9-4-2024

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Keywords: embodiment, plasticity, human biology, gender, sex

Abstract

This paper historically situates human biology research by engaging with feminist science and technology scholars to show how a key mechanism of embodiment, plasticity, is used to re/produce sex and gender binaries in anthropological research and beyond. I begin by defining embodiment and demonstrating its reliance on plasticity. Next, I discuss plasticity and review how and why it has been taken up in human biology research. After, I engage with the works of feminist, trans, and queer scholars who have examined the connection between embodiment, plasticity, and the creation of Western binarized sex and gender. Further, I present how the re/production of a sex and gender binary is entwined with the justification of racial hierarchies through plasticity. While deterministic frameworks are often the most criticized in biology for harmful racist and sexist understandings of race and gender, plasticity and gene-times-environment interaction frameworks are not without fault. Even with large shifts in scientific understanding, in this case from determinism to plasticity, science, in particular human biology, can still be a tool to create and maintain racist, patriarchal, cis- and hetero-normative systems. I conclude with recommendations and possible pathways forward for embodiment and plasticity research in human biology, suggesting that human biology research should engage with feminist science and technology critiques to be mindful of the way in which our concepts might be re/producing harm.

Introduction

Biological determinism is the framework that posits that an organism's biological structures (like, hormones, genotypes, neurological organization, etc.) determine everything about phenotype, including behavior and social position. Even seemingly more benign manifestations of determinism, such as the Genome Wide Association Studies of the last 15 years, still attempt to map complex, culturally specific behaviors to specific alleles (e.g., de Vries et al., 2020; Kong, et al., 2017). Biological determinism has rightfully been critiqued as a framework that produces racist and sexist science because it assumes that organisms have essential traits; that these traits cannot be changed; and that there are stark demarcations between groups with and

without particular traits (e.g., Graves, 2015; Lewontin, 1980; Miller and Costello, 2001). In contrast, and often positioned as the remedy to determinism, is plasticity. Plasticity refers to the ability of an organism to express or change their phenotype in response to an environmental change, with different phenotypes in different environmental circumstances (Mascie-Taylor and Bogin, 2011; Nettle and Bateson, 2015; Sultan, 2021; West-Eberhard, 2021), and is a central assumption of embodiment in human biology research. That is, without an organism's ability to respond *to* environment, there would be no embodiment *of* environment. However, plasticity, like determinism, is not cut off from the sociocultural and political world within which we conduct research.

Many anthropologists have written about the shortcomings and pitfalls of plasticity as a solution to or progression from determinism, especially in the realm of epigenetics (ex: Lock, 2013; Meloni, 2016; Niewohner, 2011; Warin, Kowal, and Meloni, 2016). However, plasticity is still often situated as an "after" to determinism, the natural step forward in scientific progress, and relatively little attention is paid to how plasticity has historically been used to re/produce[1] not only racial and socioeconomic hierarchies, but also gender and sex. Even with large shifts in scientific understanding, in this case from determinism to plasticity, human biology must be aware of its part in the re/production of these systems and that science itself is a component of these systems. This paper explores how often research using plasticity as a framework, including embodiment research, has historically been used as a tool to create and maintain colonial, imperialist, white-supremacist, capitalist, patriarchal systems (hooks, 2013), particularly through the biological study of sex and gender.

Through critically engaging with plasticity, we can further challenge our understanding of it as an antithesis to determinism and better conceptualize and study embodiment. This is particularly applicable to the study of gender and sex. Despite ample biological evidence to contest these categories (ex: Fausto-Sterling 1993; Fausto-Sterling, 2008; Jordan-Young, 2011; Shattock-Heidorn and Richardson, 2019; Joel et al., 2012; Joel et al., 2015), gender and sex are often conflated with each other, taken as given, immutable categories (for example, binarized in statistical analyses), and determined sex at birth is assumed to determine current gender or sex (through questions such as "are you male or female"). Because of the potential harm human biology work can have, we must be exceedingly mindful of how our research might be taken up to reinforce rigid binaries of sex and gender and in turn, hierarchal categorizations of race.

To better interrogate why plasticity falls short of being the cure all to racist and deterministic human biology research, I will begin first by defining embodiment to show that plasticity is a necessary component of embodiment research. Thus, we who study embodiment should critically engage with plasticity. Next, I discuss what plasticity means and how it is used in human biology research. Additionally, I situate plasticity historically and I engage more specifically with feminist, trans, and queer scholarship to better understand why simply adopting a plasticity framework is not enough to prevent our research from reproducing harm. I do this by examining how plasticity has been historically used in the re/production of gender and sex, with an emphasis on how these categories are intertwined with the categories of race in Western sciences. Finally, I conclude with a discussion of current human biology research that is utilizing feminist, queer and trans perspectives and suggest that human biology research should engage with science and technology critiques to be mindful of the ways in which our definitions and frameworks could be re/producing harm.

