Confronting the Legacy of Eugenics and Ableism: Towards Anti-Ableist Bioscience Education

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ABSTRACT

Society and education are inherently ableist. Disabled people are routinely excluded from education, or have poorer outcomes within educational systems. Improving educational experiences and outcomes for people of color has required educators to design antiracist curricula that explicitly address racial inequality. Here, we explore parallel antiableist approaches to bioscience education in an essay coauthored by a disabled bioscience student and able-bodied faculty member in bioscience. Our work is underpinned by Critical Disability Theory and draws on disability and pedagogical scholarship as well as our own experiences. The biosciences has a unique need to confront its history in the discredited pseudoscience of eugenics, which has led to discrimination and human rights abuses against disabled people. We provide a brief history of the relationship between biological sciences research and eugenics and explore how this legacy impacts bioscience education today. We then present a recommended structure for antiableist biology education. Our approach goes beyond providing disability access, to a model that educates all students about disability issues and empowers them to challenge ableist narratives and practices.

INTRODUCTION

Educators are increasingly confronting the impact of structural bias and discrimination on their curricula (Killpack and Melón, 2016; Law, 2017; Arday *et al.*, 2021). Many have done so through the lens of racism, highlighting the legacy of racial oppression on their discipline. In this article, we call on bioscience educators to pay equal attention to disability-based discrimination, oppression and ableism. Disabled students have poorer educational outcomes (Disabled Students UK, 2022), and often face exclusion, inaccessibility, and prejudice during their studies (Holloway, 2001; Reinholz and Ridgway, 2021; Gin *et al.*, 2022). Bioscience is no exception to structural bias. As bioscience educators, we have a unique responsibility to confront ableism, as biology has been used to justify disability-based discrimination, oppression and human rights abuses (Levine, 2017; Reese, 2023). Biology directly informed the discredited pseudoscience of eugenics, the selective breeding of humans to eradicate "undesirable traits" (Bashford and Levine, 2010; Rutherford, 2022). Eugenics became a dominant philosophy around the world in the late 19th and early 20th centuries, resulting in the oppression of countless disabled people. With the development of genetic testing and gene editing, modern medicine risks creating a "new eugenics" where disabled people are eliminated through private reproductive choices rather than state control (Dive and Newson, 2022; Rutherford, 2022). We argue that bioscience educators have a personal and ethical responsibility to address this historical and contemporary oppression within our discipline (Killpack and Melón, 2016; Hales, 2020).

This article is cowritten by a disabled student and able-bodied faculty member, both from bioscience. Our approach goes beyond considering disability access needs, to actively challenging ableism embedded in bioscience, in parallel with equivalent

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antiracist approaches to education (Arday *et al.*, 2021). We explore ableism and the eugenics movement, their connection to bioscience research and their ongoing impact on bioscience education. We also offer recommendations for antiableist bioscience education that can be implemented in a range of educational contexts.

Positionality

We write through the lens of UK Higher Education, and use the legal definition of disability in the UK Equality Act (2010). This defines disability as physical or mental impairment that has a "substantial" and "long-term" negative effect on your ability to do normal daily activities. It covers specific learning differences (e.g., dyslexia), neurodivergence (e.g., autism), intellectual disabilities, long-term illness, mental health conditions as well as physical disabilities. Our work is grounded in pedagogical and disability scholarship, but we also draw on personal experience. These examples do not imply that our institution is better or worse than others for disability inclusion, but illustrate how widespread ableism is in education. While our focus is on university/college level education, much of what we present would be relevant to school-level audiences if presented age-appropriately.

Sarah-Marie: I am a Zoology postgraduate who identifies as disabled. I have a spinal condition and many chronic illnesses, so I use a wheelchair full-time to navigate my life. My disabilities started when I was 14, but I did not identify as disabled until I was 20 y old as I perceived disability as many other people do: negatively. I considered my illnesses and conditions to be less severe than other people's, so in my mind, that meant I was not disabled, even though I still needed help with cooking, getting dressed, etc. I was trying to hold onto the life I had before I was a wheelchair user and that was holding me back from grieving my old self and moving forward with my life.

I consider my wheelchair to be my freedom now as I can go almost anywhere in it. However free I felt being able to navigate the world came to a halt whenever I went to my university campus. There would often not be an accessible desk, a place to sit in my wheelchair or a way to get into the lecture theatre other than stairs. After having very similar experiences of exclusion and ableism at my 6th form college (equivalent to 12th grade in USA), I had to do something about it. I became involved in Disability Rights activism and was elected as Disabled Students' Representative for the university. In my role, I pushed the university to make changes that should have been made decades ago. As proud as I am about the changes I was able to make happen, there is so much more to do. Academia should be for everyone. The hard truth is that academia is not accessible to everyone and is inherently ableist towards disabled students.

Katharine: I am an academic staff member in biosciences who does not identify as being disabled. I have a mental health condition that can seriously impact my daily life, classing me as disabled under the Equality Act (2010). While I have used these legal rights when negotiating with my employer, I self-define as someone with a mental health condition, not as a disabled person. While writing this article, I have undergone multiple tests for fetal disabilities as part of routine pregnancy management in the UK. My nephew has a rare genetic disorder that causes severe physical and intellectual disabilities. Both have prompted me to consider my attitudes to disability, as well as the way I teach these topics. I recognize my able-bodied privilege, so I defer to those with lived experience of disability. Sarah-Marie has actively challenged my thinking on this topic for which I am thankful. I wrote this article to educate myself, identify where educators may lack understanding of disability, and propose practical steps to reduce ableist bias.

Theoretical Framework

Our work draws on Critical Disability Theory (CDT). Bioscience educators may be more familiar with Critical Race Theory (CRT), a broad field that positions racism as a structural feature of society, embedded in institutions, economic, and political systems and legislation (Delgado and Stefancic, 2023). CDT or "DisCrit" builds on CRT and Disability Studies, viewing ableism as a societal power structure that oppresses disabled people, often inherently associated with racial oppression (Annamma *et al.*, 2013; Hall, 2019). This theory underpins disability justice, which goes beyond disability rights to seek the liberation of disabled people (Reinholz and Ridgway, 2021). DisCrit also recognizes the psychological impacts of being "othered" on the basis of disability, and seeks to amplify voices of historically minoritized people (Annamma *et al.*, 2013). DisCrit can be used to understand ableism in education, and its intersection with educational racism (Annamma *et al.*, 2016; Annamma *et al.*, 2018). For example, disabled students of color are more likely to be placed in special schools for the disabled than white peers, who are more likely to be educated in mainstream settings (Annamma *et al.*, 2013).

