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The New Science of Sex Difference

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Abstract
While scientists across the academy have abandoned the nature/nurture dichotomy, evidence for the influences of society on our biology is greater than ever. This article reviews new developments in the biological sciences – in the sub-fields of genetics, hormones, and neuroscience – with special attention to the implications for sociologists interested in gender. The article closes with an argument that embracing these developments has both theoretical and methodological promise and can enhance rather than harm research and activism regarding gender equality and other social hierarchies.

> … any living cell carries with it the experience of a billion years of experimentation by its ancestors. You cannot expect to explain so wise an old bird in a few simple words.
> – Max Delbrück (1949a,b)

In the early 1800s a French biologist named Jean-Baptiste Lamarck, working on the question of what would someday be called "evolution," proposed that individual animals could pass on acquired as well as inherited traits to their offspring (Bowler 2003). That is, adjustments an organism made to its environment during its life could somehow appear in the biological building blocks of the next generation. His most famous example involved the neck of the giraffe, a feature that bewildered early scientists. Lamarck theorized that each generation of giraffes stretched their neck to reach higher and higher leaves, passing on a slightly longer neck than they had inherited themselves. Likewise, Lamarck speculated, the traits that humans developed over the course of their lives could be inherited by their children. For example, if a man became strong, his children would be born with a greater predisposition for large muscles; if a woman became educated, she would pass onto her children heightened intellectual potential.

After Darwin, this model of evolution fell out of favor. In its place was the theory of natural selection: evolution works not through organisms actively responding to the environment, but through random genetic variation and the failure of the maladapted to reproduce. The idea that we could change our genes during our lives and pass on a different genome than the one we inherited came to seem laughably naïve.

Emerging research now suggests that Lamarck was onto something. Indeed, our understanding of biology and its relationship to the phenomena of interest to sociologists – cultural ideas, social interaction, and social structures – is undergoing a paradigmatic change (Silverman 2004; Strohman 1997). In this essay I review three biological bases of sex difference and similarity – genes, hormones, and brains – and explore the new research that shows how each mechanism interacts with the socio-cultural context. I conclude by joining the call to reorient our relationship to the life sciences (e.g., Bearman 2008; Franks 2010; Freese et al. 2003; Mazur 2005; Udry 1995). These developments should inspire us to further develop research programs that take advantage of the interaction of biology and society. Engaging with the biological sciences in this way need not naturalize inequality, though this is an outcome against which we must be vigilant, but rather can offer social scientists stronger tools with which to identify, criticize, and eliminate mechanisms of oppression.

How sexually dimorphic are humans?

Perhaps the most important thing to understand when approaching contemporary research on sex differences and similarities is that men and women are overwhelmingly alike. When we consider the full range of biological adaptations to sexual reproduction, humans are not particularly sexually dimorphic. Some species show dramatic differences between males and females in appearance; we do not. Moreover, because we are not particularly dimorphic in appearance, we should expect significant overlap in our abilities and interests, considering that morphological sexual dimorphism correlates with divisions of labor.

In fact, meta-analyses aimed at summarizing the literature on human sex differences and similarities in traits, personality, cognitive abilities, sexuality, temperament, and motor skills offer better evidence for similarity than difference, even in the face of cultural and social structural forces that reflect a gender binary (Else-Quest et al. 2006; Hyde 2005; Petersen and Hyde 2010; Wallentin 2009). On 30 percent of variables scientists have found no compelling evidence gender difference; on an additional 48 percent of variables, scientists have documented a small difference (one for which 54–64 percent of one sex scores better than 50 percent of the other). Together, these included reading comprehension and abstract reasoning; talkativeness, likelihood of self-disclosing to friends and strangers, tendency to interrupt others, and assertiveness of speech; willingness to help others, negotiation style, approach to leadership, and degree of impulsiveness; self-esteem, symptoms of depression, coping strategies, life satisfaction and happiness; vertical jumping ability, overall activity levels, balance, flexibility; willingness to delay gratification and attitudes about cheating; likelihood of wanting a career that makes money, offers security, is challenging, and brings prestige; and some measures of sexual attitudes and experiences (e.g., disapproval of extramarital sex, levels of sexual arousal, and sexual satisfaction).

