Spring 2017

Supporting Transgender Students in the Biology Classroom: A Curricular Approach

Amit Schwalb , '17

Supporting Transgender Students in the Biology Classroom: A Curricular Approach

Amit Schwalb

Swarthmore College

Table of Contents

Introduction:

In recent years, transgender students have become the subject of heated national debate. Following legal and legislative battles over the rights of transgender individuals to access gendered spaces in North Carolina in early 2016, the US Department of Justice and Department of Education issued a joint directive in the form of a letter sent out to school districts around the United States on supporting transgender students (Hauser, 2016). The directive largely addressed concerns for trans students regarding the structure and culture of schools, including documentation, access to gender-segregated spaces, and freedom from sexual harassment (Lharmon & Gupta, 2016). It was celebrated by trans advocates for its recommendation that trans students be honored as the genders they know themselves to be regardless of the gender markers on their legal documentation. What both the directive and the resulting media hubbub failed to consider, however, is the space where students spend the vast majority of their time in school: the classroom.

With the passage of anti-trans legislation, including the repeal of the Obama era directive for schools, and rates of hate crimes against transgender people again on the rise, educators must consider how best to support their transgender students not only in wider school communities but in their own classrooms. In biology classes, wherein issues such as sexual development and sexual roles are discussed at length, and in which discussion tends to swing more towards nature than nurture, this can be particularly challenging. Yet, while scholars of transgender studies and of biology have often been at odds amidst feminist critiques of biological determinism, the biology is one of few classroom contexts in which sexual roles are discussed, and thus presents an opportunity for curricular consideration and exploration of issues related to transgender people and experiences. Moreover, the biological realities of sexual categories and systems are far more complex than the static, binary understandings of gender assumed more broadly, thus offering an opportunity to represent a more complex picture of gender in the classroom, and in doing so, support trans students.

The growing shift in alignment towards Next Generation Science Standards and away from state standards similarly presents an opportunity for educators to integrate discussions of trans experiences into the biology classroom. In contrast to their discrete, largely content-based predecessors, the Next Generation Science Standards (NGSS) put a premium on scientific practices and on concepts that appear across disciplines. Thus, the high school life sciences standard addressing development (HS-LS1-4) is recommended to appear in combination with the crosscutting concept that science and society influence one another (HS-LS3-3), and the scientific practice of making and defending a claim (HS-LS3-2) (NGSS Lead States, 2013). So, rather than simply learning the major steps of the process by which humans go from fertilized egg to sexual maturity, the NGSS approach would encourage a student to explore the influence of social conceptions of gender on our understanding of sexual development and vice versa, as well as to use human development data to back up a claim that sexual development varies within sexual categories. This is just one example among many. With its increased focus on interdisciplinary concepts and critical reasoning-based scientific practices, the implementation of NGSS offers an opportunity for biology teachers to integrate discussion of transgender issues in their curricula.

Concurrent examination of the literature surrounding transgender students and best practices in science education suggests that biology classroom instruction is a critical, even if overlooked, venue for supporting transgender students. This thesis reviews relevant theoretical background and definitions related to transgender experiences and marginalized identities in the science classroom, before moving into a more in-depth examination of the literature around trans student experiences. Based on hitherto discussed literature, some broad recommendations for the classroom and school environments are offered, and then instructional topics and strategies for the biology classroom justified and discussed.

Conceptual Framework:

Sex:

In general, *sexes* are broad categories that humans have created to describe organisms based on their reproductive roles and functions. In order to provide background for exploring distinctly human questions around transgender identity and experience, this paper will largely refer to what these categories look like and how they function in human systems. However, it is worth noting that there exists an enormous diversity of sexual systems in the animal and plant kingdoms. In humans, sex is multilayered, being defined primarily by one's genetic make-up, internal reproductive organs, external reproductive organs, sex hormones, and secondary sexual characteristics (those typically acquired at puberty) (Fausto-Sterling, 2012). Humans typically categorize newborns by sex based on external reproductive organs at birth or by genetic testing in utero. Moreover, within each of these components, there exists immense variation. For example, body hair and pitch of voice are in large part determined by the amount of female or male sex hormones present in the body, yet many males have facial hair while many others do not, and some females have much lower voices than other females. Additionally, these layers don't always come as a package deal. For example, polycystic ovarian syndrome (PCOS) is the most common endocrine disorder affecting females of reproductive age (Teede, Deeks, & Moran, 2010). Individuals with PCOS are genetically female, have female reproductive organs, and have increased levels of male sex hormones as compared with females lacking PCOS. This can result in symptoms including facial hair, irregular menstruation, and fertility problems. Male and female are socially constructed categories set up to classify and simplify biology, but as with most classification systems, the biological realities are far more complex than can be completely described by these two sexual categories alone.