Many educators are attempting to decolonize their curriculum (Arday *et al.* 2021; Dessent *et al.* 2022; Reese 2023; Joshi *et al.* 2024). Decolonial theories challenge the historical and current legacies of colonialism and exploitation by white able-bodied Europeans (Mendoza, 2020). We argue that genuine decolonization also requires consideration of disability, and its intersection with race. "Scientific racism" refers to the use (or abuse) of science to provide a veneer of objectivity to racist stereotypes (Dennis, 1995; Reese, 2023). Modern genetic analysis confirms that race is a social construct, not a biological reality (Duello *et al.*, 2021). However, disability based arguments were often used as justification for racial discrimination. For example, people of African descent and Indigenous peoples were classified as less intellectually capable, or not even fully human (Figure 1; Annamma *et al.*, 2013). Disability itself has also been understood through pseudoscientific categorization. "Idiot", "moron", and "imbecile" were clinical terms to describe people with intellectual disabilities through much of the 19th and 20th century (Figure 1) (Thomson, 2010; Rutherford, 2022). Just as colonized peoples were excluded from knowledge creation (Quijano, 2000), disabled people have been excluded from research other than as study participants, and disabled voices and perspectives are lacking in educational and scientific communities (Ashby, 2011). To truly decolonize bioscience education we must recognize these structural biases, and take proactive steps to confront them in our teaching.

ABLEISM AND MODELS OF DISABILITY

Ableism is society's negative attitude and prejudice toward disabled people. The phrase "this world is not built for me" rings too true for disabled people, as the world is an inaccessible place that is often unwelcoming to them. The leading disability

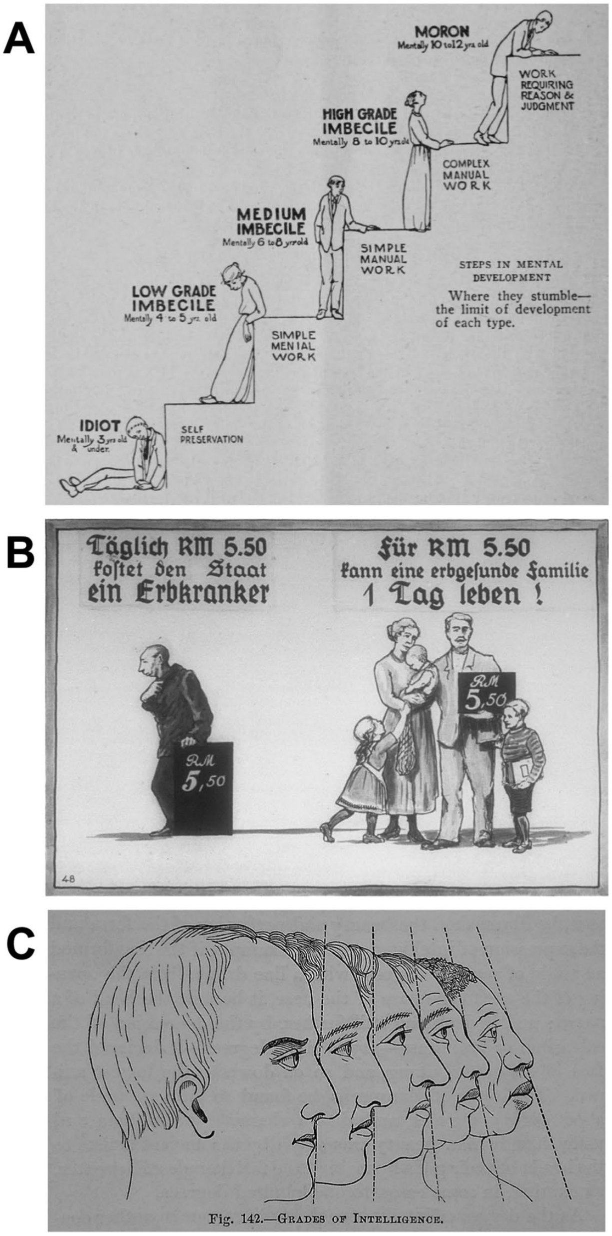

FIGURE 1: Examples of historical ableism and scientific racism. A: Image describing levels of "mental defectives" from (MacMurchy, 1913). B: Nazi propaganda against disabled people; the caption reads, "A hereditary disease costs the state RM5.50 a day. For RM5.50, a hereditary healthy family can live for 1 d". C: "Grades of Intelligence" from (Wells, 1868) illustrates the connection between racial stereotyping and assumed intelligence.

scholar Thomas Hehir states that ableism is when a child is told that it is preferable for them to "read print rather than Braille" or "walk rather than use a wheelchair". An ableist perspective would encourage children "to be friends with nondisabled kids rather than with other disabled kids" (Hehir, 2007). Ableist behavior harms the child's relationship between themselves and their disability. How can someone grow up feeling content with themselves if society tells them that something that is truly a part of them is broken or inadequate?

Ableist behavior relates to the medical model of disability, focusing on what is "wrong" with the person and how to treat it (Reinholz and Ridgway, 2021; Gin *et al.*, 2022). For example, a doctor may recommend a cochlear implant for a child after medically diagnosing deafness. As a non-medical alternative, the child could learn sign language and immerse themselves in d/Deaf culture. The medical model of disability can result in disabled people feeling isolated and treated as if they have no capacity of their own. It also shapes the attitudes of able-bodied people, who may react with pity or incredulity when disabled people speak about their disability in a positive light (Goering, 2015). Within education, disabled students are routinely "othered" by institutions who typically provide reasonable adjustments on a one-to-one basis, reinforcing a medical model (Gin *et al.* 2020, 2022).