Scientists document medium-sized gender differences (one for which 65–74 percent of one sex scores better than 50 percent of the other) on 15 percent of variables and large or extra large differences (where at least 75 percent of one sex scores better than 50 percent of the other) on the remaining eight percent. The largest gender differences were for some measures of physical ability, especially throwing, and some measures of sexuality, including masturbation incidence and likelihood of approving of casual sex. In addition, two traits show very strong sexual dimorphism: sexual identity (most men identify as male and most women identify as female) and sexual object choice (most men are sexually interested in women and most women in men) (Hines 2009).

Rebecca Jordan-Young (2010) argues that these data establishing sex differences and similarities should be thought of not as evidence of an unchanging reality, but as a mere snapshot of what is really a moving target. Indeed, most of these differences and similarities grow or shrink as we look across time, across cultures, or within subcultures in a given country (Else-Quest et al. 2010; Wood and Eagly 2012). Likewise, the results of many tests can be easily manipulated in the laboratory, revealing that context, framing, priming, instruction, practice, and other mechanisms all influence subjects' performances (Cherney 2008; Fine 2010).

Nevertheless, we *are* a species that reproduces sexually and, so, there are biological differences between men and women. In this paper, I review three areas of inquiry in which scientists have documented clear biological differences between men and women: genetics, hormones, and brain structure and function. In each case I review the differences that have been established through replicated research on humans and then offer an overview of our emerging understanding of how these biological processes interact with the socio-cultural environment.

Genes and gender

Overview

Scientists divide the genetic contribution to sex differences into three types of influences: sex-linked, sex-limited, and sex-influenced. Sex-linked traits refer to those that are influenced by the fact that genetic males and females have different sex chromosomes (XY and XX, respectively). Although the fact that men, but not women have a Y chromosome seems a likely candidate for a cause of difference, scholars largely agree that the Y chromosome does little other than give XY fetuses testes and facilitate the adult male's fertility (Craig et al. 2004; Hawley and Mori 1999).

Women's two X chromosomes are a more significant contributor to sex difference, primarily by making females less vulnerable to chromosomal conditions. Since people (e.g., men) need only one X to survive, most cells in a genetic female will include one deactivated X (in about 50 percent of the cells it is the maternal X, the other 50 percent, the paternal). In this sense women are similar to men – they both have only one functioning X chromosome in each cell – but women have the advantage of having a "back up" in the case of a defective gene on the X chromosome. If one fails, the other mediates or eliminates the negative effect. Genetic men, then, are more vulnerable to problems caused by defective Xs. Relatedly, if a trait carried on the X chromosome is recessive, than men will be more likely to show it, since they only need to inherit one recessive gene to express the trait, whereas women need to inherit two. Color blindness and hemophilia are examples of X-linked recessive traits seen more commonly in men.

Sex-linked traits are the most obvious source of sex differences because men and women have different sex chromosomes, but genes on other chromosomal pairs are relevant too. Some are sex-limited, meaning they are only expressed if they are in a male or female body. The genes governing lactation, allowing a woman to produce milk for an infant, are carried by both men and women, but they are usually expressed only in mothers. Likewise, a common developmental problem, undescended testes, is genetic, but does not cause trouble for women.

A final set of genes, called sex-influenced, do different things in male and female bodies. It is this type of gene that explains why men are more likely to go bald. The baldness gene only has a strong influence on phenotype in the presence of high levels of testosterone, so most women who carry the gene do not show signs of baldness. Another example involves our singing voices. The same genes that produce an especially high voice in women cause a particularly deep voice in men.

Genetic influences, then, set us on paths to have male or female bodies and contribute to some differences between men and women. The new science of genetics, however, has revealed that the "blueprint" metaphor in which genotypes dictate phenotypes has turned out to be wholly insufficient for understanding how genes work, and this has significant implications for thinking about the relationship between genes and gender.