When the layers of an individual's sex don't all map neatly within the sex category of male or female, this individual is considered to be *intersex*. Most frequently, this term is used to describe those whose sexual irregularities are congenital. By contrast, those who undergo medical treatments such as hormone replacement therapy or genital surgeries resulting in mixed sexual characteristics that would not otherwise be present are typically not considered to be intersex. There exists an impressive diversity of intersex conditions in humans, which combined with the enduring marginalization of intersex communities has made it difficult to generate agreed upon incidence statistics. Most often, Hull & Fausto-Sterling's estimate of 1.7% of live births is cited (2000). It is worth noting that while still largely in use in the field of biology, the term *hermaphrodite* is now considered outdated and offensive when used to refer to humans. The term is derived from Hermaphroditus, a figure of ancient Greek mythology who was depicted as having feminine facial features, breasts, and a penis. Today's intersex advocates take issue with this mythic origin, the narrow scope of intersex conditions it evokes, and the stigma that became attached to the term over the years. These advocates prefer the term *intersex* which indicates a natural rather than mythical condition (Fae, 2012).

Gender:

Gender often refers to the social behaviors, roles, and classes associated with sex. For example, being female is considered to be the foremost characteristic of the gender of woman, and some associated gender roles or characteristics include things like being a mother or enjoying ballet. Gender is distinguished from sex in its primarily social rather than physical character. However, sex is not devoid of cultural baggage. As described above, sexes are broad categories created by humans and as such, don't always reflect the diversity or the complexity of biological traits associated with reproduction. In this way, social and cultural expectations and assumptions shape how we talk about sex (Serano, 2007, p. 24). While sexual categories are indeed socially constructed as such, sex nonetheless refers to the biological characteristics encoded in these categories. These characteristics are often seen as a part of or having an impact on gender, but gender also goes beyond the physical and biological. Tone of speech, clothing preferences, and family roles are all influenced by gender, but not clearly the result of biology. Thus, gender is simultaneously personal, socially mediated, and influenced by sex. In the expert analogy of Julia Serano, "It's like a junior high school mixer where our bodies and our internal desires awkwardly dance with one another and with the external expectations that other people place on us" (2010). Nonetheless, for the sake of clarity, throughout this paper, sex will mostly refer to the more physical and biological, while gender will refer to the more social. Correspondingly, the words *male* and *female* will be primarily used when discussing sex, and the words *man* and *woman* will be used when discussing gender.

Beyond the ongoing semantic debate around to what extent the terms *gender* and *sex* overlap, distinguishing between the biological and the social can aid in describing transgender experiences. *Transgender* or the shortened *trans* is an umbrella adjective used to describe individuals who do not fully feel themselves to be or do not perform the gender assigned to them at birth. Thus, these individuals experience discordance between the gender role associated with their sex and the gender they know themselves to be. Some examples of identities included under the transgender umbrella are *non-binary* individuals, who were assigned a gender of either female or male at birth but know themselves to not be simply either male or female; *transgender men*, who were assigned female at birth and know themselves to be men; and *transgender women*, who were assigned male at birth and know themselves to be women. Within each of those categories there exists great diversity in individuals' gender identities and expressions, in addition to diversity of other social identities such as race, ethnicity, religion, and class. Some non-binary individuals might know themselves to be *agender*, having no gender identity, while others might know themselves to be *bigender*, identifying with two distinct genders. Individuals who feel themselves to be the genders they were assigned at birth, who are not trans, are referred to as *cisgender* or *cis*.

Science Identity:

In the last decade, the theoretical construct of science identity has emerged as a key framework for understanding and addressing the outcomes of science students from historically underrepresented groups. Science identity refers to whether and how students see themselves as "the kind of people who would want to understand the world scientifically," and, eventually, as scientists (Brickhouse et al. 2000). The notion arose out of Jean Lave's theory of situated learning, which considers learning to be a process of adopting an identity as a member of a community of practice, rather than the internalization a given set of information (1991). For Lave, all learning is best understood as a sort of apprenticeship in a given professional community. Thus, the first task of a science student is not to learn the correct explanation for glycolysis for its own sake, but to start to consider themself to be a scientist. As their identity is transformed, the student becomes motivated to build their skills and knowledge as a scientist in order to reinforce their newly acquired sense of identity, and to more fully and authentically participate in a scientific community. Scholars seeking to better understand the science education experiences of students from historically marginalized groups have utilized this theory of learning not only due to the pivotal role played by identity, but because of its successful accounting for both individual agency and the constraints applied by societal structures (Carlone and Johson 2007, Brickhouse et al. 2000).

In order to shed light on how students acquire science identity in real time, Brickhouse and Potter performed an in-depth study of the experiences of two working class young women of color in a high school vocational computing program (2001). The study focused on working class girls of color as the subjects of their research in order to examine science success and engagement in communities typically not seen as scientific. One student profiled, whom the authors gave the pseudonym "Crystal," was an exceptionally high-achieving student, setting the standard for good work in her biology class and making it into the honor roll. The other student, donned "Ruby" by the researchers, was described as a good but not excellent student by a teacher, and highly inquisitive and engaged by the researchers.