Embodiment

Embodiment and embodying refer to the process of a person or group incorporating and internalizing the physical and sociocultural world around them (Csordas, 1990; Kimmel, 2008). This process is not unidirectional, meaning that embodying does not act on only on a passive object but also that a subject embodies and in turn recreates and changes that which they are embodying (Csordas, 1990; Saboowala et al., this issue). Embodiment is also not solitary nor is it only between a person or group and the outside world but is an interpersonal and social process (Csordas, 1990; Kimmel, 2008). There is much more beyond biological mechanism that can be considered modes of embodiment, including, dance, vocalization, movements, behaviors, and clothing (e.g. Jones, 2002; Reed, 1998; Rees, 2017; Weidman, 2014; Zimman and Hall, 2009).

The definition most commonly used in human biology, medical, clinical and public health disciplines comes from Krieger (2005) and emphasizes potential biological mechanisms for embodiment. In her paper, Krieger defines embodiment as:

> A concept referring to how we literally incorporate, biologically, the material and social world in which we live, from in utero to death; a corollary is that no aspect of our biology can be understood in the absence of knowledge of history and individual and societal ways of living… ‘‘embodiment’’ for epidemiology is best understood: (a) As a construct, process, and reality, contingent upon bodily existence; (b) As a multilevel phenomenon, integrating soma, psyche, and society, within historical and ecological context, and hence an antonym to disembodied genes, minds, and behaviours; (c)

> As a clue to life histories, hidden and revealed; and (d) As a reminder of entangled consequences of diverse forms of social inequality (p.352).

The very first line of this definition leads the reader to question, how do we incorporate? And a key mechanism by which bodies incorporate their material and social world is plasticity. Without the ability to incorporate, change, and be impressed upon, there is no ability to embody. Plasticity and the process of plastic responses to environment are not inherently negative, and many argue that plasticity has the potential to be the connecting line between the sociocultural and biological realms (Hicks and Leonard, 2014; Krieger, 2011; Meloni, 2015). However, plasticity, as the next section will demonstrate, needs to be considered critically and as part of a larger socio-historical context.

Plasticity

Krieger's definition, though never explicitly saying so, depends greatly on the assumption of plasticity. Plasticity, broadly speaking, refers to the ability of an organism to express or change their phenotype in response to environmental stimuli, with different phenotypes in different environmental circumstances (Mascie-Taylor and Bogin, 2011; Nettle and Bateson, 2015; Sultan, 2021; West-Eberhard, 2021). West-Eberhard (2003) argues that plasticity is itself an adaptive trait impacted by evolutionary forces and can lead to evolution through genetic accommodation, or the process where novel traits expressed during development are shaped by selection. The assumption of plasticity is ubiquitous in much of the literature published on human biology. For example, a quick search of "plasticity" in the *American Journal of Biological Anthropology* yielded 1,135 articles and chapters, 561 articles in the *American Journal of Human Biology*, and 137 articles in *Human Biology (*at the time of writing*)*. Studies of embodiment through biological mechanisms, while they may not explicitly name plasticity, work on the underlying assumption that organisms respond to their environments and incorporate that response; it is their bodies responding to, internalizing, and embodying their environment, in turn producing their phenotype.

An individual's (or group's) phenotype is thus a direct outcome of their environment and lived experience and through these phenotypes researchers can know their experiences. A biological phenotype makes real the otherwise unknown lived experience. Fassin (2009) terms this framing of life being reduced to biology as "biolegitimacy" (p.49–51). That is, through

identified biological characteristics a group is recognized by the state (and the researcher) (Fassin, 2009). This framing can have material consequences in terms of access to and types of funding, biomedical interventions, and social programs that end up doing more harm through biopolitical[2] and state surveillance (Warin et al., 2020). For example, Murray (2018), working with Indigenous children in British Columbia, argues that a popular epigenetic survey, the Early Development Instrument, is based on the eugenics era classification of "vulnerable Aboriginal children" (p.225). Through the use of this instrument, there is more justification for state intervention and control of Indigenous groups, like through the forced relinquishment of children (Murray, 2018).

Thus, plasticity in practice has not been the answer to teleological, racist, or genetic determinist science that many human biologists hope or want it to be. Many human biologists working in and examining the field of epigenetics, a field that is at the forefront of plasticity research, have noted the shortcomings of plasticity as a potential way forward. While the current iteration of plasticity, particularly through epigenetic research, is positioned as a corrective to determinism and solution for human biologists in the postgenomic world (Meloni, 2015; Meloni 2016), it also has a risk of switching the determinism from a genetic source to an environmental or historical source (Meloni, 2017; Meloni et al., 2022; Warin et al., 2020). Additionally, Lock (2013) cautions about wholly accepting epigenetic research at face value, as doing so will likely lead to a tendency to reduce studies of human experience and health outcomes to easily measurable variables, thus leaving oppressive social and political systems unexamined.