> *"Doing disability all day long can be an exhausting process. I don't mean having an impairment, in my own case not being able to walk. Like most disabled people I can deal with this. I mean having to spend a significant part of each day dealing with a physical world which is historically designed to exclude me and, even more tiring, dealing with other people's preconceptions and misconceptions about me." (Keith, 1996).*

Many disabled people favor the social model of disability. The social model states that the disadvantages they face do not stem directly from their disability, but from negative perceptions and inaccessibility of the world around them (Shakespeare, 2006; Reinholz and Ridgway, 2021). The social model of disability increasingly informs educational practice, with educators reconsidering assumptions about disability and how disabled students can be more actively and authentically included, or disability adjustments mainstreamed as good educational practice for all (Omissi, 2020).

Disability is a highly personalized experience; what one person considers disabling may present relatively few issues to another (Gin *et al.*, 2022). Some people legally classified as disabled may not identify as such, particularly for neurodivergence, achondroplasia (little people) or members of the Deaf community (Shattuck *et al.*, 2014). Many disabilities are invisible, and many do not disclose their disabilities due to social stigma (Reinholz and Ridgway, 2021). Some have good support from healthcare providers, while others are undiagnosed or even dismissed by the medical establishment. Others have multiple compounding disabilities. For example, dealing with mental health issues may be more challenging for individuals with chronic pain. Disability is intersectional (Crenshaw, 1989). Barriers to disability inclusion are greater for Black, Asian and Ethnic Minority, and Indigenous people, or those from LGBTQIA+ or socioeconomically deprived communities (Reinholz and Ridgway, 2021; Gin *et al.*, 2022). It is important not to assume a singular "disabled experience", but to respect and center authentic disabled voices. Given the high prevalence of disability in the population, most people will also have friends and family members who are disabled and may have witnessed discrimination, exclusion or lack of dignity given to their loved ones.

We distinguish between accessibility and genuine disability inclusion. For example, tiered lecture theatres on our campus are legally classified as having disabled access. However, in some, students in wheelchairs can only access flat spaces at the front while able-bodied peers sit in tiered rows at the back. "Accessible" lecture theatres may not have a desk for a student in a wheelchair, preventing them from fully engaging in their studies. While this technically meets legal building standards, it is not an inclusive environment where disabled students feel welcomed and able to contribute on an equal basis. We regard accessibility as providing the minimum required to allow a disabled person to engage in an activity, while genuine inclusion allows disabled people to interact seamlessly with resources and others.

Eugenics as an Expression of Ableism

The term eugenics means "well born", deriving from the Greek "eu" (well) and "genos" (offspring; product). Deciding who is "well born" (and who is not) is highly subjective and reflects systemic biases. Levine writes:

> *"For all its evocation of scientific rationality, eugenics could not escape the social worlds, deeply influenced by race, class and gender differences, in which it was both forged and pursued." (Levine, 2017).*

To this, we must add disability. It is indicative of the pervasiveness of ableism that even this contemporary structural criticism of eugenics overlooks societal attitudes to disability. The categorization of people of African origin as less intellectually capable was racist, but the assumption that limited intellectual capability justified human rights violations is ableist. This disability-driven prejudice is often overlooked. While disabled people have been othered throughout history, it has been argued that the Industrial Revolution greatly magnified ableist prejudice (Rose, 2017). In a capitalist model requiring economic productivity from all, disabled people became a cost to the state (Figure 1). Eugenicists were particularly concerned about intellectual disability (Thomson, 2010; Levine, 2017). This was driven partly by concerns about terrible conditions for patients institutionalized in asylums, and also through fears that the "feeble minded" could proliferate undetected within the general population and cause social problems (Thomson, 2010). With the expansion of voting rights, many were concerned about the intelligence of new voters from the "lower" classes (Levine, 2017). Compulsory schooling and new standardized tests enabled systematic identification of the "mentally defective" and "feeble minded", often resulting in institutionalization (Levine, 2017). Eugenics, therefore, was seen as a practical solution to reducing the societal burden of disability (Figure 1). It reinforced existing social prejudices rather than creating them. We cannot confront the legacy of eugenics without also addressing the underlying ableism that enabled the oppression of disabled people (Powell, 2021).

BIOSCIENCE AND EUGENICS: A DARK HISTORY

To become antiableist educators, we must be able to discuss and challenge ableism, including eugenics. However, many bioscientists are unaware of this historical and social context. We, therefore, present a brief history of the relationship between bioscience and eugenics. We recommend Levine (2017) for a social history of eugenics, and Rutherford (2022) for a scientific account of eugenics intended for a broad audience.

Eugenics was distinct from other attempts to manipulate human reproduction due to its intellectual grounding in "scientific" principles and theories (Bashford and Levine, 2010). It particularly drew on new understandings of evolution, heredity and genetics (Turda, 2010). The late 19th century saw Darwinian theories of natural selection emerge, and the rediscovery of Mendel's work in the early 1900s informed the new science of classical genetics (Roll-Hansen, 2010). The concept of reproducible inheritance contributing to human evolutionary fitness underpinned eugenic thinking. Eugenicists argued that inherited traits could be removed or amplified within the population with appropriate interventions in human reproduction (Roll-Hansen, 2010). Eugenicists frequently used over-simplified models of inheritance to underpin their objectives; they typically assumed complex traits were caused by single genes, and consistently minimized the importance of the environment (Roll-Hansen, 2010; Rutherford, 2022). Undesirable traits assumed to follow single gene inheritance included deafness, epilepsy, schizophrenia, mental defectiveness, and even alcoholism, promiscuity or criminality which were presented as evidence of "feeble mindedness" (Bashford and Levine, 2010). Even at the time it was known that genetic inheritance was more complex than the single-gene models advocated by many eugenicists (Roll-Hansen, 2010). However, reductive models of inheritance were used as justification for reproductive intervention. Positive eugenics focused on encouraging people with desirable traits to reproduce, while negative eugenics prevented people with undesirable characteristics from having children (Levine, 2017). Eugenic practices ranged from sex education, marriage counselling, restrictions on marriage, and contraceptive program, to sterilization, abortion, euthanasia, and ultimately murder (Levine, 2017).

