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ISSUES AND TRENDS

Reclaiming Race as a Topic of the U.S. Biology Textbook Curriculum

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ABSTRACT: Even though human racial difference has been a longstanding topic of the school biology curriculum, there is little evidence that contemporary biology textbooks challenge stereotypical racial beliefs that are based in biological thinking. Rather, the modern biology curriculum may be a place where such beliefs about race are perpetuated unwittingly. Drawing upon a theoretical framework of racial conceptualization based in psychological essentialism, this paper argues that biology textbook curricula ought to directly challenge problematic and unscientific racial beliefs to increase understanding of human genetic variation and decrease racial beliefs associated with prejudice. © 2015 Wiley Periodicals, Inc. *Sci Ed* **99:**1092–1117, 2015

INTRODUCTION

We are living in the postgenomic era of human genetics research, an era when racially framed reports of human genetics research are on the increase in the media (Phelan, Link, & Feldman, 2013; Rachul, Ouellette, & Caulfield, 2010). The problem is that when people are exposed to genetic explanations for group-based outcomes it tends to strengthen a cognitive bias implicated in our reasoning about social categories—a bias called biological essentialism. Crudely speaking, biological essentialism of social categories refers to the belief that social groups, such as races, differ in humanly important ways (e.g., cognitively or behaviorally) because they are biologically distinct categories. Furthermore, this bias leads people to believe that group-based social disparities are genetically determined and immutable and therefore not worthy of redress (Dar-Nimrod & Heine, 2011). For example, experiments demonstrate that after reading racially framed reports of genetics research

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people tend to believe that races are genetically different (Condit, Parrott, Bates, Bevan, & Achter, 2004; Phelan et al., 2013) and they tend to be less concerned about the racial disparities observable in American society (Williams & Eberhardt, 2008).

Given the widespread use of racial categories in contemporary human genetics research (C. Lee, 2009; S. Lee et al., 2008; S.S. Lee, Mountain, & Koenig, 2001) and the increasing dissemination of such work through the media to the public (Phelan et al., 2013) biological essentialism of race is possibly becoming a more prevalent conception of race in the United States (Jayaratne et al., 2006). Indeed, popular science books marketed as science education, such as Wade's (2014) *Our Troublesome Inheritance: Genes, Race, and Human History*, have recently advanced the thesis that complex human traits and political systems differ between racial groups because of genetic differences caused by human evolution. Like *The Bell Curve* (Herrnstein & Murray, 1996) before it, this book has been criticized by leading population geneticists as nothing more than erroneous speculation (see Coop, Eisen, Nielsen, Przeworski, & Rosenberg, 2014). But because books such as *Our Troublesome Inheritance* play directly into essentialist biases about race they tend to have a long half-life in American society (Nelkin & Lindee, 1995). Such books continue to perpetuate failed scientific ideas about the genetic basis of racial difference long after their flaws are exposed by scholarship (Beckwith, 2013; Kitcher, 2001).

More to the point, the mainstream American biology textbook curriculum has done little throughout its history to prevent this predictable problem. Rather, Willinsky (1998) and other scholars (e.g., Ladouceur, 2007; Morning, 2008; Skoog, 2005) have argued that science textbooks in the early 20th century contributed to making race a categorical divide in the world by directly teaching students about a racial hierarchy based in biology. Even today biology textbooks continue to associate racial difference with genetic difference unwittingly (Morning, 2008). And, it appears that there are no mainstream modern texts that challenge biological essentialism of race even though biological essentialism is biologically inaccurate (Mayr, 1982, 2002) and associated with incorrect understandings of evolution, heredity, and biological variation in student populations (Evans et al., 2010; Opfer, Nehm, & Ha, 2012; Shtulman & Schulz, 2008). This paper contends that the biology curriculum should challenge biological essentialism of race.

As evidenced by the work of Willinsky (1998), arguments of this type have been made in the past. Within the field of science education, Zeidler, Sadler, Berson, and Fogelman (2002) advocated teaching about the history of cultural prejudice in scientific research. Castéra, Sarapuu, and Clément (2013) and Puig and Jiménez-Aleixandre (2011) briefly alluded to the need to challenge genetic determinism in school science to undermine racism and ethnocentrism. Despite this work, the field of science education has not articulated why school biology should teach about race in light of contemporary scholarship on biological essentialism of race. Nor has anyone in the field used such scholarship to outline the hypothesized consequences of science education's failure to teach about race, which is the unwitting perpetuation of biological essentialism of race and the misunderstandings of human biology associated with it. The present paper addresses these gaps in the literature.

The paper begins with a discussion of developmental research on psychological essentialism, which is used to define biological essentialism and its consequences. Then, this framework is contrasted with modern biological and social scientific research to point out the scientific flaws in biological essentialism of race. Afterward, theory and research on biological essentialism is used to predict how the treatment of race in modern biology textbooks influences belief in biological essentialism of race. Following these arguments, the paper uses the concept of biological essentialism to outline instructive examples of how not to discuss race in the biology curriculum. Then, it discusses how race could be addressed by biology textbooks in the era of the Next-Generation Science Standards (NGSS) to (i)

reduce belief in biological essentialist beliefs about race, (ii) increase understanding of human genetic variation and evolution, and (iii) enhance scientific literacy about human genetics research.

PSYCHOLOGICAL ESSENTIALISM AND RACIAL THINKING

Studies have documented that children and adults tend to think about social and biological categories as if they were committed to metaphysical essentialism (Gelman, 2004; Prentice & Miller, 2007). In other words, people act as if biological and social categories possess an underlying essence that causally determines the properties of the organisms in that category (Medin & Ortony, 1989). The tendency to act and behave as if metaphysical essentialism is an accurate account of categories of living things (and it is not, read: Donovan, 2015; Ereshefsky, 2010; Mayr, 1982, 2002) is called psychological essentialism.

From the standpoint of developmental psychology, there are three components to essentialist thinking: (i) the inductive potential of categories, (ii) the perceived innateness of categories, and (iii) the underlying structure, or essence, of categories (Gelman, 2004). Inductive potential is the belief that members of a category share similar traits and, therefore, that categories are useful for making inductions about unknown category members. It is the belief that the class of entities picked out by a category is more or less uniform (Haslam, Rothschild, & Ernst, 2000), which by consequence makes categories inductively rich. The second component of psychological essentialism is the perceived innateness of a category, which is the belief that the properties of category members are fixed at birth (Gelman, 2004). Therefore, the belief that a category is innate is tantamount to believing that the traits of category members are immutable (Haslam et al., 2000). Finally, the third component of psychological essentialism involves beliefs about a category's underlying structure (Gelman, 2004). Medin and Ortony (1989) argue that the underlying structure, or essence, of a category acts as a placeholder "essence." That is, people are committed to the idea that there is an underlying structure that makes category membership inductively rich. This essence can be biological, cultural, or merely the belief that scientists will one day find the underlying essence that determines the traits, temperaments, and abilities of category members (Prentice & Miller, 2007). Thus, belief in underlying structure entails the belief that categories possess an essence that determines the properties of individuals in a category, which in turn makes the members of a category uniform, which in turn makes category membership inductively rich. Figure 1 represents essentialist beliefs through two related diagrams.

Essentialist beliefs about living categories emerge in early childhood in many cultures around the world (Gelman, 2004; Henrich, Heine, & Norenzayan, 2010; Prentice & Miller, 2007). Thus, psychological essentialism may be a universal tendency of humans living both in Western, Educated, Rich, Industrialized Democracies—so-called WEIRD societies (Henrich et al., 2010)—and in non-WEIRD societies as well (Gelman, 2004; Gil-White, 2001; Medin & Atran, 2004). However, evidence suggests that culture interacts with the tendency to essentialize categories to produce variation in people's categorical beliefs about living things (Medin & Atran, 2004; Rhodes & Gelman, 2009). Arguably, this is why the content of the essence in essentialist belief systems appears to vary across individuals and cultures. For example, across cultures people believe that the locus of the essence in an organism can be their blood, genes, milk, or culture (Medin & Atran, 2004; Morning, 2011).