Gene/environment interactions

Anticipating the mapping of the human genome, entrepreneurs in the late 1990s and early 2000s devised businesses that would capitalize on the linking of genes to desirable and undesirable traits. Upon completion of the project, however, these entrepreneurs would find themselves largely stymied (Silverman 2004). The one-gene/one-outcome mechanism that applies to certain diseases turns out to be the exception, not the rule.

For one, we have learned that our developmental processes are replete with redundancies. ''Knockout'' studies, in which seemingly-essential genes are removed in order to discern their impact, often result in no developmental difference at all (Keller 2000). Instead, genetic harm usually has to be widespread or present in several different parts of the genome simultaneously in order to have an impact on phenotype. Explained geneticist Mario Capecchi: ''… the organism has choices … If a problem is encountered, the thing has to figure out a solution. Sometimes the solution is fantastic, other times it is less so … If we didn't have extensive overlap and redundancy in our genome, we wouldn't be here at all'' (quoted in Keller 2000, 112).

Genes are also dynamic in that they shape our development in response to information. Both the immediate biochemical environment of our cells and the environment outside our bodies are important determining factors. In other words, what our genes do is heavily influenced by what happens to and around us. As Rebecca Jordan-Young (2010, 271) explains: what is ''written in our genes'' is a ''very open-ended story.'' In fact, 95 percent of our genes do not encode for proteins at all. Instead, our genes are about 5 percent story (genes that actively code for proteins) and 95 percent storyteller (chemical molecules put on our DNA that influence how genes will be used) (see also Meaney 2001). Because a single gene can encode for up to tens of thousands of different proteins, genes do not lead unidirectionally and deterministically to straightforward outcomes.

The instructions communicated to our ''story'' genes from our ''storyteller'' markers are called epigenetic tags. These change our expressed genome over the course of our lives. Even genetically-identical twins become both genotypically and phenotypically different over time; they do not necessarily develop the same diseases or continue to look alike (Fraga et al. 2005; Poulsen et al. 2007; Wong Albert and Petronis 2005). If one twin is schizophrenic, for example, a condition shown to be strongly related to genetics, the other twin is diagnosed with the mental illness only 50 percent of the time (Gottesman 1991).

These developments in research on genetics have implications for both individual and group level phenomena. Some genetic profiles, for example, increase the risk that a child will be a violent adult, but only if that child is exposed to violence when they are young (Jacobson 2009). Living in a happy home with loving parents decreases the likelihood that a person genetically predisposed to aggression will become aggressive. In contrast, poverty, a dysfunctional family life, and suffering child abuse all increase the chances that the genes for aggression will be ''turned on'' and lead to violent behavior. Genes matter: a person without a genetic predisposition for violence probably will not grow up to be violent, even if they suffer trauma (Cadoret et al. 1995). A person with the genetic predisposition may or may not; it all depends on the quality of her life.

If poor, urban, racial minorities disproportionately find themselves in violent neighborhoods, we should expect them to exhibit more violence than they otherwise would and more violence than genetically-similar youth who are not exposed to violence. Boys and men, insofar as they are more likely to experience or be recruited into violent activities, may end up more violent than girls. In other words, even if the genetic predisposition for violence is equally prevalent across two groups, we may see higher rates of violence in one because of asymmetries in the social structure. Meanwhile, generations of exposure may exacerbate the relationship between biology and society as violent adults are more and more likely to expose their own children to violence, with no underlying change in the population genome. Genetic similarities, then, can nevertheless result in group-level behavioral differences.

While most of the epigenetic tags that change our genome over the course of our lives are erased in the early development of our offspring, some are not (Reik and Walter 2001). This is where Lamarck's giraffe hits close to the mark. Parent *can* pass on to their descendents some of the changes to their genomes caused by the environments in which they lived. Genes silenced in response to limited food supply, for example, have been found in the grandchildren of men and women who suffered through famine, contributing to higher rates of death from cardiovascular disease and diabetes (Pembrey et al. 2006). Adding another layer of complexity, there is some evidence that erasure and maintenance of imprinted genes works differently in chromosomes inherited from the mother versus the father, a phenomenon called parental imprinting.