Researchers also point out that epigenetic research, like much of molecular biology, may reduce historical and intergenerational processes to singular moments in time, shifting attention to individual and one-off interventions instead of addressing the oppressive systems that are the root cause of health and wellbeing disparities (Lock, 2013; Niewohner, 2011; Saboowala et al., this issue). Furthermore, the plasticity of epigenetics has often been positioned as both mechanism and cure when it comes to health disparities from inequalities through individual intervention (Meloni and Testa, 2014; Meloni, 2016; Saboowala et al., this issue). For example, that individuals can make their own personal intervention into cancer prevention treatment by increasing their green tea polyphenol epigallocatechin-3-gallate (EGCG) intake (for review on epigenetic research on EGCG see Li, et al., 2022). However, as discussed above, plasticity (and thus embodiment) is itself likely to be used as a form of biopolitical surveillance and control by

means of state or government-controlled intervention programs (Meloni, 2016; Meloni, 2019; Warin et al., 2020).

Despite these timely critiques within the realm of epigenetics, plasticity is often still positioned as a response to either past sociocultural research on embodiment that neglected the body (Hoke and McDade, 2014; Lock, 2013) or to the harmful, deterministic narratives around gender, sex, and race that can pervade the sciences (Gills-Peterson, 2018; Pitts-Taylor, 2016; Richardson, 2017; Schuller, 2018; Schuller and Gills-Peterson, 2020; Weasel, 2016). Many of us who use the concept of plasticity, either explicitly or implicitly through the study of embodiment, have not considered its historical use in the study of human biology. Instead, we understand plasticity as ahistorical or frame it as a new response to determinism or a way of connecting the biological and social (Hicks and Leonard, 2014). However, the popularity of plasticity as a concept has ebbed and flowed in human biology research since the mid-1800s (more on this in the next section). Hicks and Leonard (2014) outline a brief history of human biology research since the publishing of Darwin's *On the Origin of Species*, and argue that plasticity (specifically developmental plasticity, or the plasticity of an organism during development both *in utero* and as the organism grows), is a useful concept to study the process of inequality while not removing evolution and adaptation from our work.

Hicks and Leonard (2014) rightly caution against and point out that human biology research runs the risk of teleological thinking, but that by adopting plasticity as a grounding framework and utilizing sociocultural and mixed methodologies, human biologists can avoid this trap. Many feminist scholars have called for a more critical understanding of plasticity, one that historically situates this concept not as a brand new and an ahistorical way to combat racism and sexism in the sciences but as frameworks which have been historically used to create and uphold racism and sexism (Pitts-Taylor, 2016; Richardson, 2017; Weasel, 2016). Interrogating this history of how plasticity has been used to reproduce gender and sex could help to elucidate why its current iteration falls into the same traps as determinist frameworks.

The plasticity of gender and sex historically situated

Feminist, queer, and trans scholars have made critical interventions into how gender and sex are defined and conceptualized and have shown both categories to be unstable and mutable over time (see figure 1 for expanded definitions and discussion). This critical scholarship has shown that

gender, sex, and race are not natural, inherent, or monolithic categories, but are instead naturalized, constructed, and reinforced and thus appear concrete and normal (e.g. Cipolla et al., 2017; Fuentes, 2019; Gill-Peterson, 2018; Gupta and Rubin, 2020; Schuller, 2018; Snorton and Haritaworn, 2014; Somerville, 2000; Stryker and Aizura, 2013; Tallbear, 2019). Gender and sex especially have historically been tied together to define what an acceptable, normal (that is, white, cisgender, heterosexual) body looks and acts like (Gill-Peterson, 2018; Schuller, 2018; Spillers, 1987; Wynter, 2003). These scholars have also made pertinent interventions into the study of human biology, interrogating how it is conceptualized, how scientific work is understood and positioned within and outside of the academy, how it is conducted, and what kinds of scientific inquiry produces/reproduces and naturalizes categories of sex, gender, and race. This section will show how human biology research, whether utilizing a deterministic or plasticity model, has historically been used as a tool to re/produce and bring legitimacy to these constantly changing and unstable categories.

Scientific definitions of a male versus a female body and who is designated male/man, female/woman, and other, have been coproduced with racial difference. Sylvia Wynter (2003) traces the colonial project of the creation of Man in Western culture as a white, male, middle class, and heterosexual. Wynter discusses how in modernity, Man has come to be defined through biological means, and that through biological sciences, Man becomes the only representative of humanity. Wynter's analysis of the creation of Man and Western culture's attempts to define what it means to be human/man demonstrates how sex, gender, race, and also class are defined by and created through biological and scientific discourse. Those who are not Man but instead defined as Other, thus are not human and are denied the categories of Man (such as gender). For example, Spillers (1987) argues that black women and men are "ungendered" (specifically ungendered from gender which is defined as white and patriarchal) so that they become flesh, a commodity for white, capitalist consumption (p.68).