The psychological tendency to essentialize racial categories is known as racial essentialism, or essentialism of race, by scholars (Morning, 2011). Because of the variation in essentialist thinking, it is common for researchers to operationalize racial essentialism as the belief that race is biological, or the belief that racial difference is genetic, or the belief

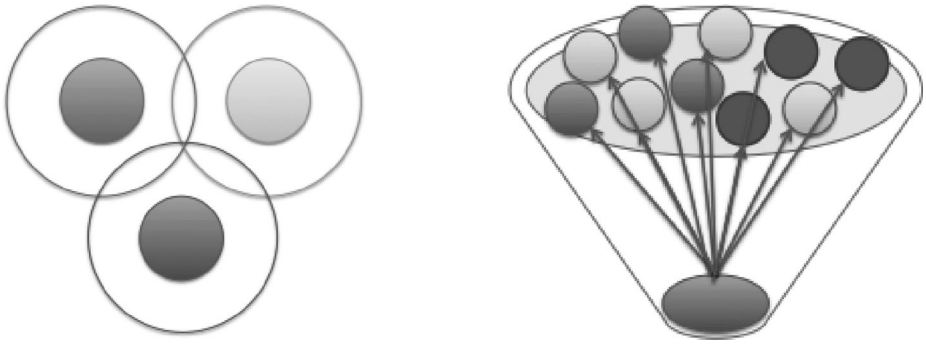

Figure 1. Two related representations of psychological essentialism. On the left, each circle represents a different social group and the circles within each circle refer to each group's nonoverlapping essence. This figure represents the belief that although groups may be similar on the surface, they are still discrete groups under the surface. On the right, the small circles at the top represent members of the same group who vary in some obvious manner. Each member looks slightly different on the surface, but underneath they all share the same essence. The funnel and arrows represent the belief that a group's essence constrains the innate potential of members within a group. Therefore, this figure represents the belief that an underlying essence determines which traits, temperaments, and abilities members of a group will develop. The figure on the right is also a three-dimensional representation of the figure on the left. For example, the inner circle at the bottom of the figure on the left is represented by the single gray oval at the bottom of the figure on the right. The larger circle around the gray circle on the left also represents the rim of the funnel in the figure on the right. Together these two figures represent the belief that groups are discrete categories that possess different underlying essences. Since these essences make individuals within a group uniform by constraining each member's innate potential, the two representations display why essentialist thinkers believe social categories are inductively rich.

that racial difference is determined by a cultural essence. Indeed, racial essentialism can mean so many different things in the literature on adult racial beliefs that it is important to carefully define the beliefs that constitute this construct if one intends to discuss it (Glasgow, Shulman, & Covarrubias, 2009). Social psychologists (e.g., Haslam, Rothschild, & Enrst, 2002; Bastian & Haslam, 2006; Williams & Eberhardt, 2008), who study the social consequences of essentialist thinking on variables such as stereotyping, prejudice, and socialization, operationalize racial essentialism with two sets of beliefs: *natural kind thinking* and *entitative thinking*.

RACES AS NATURAL KINDS AND ENTITIES

The natural kind dimension of essentialism involves the belief that races are biological categories. To be precise, the natural kind component includes beliefs about the discreteness, immutability, naturalness, and stability of racial categories as well as beliefs about the necessary characteristics that a person must possess to be a member of a race (Haslam et al., 2000). Discreteness is the belief that some categories, such as racial categories, have sharper boundaries than others. It is akin to believing that races are nonoverlapping categories, and, therefore that individuals from two different races are very different. Immutability, on the other hand, is the belief that membership in a race is not easy to change because it is fixed. That is, your race is fixed at birth and cannot change. Stability is the belief that racial categories are more stable over time than other categories, and thus have not changed much throughout history. It is the belief that all cultures around the world and throughout history classify people into the same races. Finally, necessity is the belief that each race possesses necessary features or characteristics, and without these characteristics, someone is not a member of that race (e.g., skin color and hair texture).

In contrast, entitativity involves beliefs about the uniformity, inherence, exclusivity, and informativeness of racial categories (Haslam et al., 2000). Uniformity is the belief that racial categories contain members who are very similar to one another. Consequently, racial category membership is informative about an individual because such categories allow people to make many judgments about the unknown characteristics of their members. That is, racial categories permit one to stereotype individuals accurately. Inherence is the belief that racial categories have an underlying reality, which means that although members of a racial group may have similarities and differences on the surface, underneath they share the same essence. Finally, exclusivity is the belief that some categories do not allow their members to belong to other categories. It is the belief that you can only be a full member of one race.

Studies employing principal components analysis provide empirical support for the conceptual distinctness of these two components of essentialist thinking in American undergraduates (Haslam et al., 2000). The limited research that exists on racial essentialism suggests that American undergraduates conceptualize races more strongly as natural kinds than as entities, which suggests that belief in races as natural kinds may be more robust to change through intervention than the belief that races are entities (Haslam et al., 2000). Furthermore, principal components analysis suggests that these two components of essentialist thinking are orthogonal to one another. That is, knowing whether a person conceptualizes races as natural kinds does not permit a confident prediction about whether they conceptualize races as entities as well.

The schema of races as natural kinds and entities can also be mapped onto other definitions of essentialism. Take, for example, Gelman's (2004) framework of innate potential, inductive potential, and underlying structure. Entitativity could be equated with underlying structure and inductive potential because entitativity is the belief that racial categories have an underlying essence (i.e., structure) that allows for accurate inductions about the predispositions of individuals within a group. Similarly, the belief that races are natural kinds is analogous to the belief that races have different innate potentials because if races are nonoverlapping kinds that are biologically different, then it is conceivable that each race also possesses a different innate potential that determines how individuals of that race develop. Taken together, the natural kind and entitativity dimensions of essentialist thinking incorporate the components of psychological essentialism outlined by developmental researchers. When combined into a definition of racial essentialism in the context of biology, this belief system could be labeled with the term biological essentialism of race, which is defined here as the belief that races are natural "biological" kinds that differ in humanly important ways (e.g., in complex psychological traits and abilities) because each race possesses a different genetic or biological essence.

THE UNFORTUNATE IMPLICATIONS OF BELIEF IN BIOLOGICAL ESSENTIALISM

A critical consequence of biological essentialism of race is that it causes individuals to perceive less variation within racial groups and more variation between racial groups (Chao, Hong, & Chiu, 2013; Hirschfeld, 1998; Prentice & Miller, 2007). Perceptual biases based in biological essentialism of race also increase the tendency of individuals to engage in race-based categorizations and they promote greater sensitivity in discerning racial group membership (Chao et al., 2013). This does not mean that individuals are more accurate at categorizing an individual into a race, or that they are better at discerning the phenotypic joints that cleave nature into a taxonomic tree. Rather it means that biological essentialism of race causes individuals to make more categorical distinctions when perceptual input

involves continuously varying phenotypic features (e.g., skin color). Thus, it is argued that biological essentialism of race is a cognitive bias that facilitates social stratification based on race because it causes individuals to categorically differentiate humans into nonoverlapping races (Chao et al., 2013).

Experimental research with undergraduates in the United States, for example, demonstrates that natural kind beliefs about the biological basis of race attenuate individuals' interests to socialize across racial lines (No et al., 2008; Williams & Eberhardt, 2008) and decrease emotional concern about racial disparities (Williams & Eberhardt, 2008). Correlational studies indicate that biological essentialism of ethnic groups is significantly associated with perceived group homogeneity, in-group bias, stereotyping, and discrimination in German undergraduates (Keller, 2005; Rangel & Keller, 2011). Among U.S. citizens, biological essentialism of race predicts racial stereotyping in samples of elementary school children (Pauker, Ambady, & Apfelbaum, 2010) and implicit racism in nationally representative surveys of adults (Phelan et al., 2013). Additionally, the entiative component of biological essentialism is positively correlated with anti-Black attitudes in samples of American undergraduates (Haslam et al., 2002) and in nationally representative surveys of white adults (Jayaratne et al., 2006). Indeed, it is estimated on the basis of a list experiment that 20% of non-Black Americans believe that genetic essences explain economic disparities between "Whites" and "Blacks" (Brueckner, Morning, & Nelson, 2005). Such evidence, which is replicated across individuals of different cultures and ages, clearly suggests that biological essentialism is implicated in inegalitarian thinking about race and ethnicity in WEIRD societies.