Eugenics as a term was coined by Francis Galton, a cousin of Charles Darwin (Gillham, 2009). Galton stated that with the adoption of eugenics *"the race as a whole would be less foolish, less frivolous, less excitable, and politically more provident than now" (Galton, 1904)*. His work "Hereditary Genius" statistically described and quantified human heritability, although has been described as "*a superlative showcasing of confirmation bias*" (Rutherford, 2022). Galton founded a center for eugenic research, and funded a Chair of Eugenics at University College London (UCL). This position was first held by Karl Pearson who developed the chi-square test, standard deviation, correlation, and regression coefficients. He founded the journal Annals of Eugenics (now the Annals of Human Genetics; Delzell and Poliak, 2013). He regarded the "lower races" as being genetically inferior "stock", which included the "handicapped" and those with a "mental defect" or who are "feebleminded" or "socially inefficient" (Pearson, 1905, 1931; Spencer and Paul, 1998). R.A. Fisher was appointed as the next Galton Professor of Eugenics (UCL, 2020). Fisher was one of the most influential biologists of the 20th century, who made major contributions to evolutionary biology and population genetics, and developed mathematical concepts such as analysis of variance (ANOVA), the null hypothesis and $P = 0.05$ as a statistical threshold (Fisher, 1930; Bodmer *et al.*, 2021). Fisher's (1930) book "The Genetical Theory of Natural Selection" was a key text in the modern synthesis of Mendelian and Darwinian theories, but also contained five chapters on eugenic proposals. Fisher was a proud eugenicist who thought that the "genetically unfit" should be forcefully sterilized (Bodmer *et al.*, 2021). Although the UK was the intellectual birthplace of eugenics, no forced eugenic policies were ever enacted, although they were debated in parliament but ultimately rejected in favor of institutionalization (Moghaddami, 2021; Rutherford, 2022).

In the USA the eugenics movement was led by Charles Davenport, drawing inspiration from Galton's work (Selden and Montagu, 1999; Farber 2008; Lombardo, 2011; Cold Spring Harbor Laboratory, 2021a,b). Davenport established the Eugenics Record Office (ERO) at Cold Spring Harbour in 1910, which collated questionnaire records to develop models of inheritance (Reilly, 2015; Cold Spring Harbor Laboratory, 2021b). Over 750,000 records were collected, detailing physical disabilities, "feeble mindedness", "criminality", and "rebelliousness", which were all assumed to be Mendelian traits (Cold Spring Harbor Laboratory, 2021b). The ERO became a leading center for eugenic research. The work of Davenport and his deputy Harry H Laughlin was less rigorous than that of their UK contemporaries, but was more politically influential. Davenport's "Race crossing in Jamaica" was directly criticized by Pearson on technical grounds, but built support for state laws preventing racial intermarriage (Roll-Hansen, 2010). Laughlin presented ERO findings to Congress, directly leading to the Johnson-Reed Act (1924) which limited immigration from "inferior" regions of the world (Ludmerer, 1972). Laughlin also drafted forced sterilization laws which were adopted by multiple US states (Kevles, 1999; Farber, 2008; Lombardo, 2011; Reilly, 2015, and led to reproductive control and suffering of disabled people. While ERO "research" was discredited by the 1930s, the precedent enabling forced sterilization on disability grounds (Buck vs. Bell, 1927) has never been overturned (Lombardo 2011; National Women's Law Center, 2021). A direct line can, therefore, be drawn between the academic study of inheritance to legislation and practices that impacted upon countless disabled and marginalized people.

Eugenics was a global phenomenon, although specific eugenic practices varied considerably by country (Bashford and Levine, 2010). Some countries focused efforts on physical and intellectual disabilities, while others used eugenic strategies to influence the racial makeup of their population, often by targeting indigenous peoples. Eugenics in the French and Latin American traditions drew intellectual inspiration not from Mendelian genetics but from Lamarckian ideas of environmental heredity (Levine, 2017). Lamarckism proposes that physical characteristics acquired by an individual during their lifetime can be inherited by offspring. This theoretical framing resulted in reproductive control over individuals who contracted sexually transmitted diseases, prostitutes, alcoholics and criminals. Eugenics in Latin America did not generally involve forced sterilisation (Sánchez-Rivera, 2021). However, disability was still a reason to restrict reproduction. The Mexican Eugenic Code stated that "*Sick parents, either mentally or physically ill, cannot produce healthy offspring; most of them are insane criminals, blind, and perverted ….. If a couple is not completely healthy, they should abstain from sex and not bear any children.*" (Sánchez-Rivera, 2021).

Before World War II there was widespread support for eugenic ideas, although this was by no means universal (Hart, 2012). Known supporters of eugenics included Winston Churchill, Alexander Graham Bell, George Bernard Shaw, Theodore Roosevelt, HG Wells, and Marie Stopes (Bashford and Levine, 2010). Many approved of contemporary eugenics programs which led to the sterilization and deaths of many disabled people. For example, between 1930 and 1970 Sweden sterilized around 60,000 people to reduce the number of children born with genetic diseases (Kevles, 1999).

Nazi ideology took these ideas to their abominable extreme. Alfred Ploetz was the German equivalent of Galton and Davenport, developing the idea of "Rassenhygiene" or "racial hygiene" and establishing the world's first professional eugenics organization and eugenics journal (Rutherford, 2022). Hitler's deputy Rudolf Hess stated that *"National Socialism is nothing but applied biology"* (Lifton, 1988). The Nazis directly drew on Laughlin's forced sterilization legislation in writing their own eugenic laws (Farber, 2008; Reilly, 2015). These laws included the Law for the Prevention of Genetically Diseased Offspring, which allowed the legal and compulsory sterilization of any citizen with a genetic disability, including people who were schizophrenic, blind, epileptic, deaf, or those with physical deformity (Grodin *et al.*, 2018). Pearson and Fisher publicly stated their approval of Hitler's eugenic programs in Nazi Germany.