This process of defining (and assigning and denying and rejecting) gender in terms of whiteness is often upheld and bolstered by Western scientific thought. In her book *Biopolitics of Feeling*, Schuller (2018) builds upon Wynter (2003) and Spillers (1987) and focuses specifically on embodiment and plasticity frameworks used by science to uphold and recreate sex, gender, and race in the 19th century. Schuller (2018) discusses in depth how distinct, binary sexes and gender stereotypes were created through scientific studies in order to reconcile the racist,

hierarchal views of the 19th century United States, placing white male bodies as the peak of evolution. Through her discussion of the biopolitics of feeling and sentimentality, Schuller (2018) shows that white men and women are distinguished not just by their genitals but also by their capacity for feeling. White people in 19th century America were considered superior because of their "impressibility" or their ability to be impressed upon and molded by their civilized cultures, that is they are more malleable (literally can be pressed on and formed by culture), responsive, and plastic to cultural environments and biologically embody civilization more thoroughly (p.7). In contrast to white impressibility, people of color were not able to evolve past a "primitive state" because they lacked the capacity to be impressed upon by civilizing forces (p.8). This social construction presented a problem however, in that being full of sentiment, sentimentality, and impressionability could possibly cause a species to be weak or over influenced. So, how does white supremacy reconcile this? By further delineating sex and gender. That is, white women came to embody the "sentimental" sex, while white men came to embody the rational, impressing sex. The language of impressionability and plasticity used by the scientists in the 19th century that Schuller (2018) describes would not look too out of place in the more current Gene x Environment interaction frameworks of embodiment that have become more popular. Meloni et al. (2022), in their review of epigenetic and Developmental Origins of Health and Disease studies of race/ethnicity and health, found that 58% of their sample reported "a 'multifactorial combination' or 'complex interplay' between genetic and environmental exposures," and another 23% referenced the environment as a direct source of phenotypic difference (n=49) (p.12).

Gill-Peterson's (2018) book, *Histories of the Transgender Child*, situates another subject within a biological, medicalized, racialized history of embodiment and plasticity: the transgender child during the mid-20th century. The transgender child, Gill-Peterson (2018) argues, is currently spoken about as an invention of the 21st century with no history at all. As Gill-Peterson (2018) argues this is not the case. What's more, the medicalized and scientific narratives around trans children are set within assumptions of racial difference, especially racialized difference in plasticity. For example, Gill-Peterson (2018) states,

> far from being a progressive vector of malleability or change, the racial plasticity of sex and gender was a decidedly disenfranchising object of governance from the perspective of trans children. At its institutional best, it granted access to a rigid medical model premised on binary normalization. At its institutional worst, it allowed gatekeeping clinicians to reject black and trans of color children

> as *not plastic enough* for the category of transsexuality, dismissing their self-knowledge of gender as delusion or homosexuality (p.4).

Gill-Peterson, like Schuller, identifies plasticity as a specifically white characteristic, one through which a person's self-knowledge of gender and sex (and the concomitant qualities of the binarized sexes and genders, like feeling) are considered valid only for those who also possess whiteness. Gill-Peterson (2018) further traces how "in the late nineteenth- and early twentieth-century life sciences, sex underwent two key transformations: sex became synonymous with a concept of biological plasticity that made it an alterable morphology, and, through experiments by largely eugenic scientists, it was racialized as a phenotype" (p.35). Sex became plastic through the studies of animal experiments, endocrinology, embryology, and later childhood development. However only white bodies were able to access that plastic response and embody the "binary normalization" of male and female, while black and trans of color children were "not plastic enough" (p.4). Sex, being plastic, could be impressed upon, manipulated, and guided by scientists in childhood in order to achieve what the clinicians of the era considered to be the optimal body; white, able, and binarized.

Schuller and Gill-Peterson (2020) continue their discussion of plasticity in their special issue of Social Text, *The Biopolitics of Plasticity*. They explicitly name plasticity as "a central axis of biopolitical governance" (p.1). That is, plasticity as a concept uses the potential malleability of a body and enforces state power onto the body in order to "engineer an individual and population" (p.2). Thus, plasticity is used to further delineate populations. In this case, plasticity is read as whiteness, while Blackness is denied plasticity and the ability to embody and self-transform. Historically, plasticity has been used to ascribe Man (Wynter, 2003) with the ability to be formed by his experiences and environment, and the greater the ability to be formed and embody, the more personhood and thus more human an individual is. This type of forming and reforming, however, is only possessed by individual white bodies, and bodies of color are instead denied this humanity. This plasticity on the individual scale is used to differentiate between racial categories. During the eugenics movement, the concept of plasticity was applied instead to the population level, with entire populations being able to be manipulated and changed through eugenics programs. However, as individual plasticity was still a characteristic of whiteness, the ability to influence a population's movement progressively forward through time towards an idealized form was only available to a white population, while Black populations

remained defined by their formlessness (Schuller and Gill-Peterson, 2020).