Additionally, biological essentialism appears to be associated with misunderstanding of intraspecific variation. For example, correlational and qualitative evidence suggest that biological essentialism is a cognitive bias that impedes understanding of evolution (Evans et al., 2010; Opfer et al. 2012; Shtulman & Schulz, 2008). In a study of 43 children and 34 adults, Shtulman and Schulz (2008) found that essentialist beliefs about species were reliably correlated with denial of within-species variation. Consequently, they argue that psychological essentialism leads individuals to devalue within-species variation and fail to understand natural selection. This argument is supported by data from other correlational studies as well. Evans et al. (2010), for instance, asked 32 visitors at a Midwestern museum to give an open-ended explanation of biological change in seven organisms. They found that individuals who used correct biological reasoning were the least likely to be reliant on essentialist thinking. Thus, they contend that highlighting within species variation may provide an important means of modifying essentialist perspectives. Building on these findings, Opfer et al. (2012) found that essentialist biases were negatively correlated with proper understanding of differential survival, variation, and heredity in a sample of undergraduate participants ($N = 320$) in a series of introductory biology courses. They also found that belief in essentialism was positively correlated with evolutionary misconceptions, such as the belief that evolution is intentional, and negatively correlated with end of the semester biology grades. Since experimental research demonstrates that essentialism leads individuals to ignore phenotypic variation within races (Chao et al., 2013), the correlations between essentialism and improper understanding of variation and heredity suggest that biological essentialism of race may be a barrier to a proper understanding of genetic variation in humans.

THE FLAWS IN BIOLOGICAL ESSENTIALISM

Scholars in the biological sciences (Feldman, 2010; Mayr, 1982, 2002), philosophy of biology (Ereshefsky, 2010; Glasgow et al., 2009; Hardimon, 2012; Kaplan & Winther, 2013,

2014; Winther, 2014), and science education (Donovan, 2014, 2015) argue that biological essentialism of race is flawed from the standpoint of biological theory and research. This does not mean that there are no biological differences between races, however. For example, the frequency of certain human leukemia antigens varies across racially defined populations and, therefore, it may be ethically justified to have race-specific bone marrow registries (Hacking, 2005). Even so, the medical significance of these differences does not support biological essentialism because each of these antigens can be found, at some frequency, in every racially defined population (Hacking, 2005). Furthermore, such differences are not indicative of deeper, more essential, differences between races, such as differences in intellect or behavior (Hardimon, 2012). Table 1 addresses the biological and social-scientific inaccuracies in each of the nine beliefs Haslam et al. (2000) use to define essentialism.

More to the point, if biological essentialism of race is a flawed belief system that is associated with inegalitarian thinking and a misunderstanding of genetic variation, then essentialist beliefs about race should be challenged by the biology curriculum. How, then, is race addressed in biology textbooks? Textbooks often serve as curriculum guides that organize how science courses are structured and how students experience school science (Yager, 1983). Moreover, students are known to view the knowledge in science textbooks as authoritative truths (Kloser, 2013). Consequently, the way that race is addressed in biology textbooks may influence how students learn about race and what they learn about it.

BIOLOGICAL ESSENTIALISM OF RACE AND THE BIOLOGY CURRICULUM

Ideas about race communicated through writing and speaking appear to be more important to the formation of essentialist beliefs about race than visual information (Hirschfeld, 1998). In other words, children do not learn about race by passively observing variation in human skin color. Instead, they construct theories about race as they encounter representations of race in culture (Diesendruck, Goldfein-Elbaz, Rhodes, Gelman, & Neumark, 2013; Hirschfeld, 2012; Rhodes & Gelman, 2009; Rhodes et al., 2012). In this section, it is argued that textbook-based science instruction either perpetuates or fails to challenge biological essentialism of race.

The first reason why belief in biological essentialism of race may be affected by the biology curriculum is that there is a long history of discussing race in American biology textbooks at the secondary (Levin & Lindbeck, 1979; Morning, 2008; Skoog, 2005; Swarts, Roger Anderson, & Swetz, 1994) and undergraduate levels (Lieberman, Hampton, Littlefield, & Hallead, 1992). For example, in a qualitative analysis of 113 high school biology textbooks published between 1900 and 2000, Skoog (2005) found that many texts in the opening decades of the 20th century directly discussed race through a eugenics framework. Throughout 1940–1960, the use of race in textbooks greatly changed, however. In general, social Darwinist and eugenicist framings of human racial difference became less prevalent. Even so, texts in the 1940s still explained the evolutionary origins of different races. For example, seven of the 14 texts from the 1950s sampled by Skoog (2005) differentiated among races and 15 of 17 texts from the1960s explained adaptive differences between races. Such findings suggest that the biology curriculum has communicated biological essentialism.

More recently, Morning (2008) investigated a sample of 80 high school biology texts between 1952 and 2002. Her work looked at whether the term race was defined, and if so how the races were cataloged and described. She also looked at how textbooks explained the development of human races and examined what the illustrations in these texts conveyed. To date, her work is the most comprehensive study of racial representations in the high school biology curriculum. Morning's (2008) analysis suggests that the frequency of racial

TABLE 1
How Essentialist Beliefs About Race Are Not Supported by Research

Essentialist Belief	What Research Says
Discreteness	Data from microsatellite loci indicate that all major geographic populations share 46.6% of the alleles present in the noncoding portion of the human genome and only 7.53% of microsatellite gene variants are private to any single region (Rosenberg, 2011). The private alleles occur at a rate that is too low to use for categorization (Rosenberg, 2011). Additionally, human skin color varies continuously with distance from the equator (Relethford, 2002). Both of these findings undermine the idea that human races are discrete.
Naturalness	There has never been any agreement within biology or anthropology about how many races exist (Doron, 2012; Goodman, 2000; Hudson, 1996; Kleingeld, 2007; Morning, 2011; Smedley & Smedley, 2005; Stuurman, 2000). Even modern scientists debate whether races are biologically real (Kaplan & Winther, 2013; 2014). If scientists cannot agree about whether races are real or how many races exist, then the naturalness of racial categories is weakly supported at present.
Stability	Research clearly demonstrates that beliefs about how many races exist and how to classify individuals into a race varies not only across scientific disciplines but also across modern human cultures and throughout recent history (Glasgow et al., 2009; Morning, 2011; Rhodes & Gelman, 2009). Therefore, racial categorization is not culturally or historically stable.
Necessity	There has never been any scientifically agreed upon set of phenotypic characteristics that a person needs to possess to be scientifically classified as a member of a race (Morning, 2011). And, since skin color varies continuously with distance from the equator (Relethford, 2002), there is no clear demarcation for where "Black people" end and "White people" begin. Both of these findings suggest that it is difficult to pin down the necessary characteristics required to scientifically classify individuals into races.
Immutability	If racial categorization is unstable across time, culture, and science, then how can racial membership be immutable? Racially defined populations do not possess an immutable essence because biological populations change in their gene frequency through time due to genetic drift, migration, selection, mutation, and non-random mating.
Inherence	Biological populations are genetically variable and they do not have biological essences (Mayr, 1982). For example, there is more average genetic variation within racially defined populations than between racially defined populations (Lewontin, 1972; Rosenberg et al., 2002). Therefore, it is not the case that every member of a race possesses a common set of gene variants that differentiates one race from another. About half of the alleles in the human genome are found in all human populations and only 7.53% of alleles are private to any single population (Rosenberg, 2011). None of these private alleles are common enough in a population to be useful for racial categorization.