> *"In Germany, a vast experiment is in hand, and some of you may live to see its results. If it fails it will not be for want of enthusiasm, but rather because the Germans are only just starting the study of mathematical statistics in the modern sense!"* - Karl Pearson at Francis Galton's retirement dinner, 1934 (UCL, 2020).

> *"I have no doubt also that the [Nazi] Party sincerely wished to benefit the German racial stock, especially by the elimination of manifest defectives, such as those deficient mentally" - Fisher, 1948*

The Nazis later extended their eugenic program from forced sterilization to killing. Victims were referred to as "*Lebensunwertes Leben*", meaning "lives unworthy of life" (Rutherford, 2022). The T4 euthanasia program of 1939–1942 targeted adults and children with physical and intellectual disabilities and terminal illnesses (Levine, 2017). Disabled people were the first victims of Nazi mass murder, and methods developed to kill those with disabilities were later used for the murder of Jewish people and other groups (Evans, 2016). Josef Mengele's infamous "experiments" at Auschwitz-Birkenau aimed to undercover the genetic contribution of traits from intelligence to deformity, but were vehicles for the torture and murder of twins, people with dwarfism, and those with genetic abnormalities (Segal, 1992). Even after the war, Fisher publicly defended the Nazi-associated eugenicist Otmar Freiherr von Verschuer, who had conducted "research" on murdered Jews and Roma twins from Auschwitz (Stern, 2021). It is estimated that at least 250,000 disabled adults and children were murdered in the Holocaust (Evans, 2016).

Eugenics in the Modern World

Although eugenics as a term and scientific discipline was mostly discredited even before 1945, it is an uncomfortable truth that eugenic practices continued after the war and occur today (Thomson, 2010). Forced sterilization continues to prevent the reproduction of people with physical and intellectual disabilities, and conditions such as epilepsy or HIV

(World Health Organisation, 2014; Bi and Klusty, 2015). For example, a legal guardian may think sterilization (e.g., via a hysterectomy) is in a disabled individual's best interest to avoid them having to deal with menstruation, but that individual is deemed medically unable to consent. Under US law in many states, a judge may, therefore, make the decision as to whether the sterilization should proceed, not the disabled person (National Women's Law Center, 2021). While in some cases the disabled person might agree with the decision although they couldn't formally consent, in others the individual sees their reproductive rights as having been taken away (National Women's Law Center, 2021). Sterilization of disabled people is no longer justified on the basis of heritability (Tabery *et al.*, 2023), but is performed on the basis of assumed parenting capability, menstrual management, or prevention of pregnancy arising from sexual abuse of vulnerable individuals (World Health Organisation, 2014). In many cases, disability rights activists highlight that permanent sterilization is an inappropriate response. Menstruation could be managed medically rather than surgically (Quint *et al.*, 2016), and the onus should be on protection of vulnerable individuals from abuse rather than sterilization to prevent unwanted pregnancy. Sterilization is more prevalent in marginalized communities, with indigenous and ethnic minorities as well as transgender or intersex people being disproportionately sterilized (World Health Organisation, 2014). The United Nations and World Health Organisation have called for an end to forced sterilization, seeing it a human rights violation (World Health Organisation, 2014).

Advances in biotechnology, assisted reproduction, and genetic testing bring eugenic ideas into the modern world (Epstein, 2003; Dive and Newson, 2022). Amniocentesis and noninvasive prenatal testing (NIPT) for multiple conditions have been used since the 1960s (Pös *et al.*, 2019). In the UK most pregnancies are genetically screened for aneuploidy (chromosomal disorders), and ultrasound scans check for abnormalities from treatable forms of cleft palate to unsurvivable brain or kidney defects (National Health Service, 2023). Similarly, in the US a variety of prenatal genetic tests are available, used for both screening and diagnosis (Prenatal Genetic Screening Tests). Some tests identify treatment options, but others typically lead to premature termination of pregnancy. Preimplantation genetic testing via in vitro fertilization is also available for over 600 conditions, and may be offered when an existing child has a particular condition, for patients with a history of repeated miscarriage or older patients with higher risk of chromosomally disordered pregnancies (Human Fertilisation and Embryology Authority, 2023). Testing and the option for selective termination for extremely serious conditions (e.g., Patau Syndrome) where the child has little or no chance of surviving is relatively (but not completely) noncontroversial. However, it is important to realize that disabled people may strongly disagree with societal and medical consensus over the severity of conditions for which termination is appropriate (Pös *et al.*, 2019). I (Sarah-Marie) have personal experience here; my mother was advised to terminate her pregnancy due to my spinal condition, and abortion was encouraged throughout the pregnancy as the child (me) "would not lead a normal life". Disabled people may also feel that selective termination on the basis of disability further undermines the dignity and respect given to disabled people living with these conditions. Some have referred to these reproductive technologies as the "new eugenics" or "liberal eugenics", achieved via private medical choices rather than state-driven population control (Epstein, 2003; Agar, 2008; Thomson, 2010). The UN Special Rapporteur on the rights of persons with disabilities stated in 2020 that:

> *"Current developments in medical research and practice may revive eugenic ideas if safeguards for those affected are not ensured.". (United Nations, 2020)*

As biomedical science advances, we have to confront the eugenic implications of testing, both as an academic discipline and in private reproductive choices.

Influence of Ableism and Eugenics on Bioscience Education

With such a substantive history, it is unsurprising that eugenic and ableist thinking has also influenced bioscience education. It is tempting to think that this influence is entirely historical, but the impacts can still be felt in contemporary curricula. We focus here on two key areas: the propagation of ableism within bioscience education, and the need to introduce students to the historical and cultural context of the discipline.