Figure 1: Key definitions

Gender
Gender is difficult to define and numerous scholars and disciplines have attempted to better understand and operationalize the concept. Trans and queer scholars (Halberstam, 2014; Stryker 2008) define gender as a marker of social difference that results in social organization. Gender is a historical category that changes from place to place, through time, and as a category it depends on a lot of different things coming together to make it "real". With that, gender is perceived to be organic or ingrained and is invisible and immutable, especially to the normative gender(s). Importantly, these scholars include gender as a form of oppression in their definitions. Gender is used to sort bodies into binary (in the United States) categories that are subject to various forms of social control. Gender, though not necessarily connected to the physical form, is assigned into one of two types of genders based on genital sex identified at birth. Gender has been further defined and broken down into multiple different levels and dimensions in the social sciences. Gender and how gender is experienced is social, interpersonal, structural and individual and can change over time (Connell, 2012; Fausto-Sterling, 2012; Fausto-Sterling, 2019; Hyde et al., 2019; Shattuck-Heidorn and Richardson, 2019; Tate et al., 2014). Gender can be a set of social norms about what it means to be a certain gender. Gender can be individual in that a person has a gender and a set of internalized beliefs which they use to interpret, interact with, and participate in social norms about gender. Gender can be experienced and re/produced through structural, institutional, and societal norms and systems. Gender is a learned, cultural, political, porous, and changing category/process of categorization/organization that can mean different things at different times in different locations. In the patriarchal, racist, and colonial context of the United States, a person's gender is understood through their sex which was identified/categorized at or before birth. That is, our society relies heavily on the binarization and subsequent identification of sex by genitals in order to forcibly sort bodies into a specific gender category.
Sex
The concept of sex itself is a construction and not a biological truth or universal (Fausto-Sterling, 1993; Fisher, 2011; Joel et al., 2012; Pigg and Adams, 2005; Richardson, 2017; Somerville, 1994). Most definitions of sex specify karyotype, however, genital phenotype is used to assign a human body either male or female. While a person's phenotype is related to their genotype, it can vary greatly from person to person. For example, Fausto-Sterling (1993) theorized sex as not being binary, but instead as having as many as five different sexes, depending on different arrangements of phenotypic traits. Joel et al., (2012), considered as many as 9 possible sexes, depending on a person's gonadal, genital, and genetic makeup. Many critical scholars have talked in depth about how sex, like all other social categories, is constructed and given meaning that is then naturalized or considered innate (e.g. Fausto-Sterling, 1993; Fisher, 2011; Joel et al., 2012; Pigg and Adams, 2005; Richardson, 2017; Somerville, 1994). When human biology studies start with sex without defining what they mean by this category and how they are categorizing participants, they are at risk of perpetuating the assumption that sex is rigid, binary, natural and unchanging. Sex is often difficult to define, and the definition and traits of particular sexes are changing and overlapping. Despite this, scientists often assume that every reader knows exactly what they are talking about when using a male and female category, without considering how this assumption is incorrect and works to try to stabilize sex as a rigid category. The category of sex is a culturally meaningful category that is itself gendered. While sex greatly influences how a person is socialized in the US, gender also influences our understanding of sex (Fausto-Sterling, 1993; Jordan-Young, 2011). Sex does not determine gender, but sex impacts where and how bodies are attempted to be categorized in this society. In this way, gender and sex, while describing two different categories that can and should be uncoupled, are linked together.

The Past and Present of Human Biology

This history reminds us that human biology research and Western science as a discipline is founded on white, patriarchal, colonial ideals and that no matter the framework du jour, we as human biologists are still reckoning with and in many cases, reproducing the structural inequalities that we study. Given this critique of the concept of plasticity, how might human biology, biological anthropology, and biocultural/biosocial[3] studies of human embodiment engage plasticity? Gill-Peterson and Schuller's work, summarized above, show how plasticity has historically been used as a biopolitical tool to uphold state power and is not the ahistorical foil to the racist and sexist determinism framework of yesteryear. While Schuller and Gill-Peterson (2020) are more so addressing other critical scholars, they state that, "despite a critical pessimism about its amenability to any dissent from its deeply entrenched biopolitical function, [scholars] also make a case for the productivity of plasticity. While the historical baggage attendant to thinking with plasticity is immense—and perhaps nowhere more so than in its racialized forms—the concept is for the same reason essential to thinking corporeal change across a range of scales" (p.11). Schuller and Gill-Peterson (2020) are not calling for the throwing away of the concept and framework of plasticity, but instead, considering its formulations and instances both outside of science discourse and within it can call attention to the ways in which race, sex and gender are (co)creating and reinforcing each other. Their argument instead is that plasticity should not be uncritically embraced and championed as a tool to dismantle racist structures and that, "understanding plasticity to be a tool of biopolitical power can help us identify moments when Left frameworks themselves are invested in valorizing bodily capacity and potential and thereby fall into the logics of racialization and debilitation rather than subverting them" (p.13).