(*Continued*)

TABLE 1
Continued

Essentialist Belief	What Research Says
Uniformity	If races do not possess an essence, and if populations are biologically variable, then a racially defined population is not biologically uniform. Indeed, most of the genetic diversity in human populations occurs in African populations so it is incorrect to believe that "all black people are biologically alike." However, as one moves along the hypothesized migration route out of Africa and into the Americas, the genetic diversity of human populations decreases (Rosenberg, 2011). Therefore, some human populations have less genetic diversity than others.
Informativeness	The causes of human behavior are incredibly complicated and gene–environment interactions or environmental factors alone can influence behavioral variation between groups (Braun, 2002; Caspi & Moffitt, 2006; Longino, 2013). In fact, there are limits to the scientific study of human behavior that preclude strong stereotypes about individuals on the basis of their race (Donovan, 2015). For example, there is no shared definition of behavior and no overarching model for human behavior in science (Longino, 2013). Additionally, there is no such a thing as a racial model of behavior in science. If there is no racial model of behavior, then how can a person's race explain their behavior? To use a person's race to make judgments about the behavioral predispositions of a person is an example of the ecological fallacy.
Exclusivity	A human can have ancestry in more than one geographic population commonly associated with race because of genetic admixture (Rosenberg, 2011). Therefore, the racial membership of an admixed person is not fixed to any single race.

origin stories, characterizations of different races, and definitions of the term race decreased through the latter half of the 20th century only to slightly increase again from 1993 to 2002. In general, Morning (2008) argues that many of the science texts in the 20th century conveyed a biological essentialist conception of race.

Regarding the more recent texts in Morning's (2008) study, it was shown that 30% of the textbooks published between 1993 and 2002 included definitions and characterizations of different races, 40% of texts included descriptions of how races originated, and approximately 90% of the most recent texts included indirect references to race. The indirect references were passages that referred to race briefly but did not concentrate on it. They occurred frequently in chapters devoted to biomedicine, forensic science, evolution, and human genetics. For example, "a description of forensic science might list race among the characteristics that investigators can determine from a human skeleton" (Morning, 2008a, p. S115). Or, a human genetics reading might associate particular races with specific genetic diseases (e.g., African Americans with sickle cell anemia or Caucasians with cystic fibrosis) (Morning, 2008).

Having found that race is seldom addressed in contemporary biology textbooks, it could be argued, quite reasonably, that biological essentialism of race is not perpetuated through the modern textbook curriculum because strong essentialist treatments of race are no longer present in biology textbooks and subtle references to race appear innocuous. For example,

it seems unreasonable to presume that students will infer that races are natural kinds or entities after reading about associations between particular races and specific diseases. This presumption is not unreasonable, however, as theory and research predict that subtle references to race in the biology curriculum can play a causal role in the perpetuation of biological essentialism of race.

Genetic essentialism theory, for example, predicts that the perpetuation of biological essentialism of race may be a consequence of text-based instruction in school biology that indirectly associates specific races with particular genetic diseases. When individuals perceive that a group outcome correlates perfectly with the presence or absence of a gene, as may be the case when students read about the prevalence of sickle cell anemia (SCA) in only African American populations, it is predicted to lead individuals to believe that members of that group share a genetic foundation that makes the group uniform and discrete (Dar-Nimrod & Heine, 2011). Additionally, when individuals are exposed to genetic explanations of group outcomes, such as genetic explanations for group differences in diseases like SCA, it is predicted to lead individuals to perceive those outcomes as (i) immutable and determined, (ii) having a specific etiology, and (iii) natural. In other words, exposing individuals to information that associates group outcomes with particular genes leads them to essentialize race because beliefs about the immutability and discreteness of race are components of the natural kind dimension of essentialism and beliefs about group homogeneity (i.e., uniformity) and specific etiology (i.e., inherence) are components of the entitativity dimension of essentialism. Therefore, when students read about racial differences in genetic disease prevalence it should lead to an increase in biological essentialist beliefs about race.

Findings from field experiments suggest that the predictions of genetic essentialism theory do indeed apply to text-based instruction in the science classroom that involves indirect references to race. Donovan (2014), for example, used a double-blind field experiment to investigate the impact of textbook-based genetics learning on biological essentialist conceptions of race among adolescents. The study was carried out in eighth-grade classrooms in a California Bay Area school. Students recruited for the study ($N = 43$) read either a subtly racially framed or a nonracially framed textbook passage on human genetic diseases and then completed two different biological essentialism of race instruments. One treatment associated particular races with specific genetic diseases indirectly, whereas the other text did not associate races with disease at all. Both texts were of equivalent reading difficulty. After reading, significant effects were observed on both biological essentialism instruments by treatment status. Students in the racially framed condition exhibited stronger beliefs in the genetic basis of racial difference than students in the nonracially framed condition. For instance, students in the racially framed condition (as compared to the nonracially framed condition) agreed more strongly that "Racial differences in academic ability are caused by genetics." Thus, there is experimental evidence that references to race in the genetics curriculum strengthen biological essentialism of race. Furthermore, students appear to transfer this essentialist schema, which was induced by a reading on human genetic disease, to understand racial differences other than those related to disease, such as differences in academic ability.

Importantly, Donovan's (2014) results are consistent with nationally representative experimental findings demonstrating that subtle references to race in journalistic reports about the genetic basis of disease increase belief in racial essentialism in the American public (i.e., Phelan et al. 2013; Condit et al., 2004). His results are also consistent with experiments showing that genetic framings of race in science textbooks can be used to manipulate belief in genetic essentialism of ethnicity in samples of German undergraduates (Keller, 2005). For example, Keller (2005) used a college science text that explained population genetics

research on Eastern European populations to manipulate belief in biological essentialism of ethnicity in a sample of undergraduates. If these findings are the rule and not the exception, then it is probable that other indirect references to race in the curriculum of the biology pipeline also affect belief in biological essentialism of race. Further scholarship is needed, however, to understand which kinds of references to race are likely to have this effect among the general population of U.S. students. Nevertheless, the consistency between Donovan's (2014) findings and those of Keller (2005), Phelan et al. (2013), and Condit et al. (2004) demonstrate proof of concept: theory and research are consistent with the claim that it is possible to strengthen belief in biological essentialism of race by having students read genetics texts that indirectly reference race.

To the extent that this claim is correct, genetic essentialism theory predicts that an increase in biological essentialism of race will also lead individuals to believe that social disparities between races are out of the control of group members, unaffected by environmental factors, and therefore not subject to change (Dar-Nimrod & Heine, 2011). There is some support for this prediction, too. Students in Donovan's (2014) study agreed more strongly, on average, that "Racial differences in academic ability are caused by genetics" if they received the racially framed treatment rather than the nonracially framed treatment. Furthermore, since biological essentialism leads individuals to ignore intraracial variation (Chao et al., 2013) and because it is associated with the failure to perceive intraspecific variation (Evans et al., 2010; Shtulman & Schulz, 2008), we might expect students to have greater difficulty reasoning about human genetic variation or evolution after reading textbook passages that indirectly associate race with genetic outcomes. On the basis of prior research, such as Williams and Eberhardt (2008), we might also expect to see a decrease in the desire to socialize across racial boundaries and a decrease in concern about racial disparities among students. Indeed, it is possible that many of the unfortunate social and cognitive implications of belief in biological essentialism are activated when students read about the association between genetic disease and race in biology textbooks.

It is also important to note, however, that some students are more at risk of developing these essentialist biases through experiences with biology texts than others. Experimental studies suggest that individuals already believing in essentialism are at a greater risk of strengthening essentialist biases when they encounter subtle references to race in the biology curriculum. For example, Keller (2005) demonstrated experimentally that chronic prior belief in essentialism interacts with subtle references to race in the genetics curriculum to strengthen social prejudices about ethnic groups in a sample of German undergraduates. Such an outcome likely stems from the well-established finding that when reading science, new knowledge is constructed upon the reader's prior knowledge (Norris & Phillips, 2003; Pearson, Hansen, & Gordon, 1979). Consequently, indirect references to race in biology textbooks may strengthen essentialist thinking about race to a greater extent among students who already believe in biological essentialism of race prior to reading. Put differently, these students may confirm their prior essentialist beliefs through the reading process.

Given that essentialist biases are observable in both rural and urban populations within the United States (Rhodes & Gelman, 2009), a significant proportion of American students may come into the biology classroom already primed with biological essentialist beliefs about race. Studies that correct for social desirability bias demonstrate that one in five non-Black Americans believe that economic disparities between races are caused by genetics (Brueckner et al., 2005). Arguably, then, around 20% of the "non-Black" U.S. adult population conceptualizes racial difference through a schema of biological essentialism. If this schema is taught to children living with such adults, then it stands to reason that around 20% of non-Black children are exposed to biological essentialist beliefs about race in the home.