In sum, our genome is designed to dynamically respond to life events. The geneticist Richard Strohman (1997) warns us not to underestimate this flexibility. The role of epigenetics in multiplying the sheer possibility of outcomes is, he writes, "transcalculational, a mathematical term for mind boggling" (p. 197). A single gene can do many (unpredictable) things at different times during development or may control multiple different phenotypical phenomena (called pleiotropy). Different genes can produce similar outcomes (phenogenetic equivalence) and no one gene is necessarily required for any given outcome (due to genetic redundancy). Evelyn Fox Keller (2000, 137–8) goes so far as to say: "… our new understandings of the complexity of developmental dynamics have critically undermined the conceptual adequacy of genes as *causes* of development." Even "the question of what genes are *for*," Keller continues, "has become increasingly difficult to answer."

Hormones and gender

Overview

Hormones are messengers in our chemical communication system. Released by glands or cells in one part of the body, they carry instructions to the rest of our body. All human hormones circulate in both men's and women's bodies, but some of them do so in different proportions. Men tend to have higher levels of androgens and women higher levels of estrogens. The relationship between hormone level and observed difference, however, is not straightforward; men seem to be insensitive to wide variations in testosterone levels (between 20 percent and 200 percent of normal), while women have been shown to be sensitive to smaller changes, making it possible for women to experience an equivalent effect with a smaller amount of hormone (Archer 2006; Sapolsky 1997; Wood and Eagly 2012; Yates et al. 1999). In short, the colloquial terms "male hormones" and "female hormones" are misnomers.

It is equally incorrect to say that androgens and estrogens are masculinizing and feminizing hormones. Research on animals shows, for example, that estrogen and testosterone sometimes perform identical functions and estrogens can have masculinizing effects (Hines 2009). So, just as we are not "opposite sexes," our hormones are far from opposite in their chemical structure, presence, or function. Still, men and women do vary in their hormonal profiles and these differences have different effects at different stages of development.

Scientists divide the influences of hormones into organizational and activational effects. Organizational effects are those that occur early in life: before or shortly after birth. These are generally more permanent than the activational effects of hormones. They include, for example, the development of masculine and feminine internal and external genitalia during fetal growth and they may have an organizational effect on the brain, producing some of the differences reviewed in the next section (for a measured review, see Jordan-Young 2010). The remainder of this section will focus on activational effects.

Activational effects occur throughout life, producing changes that often last only so long as the hormone is present. The common phrase ''adrenaline rush'' suggests that experience can invoke a hormonal response. In fact, our bodies can be flooded with adrenaline in a mere instant, a physical change that can be entirely reversed in the space of two minutes. Similarly, estrogens and androgens have been shown to have several differential activational influences on men and women. I offer three examples below.

First, research shows that testosterone, an androgen, is strongly related to sex drive in both women and men and may be weakly related to physical aggression in men (Book et al. 2001; Hines 2009; Mazur and Booth 1998). Since men have more free testosterone than women, this might have some influence on why men, on average, have higher levels of aggression and sex drive than women (Baumeister et al. 2001). Notably, higher levels of estrogen is also associated with dominant behavior in women, a reminder that so-called ''female hormones'' can have masculinizing effects (Stanton and Edelstein 2009).

Second, testosterone levels correlate with visual-spatial ability, a cognitive skill that shows a robust sex difference (Halpern 2012). Very high and very low levels of testosterone are correlated with poor ability, so high-testosterone women and low-testosterone men do best on visual-spatial tests because they both fall into the middle range. As men's and women's hormones fluctuate, their performance on tests fluctuates as well; women score better right before ovulation (when their testosterone levels are highest) and men in the Western hemisphere score better in the spring (when their levels are lowest). All of these differences are quite small, however, and have not been shown to have consequences outside of the laboratory (Hines 2009; Klebanov and Ruble 1994).

Third, there is good evidence that the hormone cycles that regulate women's menstrual cycles correspond to mild changes in libido, partner choice, interest in extrapair copulation, and mood, with a decrease in positive feelings just prior to menstruation (Halpern 2012; Oinonen and Mazmanian 2001). Men experience hormone fluctuations as well, on both daily and seasonal cycles. Interestingly, in relation to mood, studies of mood fluctuations in men find that they are just as emotionally ''unstable'' as women (McFarlane and Williams 1994; McFarlane et al. 1988). These mood swings are small in both men and women. Hormones are a relatively minor force in determining our mood compared to even mundane life events (e.g., whether it is Monday morning or Friday afternoon) (Fausto-Sterling 1992).