This last point, that Left frameworks, but also, I would argue, human biologists, should "identify moments…invested in valorizing bodily capacity and potential," is vital for our work. Schuller and Gill-Peterson (2020), through their analysis are inviting not just science studies scholars to think critically about plasticity, but also human biologists and other scientists invested in the narrative of plasticity. The narrative of plasticity especially would be better addressed by reflecting on the language that we as human biologists use to introduce, describe and interpret our data. Are we inherently placing a value judgement on the malleability of the body? Is this malleability being situated within a broader framework of natural selection and

how? Importantly, what bodies are now included in a plasticity narrative when many biological anthropology studies draw from and reproduce research conducted by white scientists? Which bodies are positioned as healthy and which as unhealthy?

These questions are particularly important when thinking about which bodies are plastic in the current discourse of embodiment. Many human biology studies on embodiment are conducted on non-white or marginalized populations, are investigating biological or health outcomes that are perceived as negative, or are investigating these negative outcomes in marginalized populations (Saboowala et al., this issue) often in contrast to white, cis, heteronormative and WEIRD groups who are studied or positioned as the control (Clancy and Davis, 2019). In our current discourse, it is often bodies of color and bodies which are marginalized that are ascribed plastic responses, the opposite of the historical scientific discourse that Schuller and Gill-Peterson (2020) describe. These plastic responses often are tied to negative, non-normal (i.e., white), or unhealthy outcomes through perceived negative biological responses (e.g., increased baseline cortisol). Plasticity in our modern research is positioned and used in ways that appear to be in opposition to plasticity at the turn of the 19th century—that is, plastic responses are the realm of white bodies versus bodies of color, plasticity results in positive versus negative responses, and plasticity is the framework of racial difference versus the framework of antiracist science. However, this framework is still being used in a binarizing and differentiating way. What implicit narratives are being constructed when only bodies of color are susceptible to negative health outcomes? What does it mean that plasticity is only considered within negative contexts, what judgement on those who embody and have plastic responses does this imply? How is plasticity still being used, if not in more subtle ways, to create and maintain gendered and racial difference?

Embodiment, plasticity, gender, and sex are all interconnected and used in human biology discourse in tandem with the re/production of racial difference. When considering embodiment, plasticity, gender, and sex as topics of study, we cannot think of them as well demarcated, wholly separate, unbiased, ahistorical categories outside of racism. We as human biologists need to attend to these frameworks' and categories' re/production of racial, cis, and hetero normative assumptions, and their use to maintain and reinforce racial difference and hierarchy. Gill-Peterson (2018) wrote, "sex and gender were reconceived as plastic phenotypes during the twentieth century, which makes *all human embodiment*, including cisgender forms, a

racial formation" (p.27, emphasis my own). In any projects that are directly interested in embodiment and, especially the embodiment of gender, Gill-Peterson's (2018) argument that all embodiment is a racial formation should be a starting point for how we conceive of embodiment and plasticity. Gill-Peterson's argument follows, as many have pointed out that the positivist and "objective" position of Western Science is a tool used to legitimize and make "natural" a white and white supremacist reality (Harding, 1995; Fleming, 2018; Melville et al., 2022; Wynter, 2003). By being aware of where our scientific inquiry fits within the historical scientific discourse, we can then be more attentive to the language we use, the research design we implement, and the interpretation of our results.

Potential futures

Anthropologists working within both the biological and sociocultural disciplinary realms have put forward new ways of theorizing embodiment, plasticity, and evolutionary processes that aim to not binarize social versus biological, sociocultural variables versus biological outcome, plasticity versus determinism (Ingold and Palsson, 2013; Niewohner and Lock, 2018). Ingold and Palsson (2013) suggest understanding humans and our study of ourselves as "biosocial becomings," which emphasizes the "processual, developmental, and relational" biological and social processes that are entangled together in the becoming of life (Inglold and Palsson, 2013, p.9 and p.20). Niewohner and Lock (2018), introduce the concept of "situated biologies" with the intent of emphasizing not only the biological and differential health outcomes most often of interest to human biologists but to also incorporate the richness of ethnographic research which emphasizes how co-constructed humans' biologies, experiences, cultures, and histories are. They argue that situated biologies help to bring attention to how the boundaries between material, culture, environment, and body are constantly disintegrating and being rebuilt. Importantly, they state that incorporating sociocultural theory and ethnographic methodologies into our studies of human biology are necessary for interrogating human lived experience. Clancy and Davis (2019), along with emphasizing ethnographic and qualitative methodologies, also make the point that human biologists will likely need to move away from prioritizing statistical significance, replicability, and rigid categorizations in order to better encompass all forms of human variation.