In point of fact, research demonstrates that essentialist biases can be transferred unwittingly from parent to child through the use of generic language (Rhodes, Leslie, & Tworek, 2012). Generic statements describe a kind or category rather than particular members of a category (e.g., compare "boys wear blue", which is a generic statement, to "some boys wear blue" or "this boy wears blue", which are not generic statements). It is hypothesized that when children hear generic statements, it leads them to construct essentialist beliefs about categories because such statements imply that categories are uniform and informative. Support for this hypothesis comes from a study by Rhodes et al. (2012) who demonstrated experimentally that when adults and children hear generic language about a novel category, it leads both groups to essentialize that category. Furthermore, they demonstrated experimentally that when adults hold essentialist beliefs about a category they tend to use more generic phrases to describe that category when discussing it with children. In turn, when children hear adults using generic language to describe a novel category it elicits essentialist thinking about the category from the children (Rhodes et al., 2012).

On the basis of this research, a reasonable presumption is that around 20% of "non-Black" biology students come into the study of human genetics already possessing at least some essentialist beliefs about race acquired unwittingly in the family environment through a mechanism based in generic language. And, if teachers use generic phrases such as "Sickle-cell anemia is a disease that affects African Americans," or "Cystic fibrosis is a disease that affects Caucasians" when using textbooks to teach about monogenic diseases it may amplify the effect that biology textbooks have on the development of essentialist beliefs about race among these students.

The only study in the literature that gives any indication concerning the frequency with which high school teachers explicitly discuss race and biology is a 1979 study by Mertens, Hendrix, and Henriksen. They conducted a random survey of high school biology teachers from Alabama ($N = 113$), Massachusetts ($N = 114$), Oregon ($N = 121$), and Indiana ($N = 194$) and revealed that 32.7% of the teachers surveyed conjointly discussed the topics of race, genes, and intelligence quotient in their classroom. However, the researchers provided no evidence to characterize the nature of the curricular discussions involved in these lessons. Did these discussions teach students about the circularity of arguments involving hereditary explanations of intelligence (Gould, 1996)? Was the overwhelmingly negative contribution of this research to the lives of disadvantaged racial groups discussed (Gould, 1996; Morning, 2011)? Was the significant controversy surrounding the heritability of intelligence in different racial groups discussed (Flynn, 1999; Lewontin, 1974)? Given that American science textbooks often ignore social controversies surrounding science (Rosenthal, 1984), the likely answer to these questions is no.

Rosenthal (1984), for example, studied science texts to determine how the treatment of social issues has changed through time in science classes. She subjected 22 high school biology textbooks between 1963 and 1983 to a quantitative content analysis investigating 87 social issues identified from the literature. Her findings indicated that the total attention to social issues in science texts had declined through time. Yet, when textbooks did discuss social issues, they sometimes involved ethical questions related to the control of human genetics and racial superiority. In discussing such topics, however, science texts often lacked explicit recognition of the controversy surrounding them. Rosenthal (1984) stated that, "the social implications of... scientific disputes are virtually ignored" (p. 828) in science textbooks.

From a social justice perspective, textbooks that perpetuate biological essentialism of race and those that fail to challenge it are both unacceptable. Moreover, the evidence seems to suggest that biology textbook curricula fail to help our students develop accurate conceptions of racial difference. For example, in a study of 52 American college students

who were mostly biology and anthropology majors, Morning (2009) found that between 47% and 70% of students endorsed natural kind beliefs about race depending on the type of questions asked of them. Her sample of students argued that the conditions of slavery, selective breeding by slave owners, and the environment of Africa were evolutionary forces that produced the physical and athletic superiority of African Americans. Many of these students also believed that non-Black races had been naturally selected for intellectual traits (Morning, 2009). One student even believed that "different genes . . . lead to . . . different behaviors . . . that will define a race" (Morning, 2011, p. 154). It is impossible to say whether the latter student's belief in biological essentialism of race was strengthened by his previous experiences with the biology curriculum. Nevertheless, it is apparent that high school biology education failed to challenge this student's belief in biological essentialism of race.

In summary, there is no experimental research to suggest that the modern biology textbook curriculum successfully challenges biological essentialist beliefs about race held by students. Yet there is experimental evidence to suggest that the curriculum is capable of perpetuating biological essentialism of race. Rather than addressing race in an indirect manner, which might perpetuate biological essentialism of race, the modern biology curriculum could directly address race to challenge essentialist thinking and increase students' understanding of human evolution. How should textbooks address race, then?

HOW RACE SHOULD NOT BE ADDRESSED IN BIOLOGY TEXTS

Rather than outlining curricular guidelines at the outset, it is perhaps more instructive to first look back through the biology curriculum to find examples of how not to address race in biology textbooks. The next three sections describe three different portrayals of race in science textbooks during the middle to latter half of the 20th century to explore how race could, and should not, be addressed by a 21st-century biology curriculum. The first example is the 1941 high school biology text *Biology and Human Affairs (BHA).* The second is the 1968 *Biological Sciences Curriculum Study Yellow Version (BSCS Yellow)* and the third is the 1984 text, *Introduction to Biology: A Human Perspective*. *BHA* is a clear example of what to avoid in a biology curriculum about race. The *Yellow Version of BSCS* is a mixed example of a curriculum on race. It is an improvement on the previous text because it challenges entitative thinking about racial difference. Nevertheless, it might still perpetuate natural kind beliefs about race. Finally, *Introduction to Biology: A Human Perspective* is a clear attempt at an antiessentialist biology curriculum on race, yet it could be criticized because it might tacitly reinforce biological essentialism of race.

BIOLOGY AND HUMAN AFFAIRS (1941)

The second chapter of *BHA*, called *The Diversity of Life*, has 28 pages devoted entirely to distinguishing among the four "Great Divisions of Mankind" (Ritchie, 1941, p. 59). Three of the six sections in this chapter are entitled: (a) What are the principle races of mankind? (b) How and when did the primary races of mankind originate? (c) What are the priniciple branches of the Caucasian race? The pages within this chapter contain many figures that define the evolutionary origins of racial groups (Ritchie, 1941, p. 73) and cultural and biological charactersitics of different racial groups (Ritchie, 1941, p. 64–81). *BHA* states that hair character, the shape of the head, the shape of the nose, and the amount of facial and body hair are all important indicators of racial identity (Ritchie, 1941). Human race is a "matter of biological kinship and not a place of residence" (Ritchie, 1941, p. 59). And while *BHA* does say that skin color is not a reliable classificatory mechanism for

race, it nonetheless states that "the Caucasian, Australoid, Negroid or woolly-haired, and Yellow-brown or Mongoloid" (p. 59–60) are scientifically agreed upon racial classification systems. In this way, *BHA* clearly communicates the idea that races are natural kinds.

There is also evidence that *BHA* strengthened belief in entitativity by stressing that social disparities are a reflection of biology. For example, it states that "a biologist expects to find natural differences in people. He is prepared to find great differences in mechanical, artistic, and intellectual ability . . . he knows that there are innate differences in persons that cannot be removed" (Ritchie, 1941, p. 39) and that "it is hard for many persons to become reconciled with these differences . . . and to the social and economic difficulties rising out of them" (p. 39). The solution *BHA* provides to this dilemma is that "an understanding of biology prepares for living more comprehendingly in the world of natural inequalities that we have and will have until all persons are born alike" (p. 40).

While it is difficult to refrain from a presentist critique of *BHA*, it should be apparent that this text is a clear example of how biological essentialism of race was communicated by biology texts in the early 20th century. It should go without saying that this is the kind of curriculum that should be avoided at all costs in our present era. It was only after World War II, during the period of the 1950s and 1960s, that biological essentialism was widely challenged by scholars and the popular media (Morning, 2011; Nelkin & Lindee, 1995). This was also an era of curriculum reform in science education (Rudolph, 2002; Welch, 1979; Yager, 1992), with one of the more famous reforms being the *Biological Sciences Curriculum Study (BSCS)* (1968).