We have good data, then, that levels of circulating hormones correlate with sex differences, but it is a mistake to divide hormones and mood or behavior into independent and dependent variables. Instead, the production of hormones in our bodies is closely tied to the real and imagined experiences we have with others. That is, hormones are one way that society ''gets under the skin'' (Taylor et al. 1997).

Hormone/environment interactions

Hormones can be thought of, in part, as mechanisms of social interaction. They enable us to respond emotionally to interactions, contributing to feelings of love, the desire to nurture, stress, happiness, and the flight or fight reaction. To illustrate our chemical response to social interaction, I will use the example of testosterone, primarily in men.

Like other hormones, testosterone rises and falls in response to our experiences. Levels in men rise in anticipation of playing competitive sports; they rise further in men who win and decline in men who lose (Booth et al. 1989, 1999; Nisbett and Cohen 1996; Sapolsky 1997). This is not only true for physical activity, but also primarily mental games like chess, symbolic activities like video games, and vicarious competitive experiences such as watching sports on television (Bernhardt et al. 1998; Mazur et al. 1992, 1997; van der Meij et al. 2012). Testosterone increases, as well, in response to status acquisition and display. Driving a sports car produces an increase in testosterone; driving a sports car in front of other people produces a greater increase (Saad and Vongas 2009).

Men's testosterone levels also respond to life changes. They decline, for example, when they are in close relationships with women and if they become parents, but only if they are actively involved with their children (Alvergne et al. 2009; van Anders and Watson 2007; Booth et al. 2006; Gettler et al. 2011; Mazur and Michalek 1998; Storey et al. 2000). This phenomenon has been found at the group as well as the individual level. The average testosterone levels of fathers in societies that normalize involved parenting is lower than the average testosterone levels in societies that do not (Muller et al. 2009).

In addition to shaping our responses to social interaction, hormones are impacted by our place in the social structure. Being suddenly positioned below others in a social or organizational hierarchy, such as starting boot camp, correlates with a drop in testosterone that can last a few weeks (Kreuz and Rose 1972; Thompson et al. 1990). Likewise, correlations of testosterone with the emergence of conduct disorders in boys are much stronger when their friends regularly engage in deviant behavior (Rowe et al. 2004). This may be because, while testosterone facilitates an aggressive response when aggression is called for, it facilitates other types of responses, such as sociality, when threat is low (Booth et al. 2006; Bos et al. 2012). In all cases, interpersonal and social structural factors, such as marriage, employment, and middle- or upper-class status, mediate the role of testosterone in antisocial behavior (Booth and Wayne Osgood 1993; Dabbs and Morris 1990).

Importantly, many of the phenomena that cause a change in testosterone levels are not, in themselves, biologically rewarding or punishing. Instead, they are socially constructed "wins" that affect our bodies because we have collectively decided that they are important. We are thus designed to respond chemically not only to objective things in the world, but to anything we make meaningful. In other words, social constructions are embodied through the chemicals our glands produce, which in turn influence our moods and behaviors.

Hormones, then, are not part of a biological program that influences us to act out the desires of our ancestors. They are a dynamic part of our biology designed to give us the ability to respond to the physical, social, and cultural environment.

Brains and gender

Overview

The idea that male and female brains may have different strengths and weaknesses is part of brain organization theory. Scientists have documented quite a few small average sex differences in brain anatomy (e.g., the size and shape of its parts), composition (e.g., characteristics of the tissue), and function (e.g., rate of blood flow, metabolism of glucose, and neurotransmitter levels) (Halpern 2012; Hines 2009). Scientists have also discovered differences in size and tissue ratios. Women have smaller brains (largely explained by their overall smaller size) and men and women have different ratios of white matter (brain tissue responsible for sending and receiving information) to gray matter (brain tissue responsible for information processing) in some regions. New meta-analyses find no evidence for a difference in lateralization, whether a person uses one side of their brain more than the other; both men and women are "whole-brained," though they both tend to be left dominant (Pfannkuche et al. 2009; Sommer et al. 2008).