Many biological anthropologists are also incorporating humanistic and queer theoretical perspectives into their work to propose alternate ways of doing human biology that also bring

attention to the ways in which human biology re/produce categories of oppression through our research. Feminist, queer, and trans scholarship is important as it shows how the re/production of a sex and gender binaries are entwined with the justification of racial hierarchies through plasticity and embodiment. Smith (2021) argues that scientific knowledge should be brought under the purview of this thinking. That is, scientific knowledge production should be grounded in and analyzed through theoretical frameworks beyond evolutionary theory and white, capitalistic, patriarchal cis and heteronormative ways of knowing. Recent work by numerous biological anthropologists have begun to problematize the binaries of gender and sex and utilize queer theory to think beyond the normative (e.g. Astorino, 2019; Dubois, Puckett and Langer, 2022; Dubois and Shattuck-Heidorn, 2021; Dubois et al., 2021; Meredith and Schmitt, 2019; Smith and Archer, 2019). For example, Dubois and Shattuck-Heidorn (2021) critically engage with the ways in which the emphasis on biological normalcy as the level of analysis, with common statistical analyses that binarize, normalize, and categorize gender/sex, continues to reproduce these categories. What is critical moving forward is to make sure that these researchers and perspectives are taught not only at a graduate or independent study level, but as foundational to our discipline. What would future biological anthropology and human biology research look like if introduction to biological anthropology textbooks had chapters that included critical historical perspectives on evolution, adaptation, and plasticity and sociocultural theory and methods as part of the study of human variation?

In the meantime, while we work towards teaching and incorporating these perspectives as foundational for our discipline of biological anthropology and work to dismantle systems of oppression more broadly, there are some ways that we can mitigate our reproduction of these systems of oppression. Gender and sex are complicated and unstable as categories and can mean very different things to different people and disciplines (see figure 1). While both are complex and in flux, these categories have very real effects on how people live, experience, move through the world, and understand themselves and their positions. For human biologists interested in embodiment, combining the extremely varied lived experiences related to gender and sex would only erase this variation. Instead, researchers should be explicit about what they mean by, how they are defining, and how they are determining the sex and gender of participants (see Dubois and Shattuck-Heidorn, 2021, for an example of a gender and sex inclusive questionnaire). Researchers need to be sure not to conflate gender and sex (for example, using self-reported

gender as a proxy for sex) and not to limit gender and sex to only man and woman or male or female. One example of researchers engaging with the complexity of gender and sex is from the GenderSci lab at Harvard University. Richardson (2022), in her article "Sex Contextualism," outlines how biomedical researchers and human biologists can complicate binary sex in their own research by operationalizing sex not as an essential category but by first asking ourselves what we mean by sex and how will we operationalize sex. Richardson (2022) argues that both questions are research context dependent and that the biological variables researchers choose to study will depend on their definition of sex and why it is necessary to include sex as a variable in research design.

Along with this, we can also interrogate the study design and methods that we use. First, human biology researchers should conduct their work from a place of mixed methodology (Clancy and Davis, 2019; Neiwohner and Lock, 2018), which incorporates ethnographic and qualitative data not just for creating surveys and population specific categories, but as an equal unit of analysis to examine human variation. Many critical biocultural anthropologists have also made this call to conduct research using mixed methods (e.g. Dressler, 2005; Dufur, 2006; Gravlee, 2009; Goodman, 2013; Leatherman and Hoke, 2016; Wiley and Cullin, 2016). Ethnography and ethnographic methods have long been incorporated into biocultural studies (Dressler, 2005; Dufur, 2006; Goodman, 2013) and provide much needed context to the study of biology and sociocultural environment. Beginning with interviews and focus groups is a method used by biocultural anthropologists to identify what sociocultural experiences and stressors are meaningful to a population (Dressler et al., 2005; Gravlee, 2009). For example, in a sample from Puerto Rico participants' self-report of racial category correlated with higher blood pressure rather than quantitative measures of skin color or even African ancestry (Gravlee et al., 2009).

If unable to incorporate mixed methods and qualitative data, human biologists can try to ask questions and choose methods that do not reproduce scientific narratives of difference but instead attempt to blur the lines between categories and refuse normal/average/mean identification. For example, considering how sex and gender are defined from the start of a project and why these categories might even be necessary for the research project are all simple actions researchers can take to not further re/produce sex and gender. Furthermore, researchers can explore statistical methods that do not rely on *a priori* group identification which then produce normative groupings or situate one group over the other (for example, "group A has

greater inflammation than group B and thus is more stressed"). My own work on the embodiment of gender is committed to exploring alternative forms of statistical analysis such as generalized linear mixed models (Bates et al., 2015; Bolker et al., 2009; Bolker and others, 2022), geometric morphometrics (Ehrlich et al., 2022; Dryden and Mardia, 2016; Rohlf, 1999), and latent class analysis (McCutcheon, 1987; Nylund-Gibson and Choi, 2018) as ways of moving beyond group A versus group B *a priori* hypothesis testing. All of these suggestions are relatively easy to implement at the research design phase and will help elucidate more nuance when studying embodiment.