THE *BIOLOGICAL SCIENCES CURRICULUM STUDY* (1968)

Rudolph (2002) argues that *BSCS* was a curriculum developed to address the concerns of biologists. It emphasized evolution and scientific epistemology to challenge anti-intellectual and communist ideologies that were prevalent in American society during the 1950s and 1960s (Rudolph, 2002). It also sought to raise the public status of biology relative to the other hard sciences to increase public support for biological research. Despite these different motives, one aspect that set *BSCS* apart from other science curricula was its coverage of the social implications of biology. The writers of *BSCS* believed that the social implications of the biological sciences differentiated biology from the other hard sciences and made biology a highly relevant topic for school science. Indeed, the writers of *BSCS* felt that the "future of civilization" (Rudolph, 2002, p. 153) rested in "sound biological understanding" (p.153). The 1960s were also an important period for the Civil Rights Movement in the United States. This fact was not lost on the writers of *BSCS* (Rudolph, 2002). Indeed, the writers of *BSCS* actively sought to eliminate the "regrettable tensions and misunderstandings between race groups" (Rudolph, 2002, p. 154). Thus, it could be argued that *BSCS* considered disabusing misconceptions about race to be an important goal for science education in the 1960s. In line with these goals, the *Yellow Version of BSCS* (1968) includes the following passages:

> All men can be classified, in a rough way, into such groups as the Negroid, Mongoloid, and Caucasoid races. But anthropologists recognize that each of the features by which people might be so classified show tremendous variation within any given population . . . Despite the fact that we can divide *Homo sapiens* into races on the basis of percentage differences of many inheritable traits, the different members of the human species are still much more alike then they are different. All possess strictly comparable organs and physical characteristics, and remarkable uniformity in most chemical characteristics. All racial types

> are known to be completely interfertile, and persons of mixed racial ancestry are in their turn fully fertile. (p. 624)

> Anthropologists who study cultures of men of different backgrounds from ourselves . . . agree that people who have been brought up in completely different surroundings, with cultural traditions very different from ours, can think and behave so differently from ourselves that many of us would consider them to have basically different human natures. Nevertheless . . . differences in human nature, while affected by both physical environment and heredity, are nevertheless most strongly influenced by the physical environment–culture and tradition. (p. 625)

While the 1968 version of *BSCS Yellow* still endorses a biological notion of race, it does so in a manner completely different than *BHA*. First, the similarities between human races are given far more emphasis in *BSCS* than in *BHA*. For example, *BSCS* (1968) states that "different members of the human species are still much more alike then they are different" (p. 624), whereas in *BHA* (1941) the four "Great Divisions of Mankind" (Ritchie, 1941, p. 59) are described in a chapter called *The Diversity of Life*. Second, the classificatory scheme for different races is nowhere near as elaborate in *BSCS* as it is in *BHA*. Differences in racial traits receive a few paragraphs of treatment in *BSCS* and they are described alongside many biological similarities between races. Conversely, racial classification schemes receive a total of 28 pages of coverage in *BHA*.

The risk posed by the *BSCS* text is that it might tacitly increase natural kind beliefs about race by teaching students that each race can be distinguished scientifically. At the same time, *BSCS* explicitly challenges the entitative component of essentialism, whereas *BHA* actively reinforces it. For example, *BHA* (1941) states that there are "great differences in mechanical, artistic, and intellectual ability" (Ritchie, 1941, p. 39) of people, and that these "innate differences in persons . . . cannot be removed" (p. 39). In contrast, *BSCS* (1968) ostensibly challenges entitiativity by discussing human differences in a gene–environment framework. For example, it states that "differences in human nature, while affected by both physical environment and heredity, are nevertheless most strongly influenced by the physical environment–culture and tradition" (p. 625). *BSCS* (1968) also undermines the idea that races are discrete entities when it states different races show "remarkable uniformity in most chemical characteristics" (p. 624).

In summary, *BSCS Yellow* (1968) posed a laudable challenge to biological essentialism of race even if it unwittingly supported the notion of races as natural kinds. Although its impact on how students perceived the racial turmoil of the late 1960s will never be known, the writers of *BSCS* certainly considered social cohesion between the races to be an important goal for science education in the late 1960s. For modern textbook developers, *BSCS* exemplifies the fact that race can be discussed in the biology curriculum for the express purpose of reducing inegalitarian racial thinking.

INTRODUCTION TO BIOLOGY: A HUMAN PERSPECTIVE (1984)

A total of four pages are devoted to the topic of race in *Introduction to Biology: A Human Perspective* (1984) *(IBHP)*. In the interests of brevity, the concluding summary to the section on race from the book is presented here:

> The term *race* is not widely used in biology because it has suffered from a variety of interpretations in other disciplines. Human groupings should generally not be termed races for the following reasons: the term is ambiguous, there is no consensus on what constitutes

> a race, geographic limits cannot be set for human races, zones of mixture are becoming increasingly broad, and in no case does a single characteristic distinguish all members of one human race from all members of another. (Farish, 1984, p. 475)

Based on the passage above, *IBHP* clearly challenges essentialist thinking about race. For example, it states that no single characteristic can distinguish all members of one racial group from another and it cites the ambiguity and lack of consensus about racial definitions. Both of these arguments are consistent with biological, social scientific, and historical research (see Table 1). Yet, some important arguments about race are curiously missing from *IBHP*. For example, the role that science played in the perpetuation of biological essentialism of race (see Hudson, 1996; Kleingeld, 2007; Morning, 2011; Smedley & Smedley, 2005; Stuurman, 2000; Wolf, Kahn, Roseberry, & Wallerstein, 1994) and the fact that race poses real consequences for how people are treated in American society (see Markus & Moya, 2011) are not discussed by *IBHP*. Furthermore, ambiguous statements such as "zones of mixture are becoming increasingly broad" (Farish, 1984, p. 475) could be construed as evidence for the historical existence of discrete biological races. It is impossible to know; however, it is plausible that this is exactly what *IBHP* implies. For example, earlier in the section on race *IBHP* states the following:

> The major racial groups were once geographically separated; however, throughout history and increasingly in more recent years, these groups have been mixing . . . The term *race* as now used is a statistical concept—a type of averaging whereby *most* members of one population may generally be distinguished from *most* members of another population. (Farish, 1984, p. 474)

The above passage clearly makes a statistical argument for biological racial differences. Thus, even though *IBHP* seems to challenge essentialism, it might tacitly reinforce essentialist beliefs among students who are unaware that group-based averages do not apply to all individuals within a group (i.e., the ecological fallacy). Furthermore, it is not biologically correct to state that, on average, *most* individuals of one population may generally be distinguished from *most* members of another population. Rather, on average, a proportionally low amount of human genetic variation is attributable to population level differences (Lewontin, 1972; Rosenberg, 2011). Even so, *IBHP* is an improvement on *BSCS* because it is an explicitly antiessentialist text.

In closing, *BHA* is an example of how not to teach about race. But *BSCS* and *IBHP* establish that there is a sound basis for challenging biological essentialism of race through the biology curriculum. Textbook writers could learn from the strengths and weaknesses of these latter texts and use the best modern scholarship on psychological essentialism to write textbooks that challenge essentialist thinking and improve understanding of human genetic variation and evolution. Of course, curriculum is not written in a vacuum. Rather it is a product of political and cultural struggles (Apple, 1993) such as policy reforms. Thus, any science curriculum that addresses race in the modern American education system must be designed in line with the NGSS (2013) if it is to be used in the science classroom.

RECLAIMING RACE IN THE ERA OF THE NGSS

To teach human biology is to teach about human biological variation. Yet, the *Framework for K-12 Science Education* (National Research Council, 2012) that motivates the NGSS provides virtually no guidance about how to teach about human difference during the study of human biology. And because the NGSS Framework was not informed by research on

biological essentialism, a curriculum framed by it may be ill equipped to teach about human biological variation. For example, by the end of Grade 12 the framework states that students must understand that group behavior evolved because group membership increases the chances of survival for individuals and their genetic kin (National Research Council, 2012). The *Framework for K-12 Science Education* also states that students must understand that distinct genes control human traits, such as skin color, by the end of eighth grade (National Research Council, 2012). Surely human racial difference is implicated in the learning of such standards if adolescents believe that races are "groups" that differ in "skin color" and "behavior." The absence of any kind of discussion of race in the NGSS means that students must make sense of these core ideas on human difference, which are salient to racial difference, but without any guidance about what these ideas portend for race.