Bioscience Education and the Propagation of Ableism

As most bioscience educators will have not have received an antiableist curriculum, they may be unaware of the ableist history and connotations of their teaching. Take the example of human eye color. Most people remember that brown eyes being dominant over blue from school biology, so this example has persistence well beyond the classroom. Eye color is often used as an introduction to genetics, including asking students to construct family trees of eye color (Mackey, 2022). Not only is this noninclusive of LGBTQ+, adopted or step-families and children conceived through fertility treatments, but it directly draws on the work of eugenicists. Gertrude and Charles Davenport used this model to explain the science behind eugenics to the general public (Davenport, 1911; Davenport and Davenport, 1907). Typical for eugenicists, the model presented is oversimplified. Two blue-eyed parents can (infrequently) have a brown-eyed child, and the model has nothing to say about green eyes. While a single gene (*OCA2*) is the major contributor to blue/brown pigmentation, over 150 genes influence eye color, some of which can override the dominance of *OCA2* (Mackey, 2022). However, Davenport's textbook "Heredity in relation to eugenics" (1911) was a mainstream text for college and medical school teaching until it was discredited in the 1940s (Witkowski and Inglis, 2008).

Eugenicists actively promoted overly simplistic models of Mendelian inheritance to demonstrate how easy it would be to eradicate defective genes from the population. We risk perpetuating this in introductory genetics education, where the oversimplification to teaching of "healthy" and "diseased" genes obscures important biological reality (Griswold, 2023). The language of a gene "for" a given characteristic mirrors eugenic models of inheritance (Rutherford, 2022). There is considerable genetic variation between individuals, and there is no such thing as a "perfect" genome. Genome sequencing has identified that there are millions of genetic variants between individuals, representing ~1 in 1000 base pairs (Frazer *et al.*, 2009). However, simplistic binary models of "healthy" and "disease" genes persist in teaching resources and curricula (Griswold, 2023). While it would be inappropriate to teach advanced methodologies in introductory classes, the fact that there are many genetic differences between individuals can be discussed, and would go some way to reducing the ableism of the "healthy" and "diseased" gene narrative. This matters most when discussing prenatal genetic testing. Genetic tests are often presented as an overwhelmingly positive development. However, teaching these topics from a purely technical perspective without considering the ethics involved is inherently ableist. Biotechnological advances may directly undermine the dignity and respect shown to the disabled community. We must also consider that reductive biological models of disability learned in the classroom may impact on the real-world decisions of parents faced with the results of a genetic test during pregnancy.

Ableist connotations are also present in the language of bioscience education. For example, the terms genetic 'mutation', 'difference', 'disorder', 'disease', 'pathologic mutation' and 'defect' might be used interchangeably in a technical sense (Hales, 2020). However, when discussing individuals who carry a mutation, these terms are not equivalent. "Nonfunctional mutation" is a technical term describing a genetic difference that inactivates the protein product, whereas "genetic defect" carries ableist connotations whereby the person with the mutation is presented as "less than" others (Hales, 2020). For example, it is accurate to describe mutations to the cystic fibrosis (CF) transmembrane conductance regulator (CFTR) gene as causing a disease phenotype and reducing average life expectancy. However, it is not appropriate to automatically refer to a CF patient as having a "defect" or "low quality of life" on the basis of their genetics. Most CF patients now live into their mid-40s and beyond, living rich meaningful lives (Cystic Fibrosis Foundation, 2020).

Teaching resources may also perpetuate ableism. For example, we looked in 10 contemporary biology, evolution and genetics textbooks within our university library[1] and found several examples of ableist language and presentation:

> "Even though the extra chromosome 21 in a person with trisomy-21 (Down syndrome) is a perfectly normal chromosome inherited from a normal parent" - Human Molecular Genetics, published 2011

> "Down syndrome is associated with mild to severe forms of mental retardation" - Molecular Biology 4th Edition, published 2012

Using the language of "perfectly normal" to describe individuals without a particular condition is implicitly pejorative to those who are, and doesn't reflect that there is no such thing as a perfectly normal genome or individual. The visual presentation of topics related to human genetics also reinforced ableist bias in several cases. There was a tendency for images to highlight rare genetic conditions with severe physical phenotypes (e.g., Hutchinson-Gilford progeria syndrome, which causes severe premature ageing in children, or Greig cephalopolysyndactyly syndrome which causes abnormal development of the fingers and toes). Images were often very clinical, focusing on the physical abnormality, not the person. In the most offensive example, next to a subheading of "Mutation Rate in the Human Genome" was an image of Joseph Merrick, a man with extreme facial difference who was exhibited under the stage name "The Elephant Man" in Victorian "freak shows". While it is speculated that Merrick had the genetic condition Proteus syndrome, attempts to extract his DNA have failed due to embalming procedures used, so we cannot definitely conclude that genetic mutation was the cause of his appearance (Huntley *et al.*, 2015). This visual association of genetic mutation and severe physical phenotypes reinforces ableist ideas around the fear of disease, and does not reflect the fact that the vast majority of mutations in the human genome do not cause any phenotypic effect.

However, we did find examples where a less ableist approach had been taken. One illustrated the topic of Down syndrome with an individual doing gymnastics, and another showed an individual with Down syndrome taking part in a science lesson. We even found one book where language was actively antiableist:

> "Many [individuals with Down syndrome] live independently or at home with their families, are employed and are valuable contributors to their communities". – Campbell Biology, 9th ed.

This textbook also actively countered negative visual imagery. For example, a figure describing achondroplasia showed Dr Michael C Ain as both having this condition, and being a professional expert in the repair of bone defects resulting from achondroplasia. This approach taken with this textbook demonstrates that it is possible to create resources which balance technical information with humanity and respect for disabled people.