Sex differences in the brain may be initially and partially caused by the different hormone profiles of developing fetuses and elevated levels of hormones during the first 6–12 months of life, but the source and meaning of these average differences between male and female brains is still uncertain (Halpern 2012; Hines 2009, 2011; Jordan-Young 2010). In other words, scientists have largely failed to connect these differences to any observed strengths and weaknesses in men and women. Even establishing simple correlations between brain differences and differences in behavior, skills, or interests has been largely unsuccessful. This is likely explained, in part, by brain plasticity, our brain's ability to respond to the environment.

Brain/environment interactions

Newborns do not immediately have the neural capacity to make sense of their environment. We are not, for example, born with the ability to process sight, sound, and touch. Instead, our brain has to learn how to interpret data from our senses. Because of this, even when we have technologies that substitute for sensory dysfunction, like the cochlear implant, individuals must train their brains to be able to use them (Moore and Shannon 2009).

Brain plasticity means, however, that a person with a sensory deficit may learn to use the part of the brain originally allocated for that task to do something else. They sometimes take stronger advantage of other brain functions and senses that they do have. In some instances, people can teach the brain to do remarkable things. A boy named Ben Underwood, for example, who lost his sight at the age of three, trained his brain to echolocate, allowing him to deftly skateboard through crowded streets (Rigby 2006).

Brain plasticity has taught us that the brain requires input for it to organize itself in a useful manner, but also that it can be organized in many different ways. Further, we now know that the brain can adopt a sort of functional plasticity by which it can produce the same outcome via different strategies (Halpern 2012). Studies of brain function, for example, have found gender differences in the cognitive strategies used by men and women matched for mental rotation ability (Jaušovec and Jaušovec 2012) as well as sex differences in the brain regions used to retrieve emotional memories, but no sex difference in the quality of men's and women's memories or the degree of emotion expressed (Piefke et al. 2005). Likewise, neither brain size nor the gray/white ratio differences have yet to correlate with any observed difference in intelligence (Halpern 2012).

So, differences in the brain may not produce differences in traits or abilities. Instead, the brain may have multiple strategies for achieving the same outcome (De Vries and Södersten 2009; McCarthy et al. 2009). Alternatively, one difference in the brain (such as neurotransmitter function) might exist specifically to compensate for another difference (such as proportion of gray to white matter). In regard to gender, neuroendocrinologist Geert De Vries (2004, 1064) writes that differences between men's and women's brains might produce male- and female-typical outcomes, but they may "just as well do the exact opposite, that is, they may prevent sex differences in overt functions and behaviors by compensating for sex differences in physiology.''

While our brains are most plastic during development and early childhood, they continue to change over the entire lifespan in response to whatever challenges and opportunities we give them (Halpern 2012; Jordan-Young 2010). Neural re-organization has been documented in response to engaging in activities such as juggling, dancing, singing, meditating, and even driving a taxi (Taubert et al. 2010). Even our most reliable differences in cognitive skills respond to training. Consider the example of mental rotation, the ability to imagine an object turning in your mind (Geiser et al. 2008). This sex difference is a large one; in any given experiment, the average man does better than 72–75 percent of women (Hyde 2005; University of Medicine and Dentistry of New Jersey nd). Mental rotation is also one of the few observed sex differences for which we have some evidence of a biological foundation (Jordan-Young 2010; Puts et al. 2008) and it has been demonstrated in infants (Moore and Johnson 2008; Quinn and Liben 2008).

Despite the robust nature of this finding, the difference between men's and women's mental rotations can be significantly diminished or even erased with simple interventions (for a summary, see Cherney 2008). One study found that assigning women to a semester of Tetris (a simple video game that involves rotating and fitting various geometric shapes into one another) almost closed the gap between men's and women's scores (Terlecki et al. 2008). In another study, just 10 hours of video game play reduced the gap to statistical insignificance (Feng et al. 2007). In a third study, 5 ½ hours of video game play erased the sex difference (De Lisi and Wolford 2002). In a fourth, just two minutes of practice before the test erased the different performance levels of men and women (Cherney et al. 2003).