Adding race into a biology curriculum framed by the NGSS to challenge essentialist thinking provides a meaningful framework for the study of human biology in the context of the NGSS. If not to challenge biological essentialism about race, then what is the reason (in the framework) for requiring students to understand that genes interact with the environment to produce variation in traits by the end of Grade 12 (National Research Council, 2012)? Is it simply to know that gene–environment interactions exist, or is it to know that gene–environment interactions undermine genetic determinism (Puig & Jiménez-Aleixandre, 2011)—a belief that lies at the heart of biological essentialism of social categories (Keller, 2005)? And, if psychological essentialism is associated with misunderstandings of heredity, intraspecific variation, and evolution (Evans et al., 2010; Opfer et al., 2012; Shtulman & Schulz, 2008), then why not use the study of human genetic diversity and evolution to point out the inaccuracies of biological essentialism about race? In short, rather than allowing students to make their own inferences about what the core ideas in the NGSS portend for race, educators and textbook developers could use the NGSS framework to develop curricula that properly teach about the intersection between human genetic variation and race.

To be clear, considerations for teaching racial and ethnic minority students are outlined in the Equity and Diversity Appendix of the NGSS (NGSS, 2013). Teachers are expected to value ethnic and racial diversity and account for it in their teaching of the core ideas, practices, and cross cutting concepts. In this appendix, it is written that teachers are supposed to be cognizant of "biased stereotypical views about the interests or abilities of particular students or demographic groups" (National Research Council, 2012, p. 11–12). As explained earlier, biological essentialism is a cognitive bias that is predictive of racial stereotyping. It therefore seems fitting to challenge biological essentialism of race through a curriculum motivated by the NGSS. Furthermore, the Equity and Diversity Appendix states that science instruction should build upon student identity and be relevant to scientific issues that affect students' "lives and communities" (National Research Council, 2012, p. 11–17). Essentialist thinking about race is implicated in racial prejudice and journalistic reports of human genetic research are known to strengthen biological essentialist biases about race that are implicated in racial prejudice (Phelan et al., 2013). In a racialized society such as the United States, a biology curriculum discussing race would thus be relevant to students' racial identities and to issues that affect their lives and communities.

POSSIBLE IDEAS FOR THE TEXTBOOK CURRICULUM

The population genetics knowledge summarized by Rosenberg (2011) would be a natural starting point for a curriculum that directly refuted biological essentialist conceptions of race and that also taught students about human genetic variation and evolution. In his paper,

Rosenberg (2011), a population geneticist in the Stanford Department of Biology, uses a genetic data set consisting of microsatellite polymorphisms from individuals in more than 50 indigenous populations distributed worldwide to answer the following questions (p. 660):

1. Are most alleles widely distributed, or are they largely confined to specific parts of the world?
2. Do distinctive alleles exist for specific geographic regions that distinguish individuals in one group from those in other groups?
3. Of the genetic variants that exist in the human genome, how many are present within a given geographic region?
4. On average, how different are two individuals from the same local population when compared with two individuals chosen from any two populations anywhere in the world?
5. To what extent is it possible to determine the genetic ancestry of an individual using the alleles in his or her genome?
6. What events in human evolutionary history are responsible for the basic patterns of genetic similarity and difference evident in worldwide human populations?

According to Rosenberg (2011), the answer to the first question is that most alleles (46.6%) are found in each of the major geographic populations of humans and only 7.53% of alleles, so-called private alleles, are found within any single region. Thus, the vast majority of alleles are found in two or more human populations. Of the small proportion of alleles private to a single region (7.53%), roughly half (56.3%) are found in Africa. Most of these alleles, however, occur at an exceedingly low proportion (about 1.06%) and they cannot be used to reliably distinguish individuals in one group from those in another group, which is the answer to question two. Regarding question three, on average 74.91% of the alleles found in the human genome can be found in any randomly picked geographic population of humans. The answer to question four is that if we randomly pick two individuals from two different geographic regions and compare them to two randomly picked individuals from the same geographic region, we can expect that the former will only be slightly more genetically different from one another, on average, than the latter. For example, 93.2% of genetic differences between randomly chosen individuals occurs within populations, 2.5% of such differences occur across populations within continental regions, and 4.3% of the average genetic difference between any two humans can be attributed to differences across the continental regions (Rosenberg et al., 2002) commonly associated with racial categories. Finally, population geneticists can determine a person's geographic ancestry from their genome, which is the answer to question five.

The evolutionary explanation (question 6) for these findings is that humans expanded out of Africa through a process involving founder effects (Rosenberg, 2011). That is, in each new migration the migrating group carried only a subset of the original genetic and phenotypic variation from the parental population. Therefore, as you travel along the hypothesized migration route out of Africa and into Central Asia and then on to Europe or East Asia and the Americas there is a steady decrease in human genetic variation (Rosenberg, 2011). As populations became established along this pathway, the major geographic barriers in the area (i.e., oceans and mountain ranges) reduced the rate of gene flow between neighboring populations. Additionally, the further two populations were from each other the more they were isolated by distance, which meant that geographically distant populations were less likely to share genes. Random processes of genetic drift within any single population further

changed the frequency of genes in each population and all of these factors led to the human genetic variation observable across human populations today.

It should be apparent from these findings that human populations are, for the most part, genetically similar. Yet, we can expect that there are some small genetic differences between racial groups when those groups are defined geographically. What Rosenberg's (2011) analysis does not show is that human groups possess a genetic essence that makes members of the group highly uniform, and yet different from other groups. For example, Rosenberg (2011) shows that there are no alleles that "are present in all members of one region but absent from individuals outside the region" (p. 668). Furthermore, it is not the case that racial groups are discrete if half of the alleles in the human genome are found in every geographic region and three quarters of these alleles are present, on average, in any randomly picked region (Rosenberg, 2011). Finally, the essentialist view that you can only be a member of one race is not supported by genetic data because racially classified humans can have ancestry in more than one geographic region commonly associated with race (Rosenberg, 2011).

It is difficult to imagine how human evolution could be taught properly without raising and answering the questions outlined by Rosenberg (2011). And, if a textbook curriculum on race explains the answers to these questions, then it should also teach students about how population geneticists answer these questions. For example, there are two important analytic methods used to understand human genetic variation and ancestry: (i) variation partitioning and (ii) genetic clustering (Winther, 2014). Variation partitioning methods average gene frequencies across loci to investigate how much genetic variation occurs within populations and across populations. Genetic clustering techniques, on the other hand, assign an individual's genome to a theoretical population using the accumulated information present in a genome.

For instance, if the frequency of an allele, let us call it "identity allele A," is 47% in Europe, 34% in Asia, and 40% in Africa, then knowing whether a person possesses identity allele A does not permit a confident inference about whether that person's ancestry is Asian, African, or European. But imagine a scenario in which we discover that an uncategorized person also possesses identity allele B and that this allele occurs at a frequency of 60% in European populations and at a frequency 40% in African populations and 44% in Asian populations. With these two pieces of information, we can be slightly more confident that the ancestry of our imaginary individual is European because identity alleles A and B are most prevalent in these regions. When all of the tiny frequency differences in the prevalence of alleles are accumulated across populations without averaging across loci, then geneticists are able to differentiate humans into clusters using probability models similar to, although much more complex than, the previously described heuristic. Thus, genetic clustering methods are how population geneticists infer a person's geographic ancestry from genetic data.

The high school biology curriculum could introduce students to the conceptual differences between diversity partitioning and genetic clustering methods to teach students that scientists use mathematics to construct models to investigate human genetic variation and common ancestry. Then, it could show students how population geneticists interpret the data in light of biological theory to construct evidence-based explanations for the patterns of human genetic diversity observed. Research tentatively suggests that high school students find epistemologically considerate texts more interesting to read and they find the claims presented in these texts more trustworthy than the claims presented in traditional textbooks, which often ignore how knowledge is produced (Kloser, 2013). Therefore, if written in an epistemologically considerate manner, a curriculum on race could target the NGSS practices of "model building," "using mathematics and computational thinking,"

"analyzing and interpreting data," and "constructing explanations" in conjunction with the NGSS core idea of "Biological Evolution: Unity and Diversity."