Inclusive Bioscience Education should Introduce Students to the Historical Context and Societal Implications of Ableism

Given the widespread influence of ableist and eugenic ideas in bioscience, to be genuinely inclusive, we need to address this within our classrooms, in parallel with similar efforts to create more culturally sensitive antiracist curricula (Joshi *et al.*, 2024; Mansfield *et al.*, 2024; Quinlan *et al.*, 2024). Contextualizing the curriculum is relevant to many areas of biology. Failure to do so may alienate students with disabilities, and means we perpetuate a lack of understanding of the historical and cultural context in which bioscience developed as a discipline. The foundational contributions of Pearson, Fisher, and others to evolutionary biology and statistics means we continue to teach the work of eugenicists in core bioscience courses, often without providing historical and cultural context (Hales, 2020). Advances in quantitative analysis were active drivers in eugenic understanding of human genetics. For example, statistical tests

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[1] Human molecular genetics 4th edition (2011), Strachan and Read; Genetic Analysis 3rd edition (2020), Meneely; The Human Genome in Health and Disease (2019), Samuelson; Molecular Biology 4th edition (2012), Tropp; Introduction to Genetic Analysis 11th edition (2015), Griffiths, Wessler, Carooll and Doebly; Evolution: Making sense of Life 3rd edition (2020), Emlen and Zimmer,; Campbell Biology 9th edition (2011), Reece, Urry, Cain, Wasserman, Minorsky and Jackson; Biology 7th edition (2005), Solomon, Berg and Martin; Evolution (2007), Barton, Briggs, Eisen, Goldstein and Patel; Evolution 2nd edition (2009), Futoyama.

mathematically separate variable populations into groups. This underpinned the eugenicists' need to categorize human beings as "different" or "not different", the precursor to establishing discriminatory treatment. Quantitative statistical analysis is often presented as being entirely objective, but it is as socially constructed as any other research methodology (Gillborn *et al.*, 2018). While statistics should remain a core component of biology curricula, we argue that students should also be introduced to historical context and societal implications of statistical testing (Gillborn *et al.*, 2018; Zwiener-Collins *et al.*, 2023). Statistical categorization also reinforces a homogenous way of thinking within categories (Zwiener-Collins *et al.*, 2023). For example, students are often crudely categorized as "disabled" and "not disabled", overlooking the vast diversity in disabilities from wheelchair use to neurodivergence. This could provide a useful teaching point if handled sensitively. For example, discussions around the benefits and limitations of category based experimental designs may improve student criticality as well as exploring ethical dimensions of research design. Exploring the balance between sample size, resolution, and respect for individual/subgroup identity may provide an engaging way to explore both technical and ethical aspects of research.

Bioscience textbooks again reflect this lack of contextualization. For example, audits of historical US high school and college level textbooks highlight multiple positive references to eugenics (Selden and Montagu, 1999, Selden, 2007; Ladouceur, 2014).

> *"A sound mind in a sound body is the birthright of every child. Such bright-eyed children as these are seldom produced by defectives." - Biology: And Its Relation to Mankind, Winchester, (1949)*
>
> *"one of the largest eugenic problems is that of the mental defectives," "the average intelligence of the population is decreasing from generation to generation" Biology, Vilee (1967)*

Although eugenics as a scientific endeavor was largely discredited by the 1930s, positive references to eugenics can be found in US textbooks as late as the 1960s (Selden and Montagu, 1999; Ladouceur, 2011). If anything, textbooks defended eugenics more strongly in the immediate postwar period than they had before World War II (Ladouceur, 2011). Our informal audit of 10 contemporary biology, genetics and evolution textbooks found that only three contained eugenics as an indexed topic, although did find ethics indexed in six. Only one included disability rights. We also looked at the presentation of Galton, Fisher and Pearson. In none of the textbooks where these figures were discussed was there any contextualization of their involvement in the eugenics movement. For example, one book had a page on eugenics which did refer to both American and Nazi programs, but did not mention the role that Galton, Fisher, and Pearson had in the intellectual development of eugenics. The connection between bioscience and eugenics was summarized as *"All of these abuses were based on misunderstanding or twisting the data and theory of evolution and genetics (and, to their credit, some evolutionary biologists and geneticists said so)"*. As such this presents eugenics as being distinct from bioscience, rather than intimately intellectually connected and overlooks the direct contribution of many bioscientists to the eugenics movement. This lack of contextualization means the connection between bioscience and eugenics continues to be obscured rather than presented appropriately to students. While a majority of bioscience educators recognize the importance of including contextualization and ethics in genetics teaching, many find the lack of appropriate resources and training a barrier (Booth and Garrett, 2004). We need to create resources that address these important topics, and support educators to include difficult topics in their curricula.

Recommendations for Antiableist Bioscience Education

So, what can bioscience educators do to confront this ableist bias? We propose a structure for antiableist bioscience education based on the Culturally Competent Curriculum Model of (Thomas and Quinlan, 2021; Quinlan *et al.*, 2024). This framework identifies four dimensions of antiracist education; representation of diversity, positive portrayals of racialized minority groups, challenge to power and inclusive classroom interactions. We adapt these constructs for disability, and add two categories unique to the biosciences to give a recommended structure for disability-inclusive bioscience education (Figure 2). We anticipate that our structure is applicable to multiple contexts including high schools and higher education, and can be used in multiple subdisciplines of bioscience from biomedical science to evolutionary biology.

Representation of Diversity and Disability: Disabled people are often absent from teaching materials other than as negatively framed case studies, giving the impression disabled people cannot succeed professionally (Dessent *et al.*, 2022; Gin *et al.*, 2022). Representation of disabled scientists allows students with disabilities to "see" themselves in the curriculum. Examples include the Nobel Laureate Dorothy Hodgkin who had severe arthritis throughout her career, adapted x-ray crystallography equipment to accommodate her disabilities and presented at international conferences from her wheelchair (Royal Society, n.d.). Niko Tinbergen had severe depression, and Temple Grandin is an animal behaviorist and autism advocate. A useful and searchable collection of scientists from a variety of backgrounds including disability is available from the https://scientistspotlights.org/ project.

Positive Portrayals of People with Disabilities: Disabled people should not be presented as a problem to be solved, having no quality of life or as a burden to society. Positive portrayal of disabled people can change perceptions and confront negative stereotypes. Disabled students should not be expected to fulfil this role in front of peers due to the inherent power imbalance and potential social stigma around disability (Gin *et al.*, 2022), unless they choose to do so as a form of self-advocacy.

Challenge to Power: The pervasive nature of ableism needs to be confronted if curricula are to be genuinely disability-inclusive (Hales, 2020; Reinholz and Ridgway, 2021). Historical and modern-day ableism and eugenics should be openly discussed, including their intersection with racism (Dessent *et al.*, 2022; Reese, 2023). Ethical issues around biomedical research should be embedded into teaching (e.g., Willmott, 2015). Again, disabled students should not be the only voices providing alternate viewpoints.