Consistent with what we know about brain plasticity, the change in ability manifests itself in our neuroanatomy. In one study the brains of 12- to 15-year-old girls were measured before and after a three month period during which they played Tetris for an hour and a half each week (Haier et al. 2009). At the end, their brains showed enhanced cortical thickness, heightened blood flow to the area, and increased mass. Thus, whatever our natural predispositions or prior experience, training and practice are key (Baenninger and Newcombe 1995). Both men and women benefit from interventions, suggesting that the natural ability in question is not men's advantage over women, but both men's and women's ability to improve their mental rotation ability (Cherney 2008). Indeed, the difference between the scores of people with training and people without training is larger than the difference between men and women (Newcombe 2007). Those who have undergone training, on average, perform better than 66–79 percent of those who have not (Hyde 2007).

If this process applies to an individual measure, we may well expect it to apply to cognitive ability more generally. Shifting demands on the brain operating at more macro levels (e.g., economic and technological change and corresponding increases in educational demands) may account for the Flynn Effect, a surprisingly strong and consistent rise in IQ scores all over the world (Flynn 1984; Neisser 1998). Research suggests that the rise may be due primarily to a lifting of the lowest scores instead of an increase in the highest ones, suggesting that societies may be increasingly less likely to let their weakest members languish (Teasdale and Owen 1989; Colom et al. 2005; but see Kaufman 2009).

In short, the brilliance of the human brain lies in its ability to adjust to a wide range of demands. In this way, writes sociologist David Franks (2010, 17), ''the brain is basically a social organ.''

Lessons for sociologists

While feminists in the social sciences, among others, have long argued that sex difference and inequality is embodied, biologists have now discovered many of the *mechanisms* by which this occurs. As our genes, hormones, and brains respond to the environment, we become materially different. The evidence in support of this is so overwhelming that scientists now agree that it makes no sense to talk about "human nature," except insofar as "… the social *is* the natural" and vice versa (Lorber 1993, 36). Biology is, literally, the flesh and blood of society.

Given this, sociologists now have powerful arguments against the naturalization of biological states. Finding evidence of a biological dimension to social stratification can no longer be used to argue that this is an inevitable or neutral state of affairs. Nor can it be used to argue that it is irreversible, even within a single generation. The idea that some features of our biology are overwhelmingly immutable, difficult or impossible to change, is no longer a tenable position.

Sociologists who embrace this have a new tool in their tool kit. Methodologically, this means using biological measures to make sociological arguments. For example, using functional MRI scans that observe the brain in action, Mina Cikara et al. (2010) found that, among men who scored high on tests of hostile sexism, viewing images of sexually objectified women was negatively correlated with activity in the parts of the brain that recognize others' mental state. In a similar study, Lasana Harris and Fiske (2006) found that observing images of addicts and the homeless activated parts of the brain associated with disgust. Dehumanization and sexual objectification are neurological processes, not the fantasies of scholars who study inequality. Hormones, too, which can often be measured with samples of saliva, can be integrated into sociological research. Scholars have used levels of cortisol, a "stress hormone" implicated in elevated rates of morbidity and mortality, to show the harm of persistent economic strain and prejudice (Adam 2005; Adam and Kumari 2009; Chen et al. 2010; Dickerson and Kemeny 2004; Friedman et al. 2012; Pollard 1997; see Taylor 2012 for a review). Likewise, Peter Bearman (2008, vi) argues that the research on population genetics offers sociologists a "new archive to dig around in" given that social structural change is a central trigger for changes in genetic expression.

