

Beyond Nature vs. Nurture: Philosophical Insights From Molecular Biology

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The “new genetics” research in molecular biology, as this month’s invited Presidential Column by Frances Champagne illustrates, has important implications for psychological science (so important, in fact, that it will be the topic for the Presidential Symposium at our upcoming annual APS convention this May in San Francisco). Professor Champagne’s analysis shows how recent findings in epigenetics speak to basic and enduring questions not just within psychology, but in virtually all discussions about human character and individual differences, from philosophical symposia to dinner conversations. How much is nature? How much is nurture? Champagne takes us elegantly and at high speed from that old question toward a new understanding of the “gene by environment” interactions that underlie what we become and how we differ. Personality and social psychologists will be struck by the close parallels in this analysis of the nature versus nurture debate and the “person versus situation” debate that long pre-occupied our field, and whose fallout still lingers. After Champagne’s discussion, I briefly comment on some of these parallels.

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Though it is emerging very slowly, there is a new perspective on the nature-nurture debate that may finally put an end to the centuries old argument about the genetic versus environmental influences on brain and behavior. The question of how genetic or how environmental a particular trait is has fuelled intellectual battles regarding the origins of aptitudes, abilities, and even physical features that have permeated well beyond the academic arena into politics and social policy. Likewise, political views have shaped the direction of science in addressing these issues. Society can easily dismiss its culpability in generating economical and behavioral inequalities if there are genetic rather than environmental forces that drive these processes.

So where has this debate brought us and where do we go from here?

Enlightened approaches to this debate have typically concluded that any trait is the product of both genetic and environmental influences. However, even this approach does not escape the nature-nurture dichotomy, and it perpetuates the idea that genetic and environmental factors can be accurately quantified and their relative influence on human development measured. This brings us to a modern development in the conceptualization of nature and nurture: the interaction between genes and environments as a predictor of the human character. Thus, we move ever so slightly away from a dichotomous thinking about the origins of individual differences to incorporate a third interactive variable whose significance, both statistically and conceptually, makes the consideration of the “main effects” of genes or environment inappropriate.

Progress towards this “gene by environment” or “G×E” approach has come as a product of modern

advances in the study of genetics. However, even prior to the development of methodologies designed to genotype humans or manipulate the genome in animal models, there were clues that this interaction was incredibly important in considering the origins of differences in behavior. One classic example comes from the laboratory studies of Cooper and Zubek, who in 1958 published a study in the *Canadian Journal of Psychology* involving rats that had been selectively bred to be either “maze-dull” or “maze-bright.” These animals differed considerably in their cognitive ability and this was attributed to genetic divergence between the two groups. However, a very striking phenomenon occurred when these animals were placed in either “enriched” environments containing increased sensory stimuli or “impoverished” environments containing little or no sensory stimuli. Despite the stable and heritable differences in cognitive performance that would normally be observed between “dull” and “bright” individuals, there were no such differences observed when rodents were placed as juveniles in these new environments. Thus even a characteristic that was generated through selective breeding — and presumably involved accumulation of genetic factors that drive cognitive performance — can be altered significantly depending on the environmental context of the individual. This raises the question of whether genetics has any meaning without knowing about the environment in which these genes are functioning.

A more recent example of the implications of gene-environment interactions comes from a longitudinal study of a cohort of over 1,000 children in the Dunedin Multidisciplinary Health and Development Study (Caspi et al., 2003). In addition to assessing variation in a gene that alters the level of serotonin in the brain, the environment to which these individuals were exposed across a 20-year period was assessed. In particular, the number of stressful life events was measured in an effort to determine the factors contributing to long-term risk of depression in this cohort. In the final analysis, this study revealed that neither life stress nor genetics alone could be used as a reliable predictor of depression in adulthood. However, in considering the interaction between genes and environment, we see very interesting results. In humans, it is clear that though certain genetic variations can lead to risk or resilience to psychological disorder, this “potential” is not observed unless variation in the environment is considered. Thus, in the Dunedin Study, depression emerges at increasing rates in those individuals with certain genetic variations who are exposed to a high number of stressful life conditions. This study really opened the floodgates of “G~E” analysis in humans and has been used to study a wide range of traits. Our ability to readily measure genetic variation in large samples of the population, mixed with our increasing sensitivity to the kinds of environmental factors that are critical for shaping development, has broadened understanding of the importance of using this interactive approach.

These “G~E” studies have even more to contribute to intellectual arguments about genes and environments than may at first be realized. If the effects of genetic variation are only apparent in specific environments, then what is it that genes actually do? What are environments doing to those genes to alter their impact? These questions are very basic, but we’ve been so distracted by the philosophical dilemma of the nature-nurture debate that it never occurred to us to ask.

Currently, it’s not even particularly clear what a gene is. Historically, “gene” was a term used to describe a unit of heritable material. Since the discovery of DNA, the study of genetics has come to mean the study of DNA and the gene is a particular sequence of DNA. This shift in the meaning of gene implies that the only factors we inherit from our parents are variations in DNA; an assumption that is perhaps premature.