After providing a conceptual explanation of the differences between these methods, the curriculum might also explain that certain scientists (e.g., Lewontin, 1972) have interpreted findings from variation partitioning studies as support for the claim that races are not biologically real. At the same time, certain scientists (e.g., Edwards, 2003) have interpreted the findings of genetic clustering studies as evidence for the claim that races are biologically real. Of course, the big idea here is that scientists can apply different methods to the same genetic data set and claim different things about the reality of race. Students could be taught about these arguments in order help students understand the "arguing from evidence" core idea in the NGSS. In so doing, students could be introduced to another big idea about the relationship between race and genetic data, which is that the reality of race is not found in genetic data; rather, it is found in scientists' culturally specific interpretations of that data (Winther, 2014). At this point, it would also be natural to teach students how there has never been any generally agreed-upon racial classification system in the history of scientific research (Morning, 2011; Smedley & Smedley, 2005).

The texts that explain these big ideas could also be used to help students understand a fourth big idea about race and science, which is that scientific racism occurs when the humans conducting scientific research interpret their data on human difference to support their prejudices or when scientists communicate their work to the public to advocate for prejudiced social policies (Gould, 1996). After introducing students to these four ideas, the curriculum could introduce students to the long history of cultural prejudice in scientific research on intelligence and criminality (read Gould, 1996 or Zeidler et al., 2002). If this curriculum also taught students that racially stereotyped traits such as intelligence and criminal behavior are now understood through a framework of gene–environment interactionism (see Caspi & Moffitt, 2006; Longino, 2013), it could also challenge the genetic determinism inherent in biological essentialism of race.

The ideas in this preliminary syllabus are by no means comprehensive and there are likely many statistical concepts (such as mean and variance) that ought to be included in the curriculum as well. Nevertheless, these ideas are a starting point and they could be tested to ensure that, if taught through text-based instruction, they decrease belief in biological essentialism of race and increase understanding of human evolution among students. At the very least, these ideas would align well with the practices in the NGSS and the core ideas on group behavior, gene–environment interactions, common ancestry, and evolution.

All that said, we must heed the old aphorism "the road to hell is paved with good intentions" when designing this new textbook curriculum on race. As *BSCS* and *IBHP* show, it is possible to communicate biological essentialism of race tacitly while attempting to challenge it. Furthermore, many students may come into the classroom already viewing racial difference through a lens of biological essentialism. Since the construction of knowledge through reading is influenced by the reader's prior knowledge (Norris & Phillips, 2003), any new biology textbooks attempting to accomplish the goals set forth in this paper need to carefully discuss race or they risk reinforcing prior conceptions of race based in biological essentialism. How can texts avoid this pitfall?

STRUCTURING THE TEXT TO CHALLENGE BIOLOGICAL ESSENTIALISM

Moving forward, textbook designers should first look to the past to find instructive examples of how not to address race, such as those outlined earlier in this paper. Then, they should turn to the literature on reading comprehension to identify how future texts

can facilitate conceptual change of biological essentialism of race. For example, in a meta-analysis drawing upon 23 studies that tested the effects of 25 different text-based strategies to address misconceptions in science, Guzetti, Snyder, Glass, and Gamas (1993) found that text can affect conceptual change by itself under two conditions. Text can produce conceptual change when it explicitly challenges scientific misconceptions *and when it also explains* the consensus scientific understanding of a concept. Texts that accomplish both of these objectives are called refutational texts and a study by Braasch, Goldman, and Wiley (2013) provides experimental evidence that students develop more accurate conceptions of scientific ideas when they read refutational texts rather than standard science texts. Furthermore, their research indicates that students possessing accurate conceptions prior to reading a refutational text still maintain their accurate conceptions after reading a refutational text. Thus, as long as refutational texts are constructed in line with the two principles outlined above by Guzetti et al. (1993), exposure to misconceptions in a refutational text should not increase the prevalence of misconceptions among students.

Refutational texts may therefore be a safe way to challenge biological essentialism of race. Texts, for example, could explain to students the commonsense understandings of human difference that are biologically inaccurate (i.e., biological essentialist conceptions of race). Next, they can use the ideas outlined in the previous sections or the arguments outlined in Table 1 to explain how scientists actually conceptualize human difference *and* how this is not consistent with biological essentialism. If texts were designed in this way, then they might avoid the unintended consequence of strengthening belief in biological essentialism of race. Furthermore, using refutational texts to teach about the ideas outlined above could also enhance students' scientific literacy.

USING THE TEXT TO ENHANCE SCIENTIFIC LITERACY

Scientific literacy is one of many motivations behind the NGSS (National Research Council, 2012). Although scientific literacy takes on many different definitions in the science education literature, in a fundamental sense it can be understood as the ability to comprehend, interpret, analyze, and critique scientific texts (Norris & Phillips, 2003). It is through this fundamental sense of scientific literacy that students develop the derived sense of scientific literacy, which is being knowledgeable, learned, and educated in science (Norris & Phillips, 2003). To develop the fundamental sense is to teach students how to read science texts, to give them interpretive strategies to deal with science texts, and to teach them that science texts are written to preclude certain interpretations (Norris & Phillips, 2003).

If the epistemologically considerate and refutational textbook curriculum outlined above is used in the classroom to develop students' fundamental literacy, it could contribute to the derived scientific literacy goal of "Understanding Reports and Discussion of Science That Appear in the Popular Media" (DeBoer, 2000, p. 592). To reiterate, race is regularly discussed in reports on human genetics in the popular media and such reports demonstrably increase belief in biological essentialism of race among American adults (Phelan et al., 2013). If students learn how to read science texts using a curriculum such as the one outlined above (i.e. developing scientific literacy in the fundamental sense), then students will possess a greater understanding of population genetics research and how it does not support biological essentialism of race. Such a curriculum could make students aware of the history of scientific racism and the big idea that the reality of race is not determined by genetic data rather it is determined through our cultural interpretations of that data. Therefore, the textbook curriculum outlined above could provide students with the prior knowledge needed to comprehend journalistic reports of human genetics research without coming to

believe more strongly in biological essentialism of race. In this way, the curriculum could contribute to the derived scientific literacy goal of "reducing racism and racial inequality through a proper understanding of human biology".

Millar (2006) argues that topics should be included in a scientific literacy curriculum if they "might make a difference to a decision or choice that a citizen could have to make, or to the viewpoint he/she might hold on an issue or decision at local or national level, or if it offered a culturally significant view on the human condition (on our ideas about 'who we are and where we are')" (p. 1507). The textbook curriculum outlined here surely offers students a "culturally significant view on the human condition" (Millar, 2006, p. 1507). And if this curriculum reduced essentialist thinking about race, then it might make a difference to a decision or choice that a citizen could have to make on a racial issue at the local or national level, because studies demonstrate that belief in biological essentialism of race reduces individuals' concerns about redressing racial disparities (Williams & Eberhardt, 2008). At the very least, teaching about human genetic variation, evolution, and race could help students understand "who we (humans) are."

CODA

It is a well-established finding that students bring preconceptions into the science classroom that may be scientifically inaccurate or incomplete (Branford & Donovan, 2005). Good science curriculum and instruction addresses these preconceptions. It uses them as fodder for learning. We would never teach physics without addressing the prevalent misconception that objects of different weights fall at different rates. Why would we teach about human biology without addressing the equally inaccurate, if not more socially problematic, misconception of biological essentialism? To engage in the process of research and development to understand how we should teach about race is what it means to reclaim race as a topic of the U.S. biology curriculum. Learning about race in school biology does have the potential to strengthen or weaken essentialist beliefs prevalent in American culture. And whether we like it or not, race was addressed directly by biology textbooks of the past and it is addressed indirectly in modern biology textbooks. In the past 100 years of school, biology students must have learned something about race through its treatment in biology textbooks. The fact that we know so little about the potential consequences (positive or negative) of these treatments, or the absence of enlightened treatment, is concerning. And in either case, our ignorance cannot be considered bliss. If a goal of science education is to increase the deliberative capacities of students in a democracy by increasing students' derived scientific literacy, then biological essentialism of race, which tends to legitimate inequality, should be challenged by a democratic science education. In our postgenomic era when human genetic difference is increasingly portrayed through a racial lens in the media, we ignore the topic of race in biology education at our own peril.

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