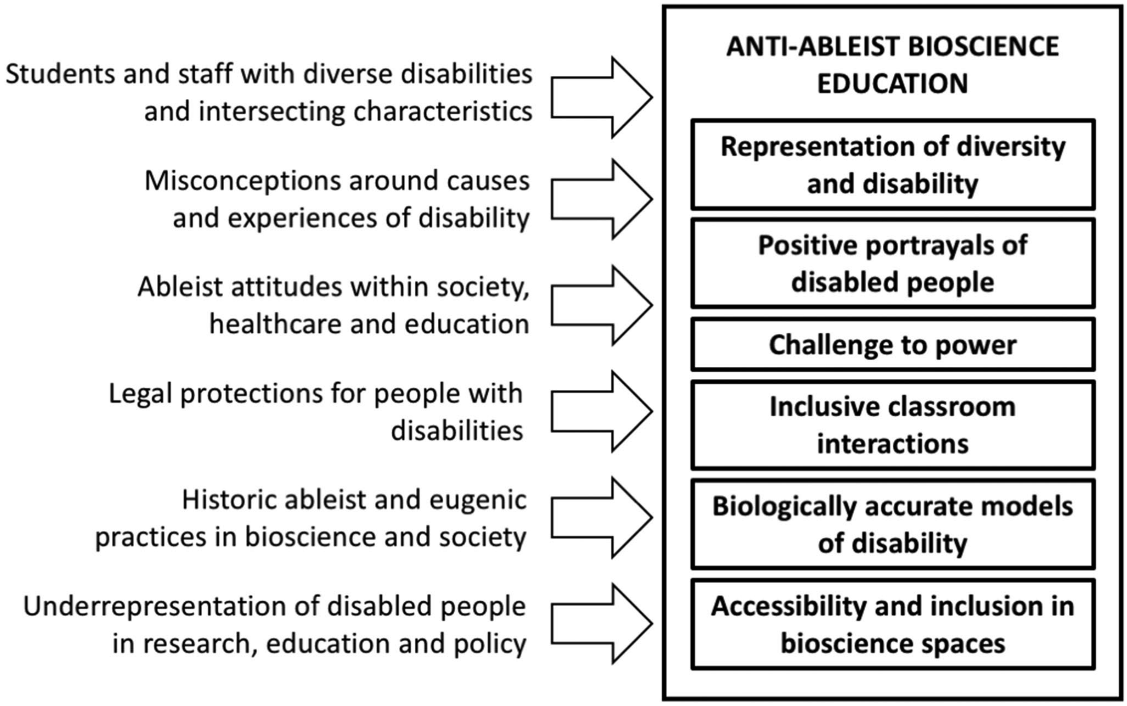

FIGURE 2: Conceptual model of the context for anti-ableist bioscience education and our six-domain recommended structure for Disability-inclusive practice.

Inclusive Classroom Interactions: Pedagogies and classroom activities should be designed to ensure disabled students can participate on an equal basis with peers (Gin *et al.*, 2020; Reinholz and Ridgway, 2021; Araghi *et al.*, 2023). Language around disability should be carefully considered (Hales, 2020), and disabled students given respect, dignity and autonomy in navigating any additional needs they have. Classroom interactions between students also need to be inclusive, and instructors should recognize that some pedagogies (e.g., active learning) present particular challenges for some students (e.g., neurodivergent students, those with ADHD, depression, anxiety; Gin *et al.,* 2020; Araghi *et al.,* 2023; Pfeifer *et al.,* 2023).

Biologically Accurate Models of Disability: Disabilities should be accurately described at a genetic and/or physiological level, contextualized appropriately against the variability of populations (Hales, 2020). Explanations should not be overly simplistic, and conditions without a known mechanism should not be dismissed as less important.

Accessibility and Inclusion in Bioscience Spaces: Biology education uses physical and digital environments which may not be accessible to those with disabilities (Reinholz and Ridgway, 2021; Gin *et al.*, 2022). Lab and field based teaching in particular should be proactively designed to genuinely include people with diverse disabilities. Instructors may need to pay particular attention to the accessibility of classroom layout, audiovisual and experimental equipment used (Braun *et al.,* 2018). Inclusivity and accessibility should also be embedded in assessment. Access requirements should be in place in anticipation of disabled people needing to use them and clearly communicated (Gin *et al.,* 2020; Reinholz and Ridgway, 2021). Instructors should also be aware that some disabled students face barriers in self-advocacy, so should not rely on the ability of disabled students themselves to raise issues of concern, particularly given the power imbalance between students and instructors (Pfeifer *et al.,* 2021, 2023).

We argue that this antiableist approach to education is important for all bioscience students, not just those with lived experience of disability. Society needs people able to challenge ableist attitudes and practices to enter education, research, healthcare, and policy. How this is achieved within biosciences curricula will depend on local contexts, and should be developed in partnership with students and those with lived experience of disability where appropriate. The impact of this approach requires evaluation, and represents an area of future research, especially if combined with evaluation of antiracist curricula or other attempts to redress structural bias within bioscience education.

CONCLUSIONS

Writing this article has prompted both of us to consider the extent of ableism within current and historical biosciences. The more we thought about it, the more pervasive we realized the exclusion of disabled people is throughout our discipline. While some issues we identified are specific to the biosciences, others reflect the widespread nature of ableism in society. The biosciences has a specific need to acknowledge the impact of historical eugenic and ableist ideas on our discipline, as well as addressing contemporary exclusionary practices and ideas. In teaching the work of eugenicists without contextualization or critique we perpetuate their legacy, reinforcing their influence on our discipline. Bioscience educators have a personal responsibility to educate themselves about disability rights issues and how this relates to their teaching (Killpack and Melón, 2016). We call on educators to really consider whether their learning environments just meet minimum legal accessibility standards, or whether they are truly inclusive spaces where disabled students can fully participate and succeed alongside their peers.

Ethical Oversight

Ethical oversight for this article is provided by the University of Hull Faculty of Science and Engineering Ethics Committee (Project Number FEC_2021_107).

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