Before I jump ahead to discussions of heritability, let’s first consider the questions of what genes, or

sequences of DNA, to be more precise, actually do. I like to think of an individual's DNA as a vast library of books that have been ordered and arranged very precisely by a meticulous librarian. These books contain a wealth of knowledge and the potential to inspire whoever should choose to read them. Many of these books will contain information that is essential to successfully passing an exam or writing a paper. However, just as many of these books will contain information of such an obscure nature that they will seldom be removed from their position within the rows upon rows of books around them. Asking what DNA does is like asking what a book in this library does. Books sit on a shelf waiting to be read. Once read, the information in those books can have limitless consequences and can perhaps even lead to the reading of more books, but that refers to the book's potential. Likewise, DNA sits in our cells and waits to be read. The reading or so called "expression" of DNA can, like the books in our library, have limitless consequences. However, without the active process that triggers "expression," this potential may never be realized. And what, you may well ask, triggers "expression"? In fact, the environment around the DNA contains those critical factors that make it possible to read the DNA and, in essence, make it do something. And so we return to the concept that genetic variation must always be considered within a specific environmental context.

Understanding the molecular biology of DNA and the "expression" of DNA has even more to offer to philosophical musings about the relationship between genes and environment. Getting back to our library analogy, there are many factors that may influence how likely a book will or will not be read. Even books containing very valuable information may sit undisturbed and unread, gradually collecting dust over the years. This may be particularly true if the book is hard to get to. It may be located on a shelf that is particularly difficult to reach or blocked by some piece of furniture that has been moved to create more space elsewhere. Likewise, DNA's "expression" can be easily blocked by factors in our cells that make the DNA harder to get to and thus more difficult to read. Conversely, there are also factors that make the DNA more accessible and thus more likely to be "expressed." Importantly, there is recent evidence that those processes that change the potential of a gene being read are environmentally driven. Laboratory studies in rodents and some longitudinal studies in humans are providing support for the notion that the nutritional and social environment, as well as the processes of learning and memory, can shape the likelihood that genes will be read. This environmental influence is not random—it shapes the "expression" of genes that will alter specific aspects of brain and behavior. In some cases, genes can be entirely "shut off" through these processes. Just as is the case for our library of books, the gene is there, but it sits unread collecting dust.

The factors that give context to DNA and determine the accessibility of DNA are referred to as "epigenetic" meaning "in addition to genetic." We have a dynamic biological system that determines whether in fact DNA will do anything. Based on this knowledge of what is going on at a cellular level, it is not surprising that we have accumulating evidence for gene by environment interactions in studies of behavior. Though genetic variation provides "potential" for influencing the development of the individual, this potential may only be apparent when particular environmental triggers are present.

The implications of this reality for the nature versus nurture debate are clear; however the consequences of these processes do not end there.

One of the key concepts in our understanding of the origins of psychological functioning is "heritability." Though we certainly do know a great deal about the transfer of genetic variation from parents to offspring, this knowledge is not in fact the basis of heritability estimates. The classic approach

to calculating heritability involves the comparison of the stability of a trait in monozygotic (MZ) and dizygotic (DZ) twins, with an increase in MZ concordance in contrast to DZ twins indicating increased heritability. But our new appreciation of the science of epigenetics has something very important to offer the interpretation of similarity or differences in MZ and DZ twins. Recent evidence suggests that some aspects of the epigenetic characteristics of a cell are heritable. In our library analogy, we can think of an inheritance of the rows upon rows of books, but also of the shelves, furniture, and meticulous ordering of those books that leave some volumes readily accessible and others hidden in obscurity. Our MZ twins share the same library, whereas our DZ twins may have different libraries, containing a few different books but also potentially having a completely different architecture. Importantly, the shelves, furniture, and layout of a library can be changed dynamically. Despite having the same books, a library can undergo very dramatic changes. At a molecular level, those changes to the “epigenetic” characteristics of a cell can be induced by the environment and alter the characteristics of the cells that go on to create offspring. Thus, we inherit far more from our parents than just DNA. The environments to which they are exposed may lead to heritable changes that alter the development of the next generation; a molecular reality that would make any Lamarckian quite proud.

This modern understanding of what genes do and how environments can alter the function of genes provides a new twist in the discussions of nature versus nurture that will certainly bewilder those who are attached to the dichotomous world of genes and environment. In truth, genes and environments are always interacting, and it would be impossible to consider one without the other. To do so would be to forget that a library is more than just a collection of books; it is a building with shelves, furniture, and a design that can shift with changing styles and ideas.

Frances Champagne’s discussion gets us way beyond the nature versus nurture debate to a deeper understanding of how to conceptualize interactions and the limitations of dichotomous thinking in psychological science. Her points apply directly to the closely parallel debate on the influence of the “person versus the situation” that has concerned personality and social psychologists for more than half a century. Both debates play out in a remarkably similar sequence. Like the nature versus nurture debate, Stage 1 of the person versus situation debate consisted of passionate arguments about which one of these contenders, conceptualized as dichotomous entities, was more important and explains more of the variance. In Stage 2, just as in the nature-nurture debate, after years of heated arguments and research intended to assign importance percentages to each in order to pit the “power of the person” against that of the situation, the fatigued combatants recognized the obvious: yes, of course, any trait is the product of influences both from the person and the situation. The danger at this second stage is to think that this self-evident recognition is the end of the story, rather than a first step toward a better understanding. Champagne then takes us to the insight that has been extremely difficult to achieve in these debates, whether about persons and their environments, or genes and their environments. She shows how advances in modern genetics research have lead to the conclusion that, “In truth, genes and environments are always interacting and it would be impossible to consider one without the other.” This is the Stage 3 insight. The take home message for me is that what’s true for genes and their environments in molecular biology must surely be true for persons and their environments in personality and social psychology: it’s impossible to consider one without the other (Mischel, in press). And that has lots of implications.

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