Broader impacts and conclusions

Maintaining and reproducing racist, colonial, capitalist, patriarchal, cis and hetero normative systems is harmful to anyone who isn't white, male, middle-upper class, cisgender and heterosexual. LGBTQIA individuals have a higher risk of experiencing physical violence, challenges accessing healthcare and poorer treatment, mass incarceration, surveillance, and police brutality. People of color are even more likely to face these problems (James et al., 2016). In 2022 and 2023 we witnessed a serious increase in anti-trans legislation in the United States and acts of physical violence against trans and non-binary women of color (Ronan, 2021). At the time of this writing, there are currently 387 anti- LGBTQ bills being proposed, many of which have or would ban and criminalize trans healthcare and dressing in drag and drag show performances (ACLU, 2023). Many of these bills are justifying these bans under the guise of "biology," arguing that they are maintaining a natural order protecting the healthy mental and physical development of children (ex: Arkansas SB43; Mississippi HB1125; Tennessee SB1; Tennessee SB 3). These trans and drag bans are a case study of how both embodiment and plasticity and determinism are being used in ways to uphold a hetero and cis normative system by claiming they are protecting children from possible exposure to persons that could influence their own mental, emotional, and physical development. Though plasticity has been taken up as a foil to determinism by human biologists, sociopolitical usage shows how both concepts can be used to maintain racist, colonial, capitalist, patriarchal, cis and hetero normative systems. By claiming these bills will protect the "immutable characteristics…determined by anatomy and genetics" of children from becoming influenced by "prurient" external influence, proponents for these bills tap into the biological language of both determinism and plasticity, lending

themselves legitimacy (ex: Tennessee SB1; Tennessee SB 3).

Especially because the current harm being enacted through the language of human biology, plasticity and determinism, biological anthropologists and human biologists have a responsibility to not reproduce but to actively dismantle harmful systemic hierarchies of oppression based on categories like gender, sex, and race. Plasticity is positioned as a solution to racist and sexist deterministic science but as many scholars have discussed, plasticity often falls short of true change, switching the determinism from genes to environment and continuing to uphold categories of oppression within and outside of our disciplinary realms. This re/production of categorization can be seen in our historical and current study of gender and sex, which have far-reaching consequences. As demonstrated above, in political discourse around gender and sex both plasticity and determinism are used in tandem to enact violence against LGBTQIA groups. Through examining the historical context of plasticity in human biology, especially as it is used to re/produce gender and sex, we can see that like gender and sex, our frameworks are unstable and changing, and often in service to maintaining the status quo. Simply changing the frameworks that we use is not enough as science itself is a structure enmeshed in the broader sociocultural and political systems at work. Swinging too far into the biological realm, seeing the sociocultural as only another variable to be studied, and viewing embodiment only through the terms and mechanisms of plasticity will always fall short of creating meaningful change through our scientific endeavors. Through interrogating our use of plasticity in embodiment research, with special attention paid towards the re/production of gender, sex and race, I hope to bring our own scientific inquiry under the purview of critical scholars and theorists. By being aware of the historical context of our own frameworks and of the assumptions about what *a priori* categories (like gender, sex, and race) mean, we can begin to imagine new ways of questioning, studying and interpreting embodiment in human biology.

Received 8 August 2022; accepted for publication 2 May 2024.

Notes

1 The terms re/produce and re/production are used throughout this article to highlight how gender and sex are both reproduced within and through a historical and cultural context and actively produced, tweaked and changed to seem both natural and ahistorical.

2Foucault's concept of biopolitics outlines how the State, concerned with population control and surveillance, seeks to describe, define, categorize, and mark specific bodies as normative (and thus residing within the State sanctioned structure) or nonnormative. These defining categories are produced, naturalized, and reinforced within scientific discourse and, through their naturalization, work to establish differences that seem inherent and unchanging between other categories, especially racial difference (Foucault, 1976).

3 Here I refer generally to biocultural/biosocial researchers, as I do more broadly human biologists, to be inclusive of all studies and research interests that are concerned with human biology and environment (as it is historically, socioculturally, physically constructed) both within and outside of anthropology. For a more extensive discussion on biocultural/biosocial anthropology and biocultural frameworks used within anthropology see Goodman, 2013; Wiley & Cullin 2016; Leatherman & Hoke 2016; Hoke & Schell 2020; Leatherman and Goodman, 2020; Cabana et al. 2022.

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