Theoretically, these new developments in the biological sciences means reimagining biology not as a limit on culture, but the very substance through which social forces exert an influence. Omar Lizardo (2007), for example, uses the concept of mirror neurons – brain cells that fire in response to observations of others as if the observer were doing the action – to explain how ideas and practices become collective attributes. Will Kalkhoff et al. (2011) use mirror neurons as well, arguing that they help account for social solidarity. Turning to genetics, Jeremy Freese (2008) argues that social scientists should be on the forefront in theorizing the relationship between genes and society. Some genetic predispositions, he argues, "… may matter much more in some originating environments than others," as the relationship between genetics and aggression reveals (p. S7). Likewise, the same genome can be maladaptive in one context and adaptive in another. A genetic propensity for obesity, for example, is problematic in a society with plentiful food in a way that it is not where food is scarce (Bearman 2008). To paraphrase C. Wright Mills (1959), our lives are deeply tied to the interaction of our genetic biographies with history.

For sociologists of gender, as well as other scholars who are interested in the production of social hierarchies, these tools promise to enhance our understanding of how difference and inequality emerge, persist, and are interrupted. We now know, for example, that we can build *cognitive* prisons. The intellectually impoverished environments disproportionately inhabited by the poor and racial minorities interfere with the ability of residents to reach their genetic potential for intelligence (Guo and Stearns 2002; Turkheimer and Halpern 2009). Similarly, but in relation to brain plasticity, neuroscientist Lise Eliot (2009) argues that sex differences in mental rotation ability are probably the result of the fact that we fail to teach mental rotation in school and boys have a greater likelihood of learning it elsewhere through activities like building toys, video games, and sports (Cherney and London 2006; Kersh et al. 2008). If women have weaker mental rotation skills than men on average, it may be because we fail to provide opportunities for both girls and boys to learn these skills. The same argument can be applied to boys from low income backgrounds who do not have as much access to cognitive-building toys and activities and, accordingly, score worse on mental rotation tests than boys from middle and high income backgrounds (Levine et al. 2005; Noble et al. 2005). Uneven social structures, then, likely create populations that reflect them. Social deprivation can become a biological deficit, in true Bourdieuian fashion (1990).

As these examples illustrate, the sociology of embodiment has a lot to gain from this sort of inquiry. Adding an intersectional analysis promises to further develop our understanding (Crenshaw 1991). What becomes embodied in each of us is the interaction of our material selves with the sum total of our life experiences. Gender is just one piece of a much more complicated puzzle. Anne Fausto-Sterling (2005), for example, has shown how genes, hormones, and gendered rules that depress girls' bone-building activities all contribute to the fact that men have 20–30 percent greater bone mass and strength than women. This sex difference is reversed, however, among Ultra-Orthodox Jewish adolescents. Boys in these communities are tasked with intense study of religious documents from a young age, so they spend much less time exercising than otherwise similar boys. As a result, their bones never grow as strong as those of their sisters, who have lighter study loads and more sunshine and activity.

This inherent complexity – in our biological and social systems as well as in their interaction – likely explains why the tens of thousands of studies aimed at understanding the biological bases of gender in humans have not, on the whole, offered many clear conclusions (Eliot 2009; Halpern 2012; Hines 2004; Jordan-Young 2010). Just as dividing causes of social patterns into nature and nurture fails spectacularly to account for the complexity of our bodies, dividing humans into male and female fails spectacularly to account for the diversity of human existence and our evolved ability to respond to that diversity. This is not to say that research into the biological bases of gender is useless, but to point out that we are mistaken if we think that such research is going to offer us a bright, bold line between the two categories. In other words, we should not *expect* to find clear cut sex differences in our biologies, even if some differences exist.

Ultimately, while many feminists have eyed the biological sciences with skepticism, the developments reviewed here may be useful for drawing attention and opposition to inequality. If we can show that biology is neither the source of inequality nor neutral in its effects but is, instead, *harnessed* by the forces of inequality and *exploited* by the powerful to their own advantage, then oppression is not just an abstract force – whether ideological, economic, or structural – but one that imposes cognitive limitations, manipulates our chemistries, and activates or suppresses our genetic potential. What is new here is not the observation that bodies have been interpreted in ways that serve the interests of elites – of this we have long been aware (e.g., Bordo 1993; Fausto-Sterling 1992, 2005; Gilman 1991; Gould 1981; Haraway 1989; Lorber 1993) – but that the oppression goes far beyond interpretation; it violates our bodily boundaries in something more akin to occupation. When control of our societies are in the hands of the few, so are our bodies.

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