throughout one's life. ‘Experience-dependent plasticity’ has been demonstrated time and again in the acquisition of skills as wide ranging as musical performance, basketball, dancing, taxi driving, and juggling (reviewed in [3]).

Behavioral neuroendocrinology has been transformed by an increasingly large body of research demonstrating the power of an individual's behavior, the behavior of others, and aspects of the environment to influence brain and behavior through reciprocal modulation of the endocrine system (see [4]). Steroid (and other) hormones, such as testosterone, have come to be regarded as key mediators of behavioral plasticity, enabling animals to be responsive to key environmental characteristics in both the short and long term [5]. In addition, although certain steroids (especially testosterone and estrogen) continue to be characterized as ‘sex hormones’ by both popular and scientific convention, the notion that these steroids affect the brain in a way that is more or less bifurcated by sex is challenged by the complexity of the endocrine system. For example, both circulating levels of testosterone and receptor responsivity are modulated by behavior and social context [4 and 5], and women appear to get more ‘behavioral bang’ for their ‘hormonal buck’ [6]. In line with a complexity that rules out simple dimorphic relations between ‘sex hormones’ and behavior, assumptions of causal links between high absolute levels of testosterone and masculine characteristics have often not been supported by the data [7]. Meanwhile, subfields within human evolutionary behavioral science, as well as data from developmental neurobiology, have strongly challenged the major tenets of the evolutionary psychology view that, as Cosmides and Tooby [8] put it, ‘[o]ur modern skulls house a Stone Age mind’, arguing a more prominent role for culture in both evolution and individual development, consistent with contemporary accounts of neurodevelopment, and human behavioral diversity (e.g., [9]).

These conceptual changes clearly complement and resonate across the three fields. Humans have evolved an adaptively plastic brain that is responsive to environmental conditions and experiences, and the modulation of endocrine function by those experiential factors contributes to that plasticity. Why, then, do popular understandings of female/male behavior as rooted in a biological core remain entrenched in scientific ideas characteristic of the previous century? Is it, in part, because the sex/gender science within these three fields is similarly entrenched?

The major account of sexual differentiation of the brain, brain organization theory, still posits that prenatal hormones give rise to (or ‘hardwire’) permanent structural and functional sex differences, despite considerable and long-standing evidence that early hormonal effects are not permanent (see [10]). In functional neuroimaging, investigation of experience-dependent plasticity has only rarely been applied to the emergence, maintenance, and plasticity of gendered behavior (e.g., [11]). Instead, studies tend simply to compare the biological sexes, as though the implicit aim were to identify fixed, universal female versus male signatures [12]. Similarly, investigations of female/male differences in ‘sex hormones’ and social behavior are often correlational, with analyses implying that hormonal level is a ‘pure’ biological and causally primary variable, rather than taking into account the fact that biological factors are ‘entangled’ with the individual’s social history and current social context (see [13]). In addition, in evolutionary psychology investigations of female–male differences, it tends to be left to researchers outside the field to identify the environmental and cultural factors that are important in moderating supposedly ‘universal’ sex-related preferences (see 9 and 14).

Feminist critics of each research domain have repeatedly noted that it is not only that the outputs of such science contribute to unwelcome and scientifically unjustified cultural understandings of female–male relations as fixed, inevitable, and ordained by nature, but also that such science itself is flawed and unenlightening 10 and 12. An understanding of gender as a complex, multilevel, hierarchical structure that shapes not only institutions, inter-relations, cognition and perception, but also the brain, endocrine system, and the manifestation of evolutionary processes, can bring about better and more informative science. Happily, there are growing examples of this. Take, for instance, a large-scale longitudinal study that found that fatherhood reduced testosterone levels in men, and more so in fathers who spent more time in the physical caring of their young offspring [15]. This complements findings from a comparison of two neighboring cultural groups in Tanzania, which found lower testosterone levels among fathers from the population in which paternal care was the cultural norm compared with fathers from the group in which paternal care was typically absent [16]. Together, these studies show how the social construction of gender roles for fathers modulates endocrine state.

The relations between science and society are two-way. Scientists who work in politically sensitive and important areas have a responsibility to recognize how social assumptions influence their research and, indeed, public understanding of it. Moreover, they should also recognize that there are important and exciting opportunities to change these social assumptions through rigorous, reflective scientific inquiry and debate.

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