Despite Crystal's academic performance being higher than that of Ruby's, when both were accepted into the school's competitive computing program, Ruby thrived while Crystal flopped. Ruby became the star of the class and the only young woman to remain in the program by 11^{th} grade, yet Crystal ended up failing out of the program all together. The authors attribute Ruby's success to her ability to be a part of a community of computing practice, which was facilitated by her social interactions with her father, who worked in computers himself. Ruby's father provided her with knowledge of masculine computing social practices, and their relationship incentivized her taking on these practices and accompanying identities. This allowed her to succeed among her male peers at school. By contrast, Crystal was missing the social interactions around computing that would have allowed her to develop a sense of group belonging, and thus identity. The authors note that Ruby maintained some sense of social distance from her peers at school, but this, evidently, did not seem to negatively impact her success in the program. Thus, the authors close with a call for educators to consider how to help students develop identities which are both desirable to them in their home communities and work for them across racial, class, and gender divides to be able to access cultures of science.

In their study of 15 successful women of color scientists over the course of their undergraduate and graduate careers, Carlone and Johnson sought to develop a model for students' science identity formation (2007). They began by establishing performance, recognition, and competence as constituent of science identity, arguing that these are components of all identity; "One cannot pull off being a particular kind of person (enacting a particular identity) unless one makes visible to (*performs* for) others one's *competence* in relevant practices, and, in response, others *recognize* one's performance as credible" (Carlone and Johnson 2007). Thus, science identity functions similarly, an emerging biologist, for example, growing into the identity of biologist by *performing* her *competence* in lab techniques for a principle investigator, and the principal investigator then *recognizing* her competence.

Through their analysis of ethnographic interviews while the study's participants were in undergraduate programs and follow-up email interviews 6 years later, Carlone and Johnson determined that while performance and competence were necessary to science identity formation, recognition was the greatest predictor of identity acquisition (2007). Recognition, according to the authors, includes both a recognition of self and recognition from meaningful others of one as a "science person." Critically, recognition by others is often influenced by one's gender, race, or ethnic identities. A Latina woman in Carlone and Johnson's study, for example, reported being ignored by the principal investigator of the lab in which she served as a research assistant, and being wrongfully accused of stealing by a fellow lab assistant, both of which she posited were because of her race. In response, the young woman decided to switch majors. Thus, students' identities can come to influence their success in acquiring science identities when their identities influence the extent to which mentors and other meaningful others see them as capable scientists.

Literature Review

Statistics and Trends of Transgender Students

There exist numerous obstacles to estimating the incidence of transgenderism in the adult population of the United States. Perhaps the most major obstacle to this projection is that the United States Census Bureau and other surveyors do not ask about or record information on gender identity. Some other barriers include the fluid nature of gender identity, which can be hard to pin down for multiple choice lists, and the reluctance of transgender people to disclose their status out of fear for their safety (Miller, 2015). Most recently, the Williams Institute, a think tank dedicated to research on sexual orientation and gender identity policy, estimated that 0.6% of the United States adult population identifies as transgender based on data from the Center for Disease Control and Prevention and the US Census Bureau (Hoffman, 2016b). While it seems clear that larger percentages of adolescents identify as transgender than older adults, population estimates on transgender adolescents remain elusive, small-scale studies ranging from 0.5%to 1.5% in their projections (Hoffman, 2016a).

Surveys of transgender people of all ages point to the persistent injustice faced by this community. Respondents to the National Transgender Discrimination Survey, the largest survey of transgender individuals, were four times as likely as the general population to have a household income of less than $10,000 (Grant et al., 2011). Those surveyed also reported double the rate of unemployment as the general population, and a quarter had lost a job due to being transgender or gender nonconforming. While 1.6% of the general population reports having attempted suicide, a staggering 41% of respondents reported having done so. Those surveyed also reported widespread experiences of discrimination in housing, in public accommodations (hotels, retail stores, etc.), in healthcare, and in encounters with the criminal justice system. While these types of discrimination were pervasive throughout those sampled, respondents of color and especially African American individuals experienced greater bias across the board than their white counterparts, illustrating that the combination of anti-transgender bias and racism is particularly devastating (Grant et al., 2011).

In face of the injustices described above, transgender people demonstrate remarkable resilience. Despite major structural barriers to healthcare access, 76% of respondents to the National Transgender Discrimination Survey were able to receive hormone replacement therapy treatments, indicating determination and resourcefulness in navigating the medical establishment. Similarly, 58% of those who reported losing a job due to bias persisted and were employed at the time of the survey, and 94% of those who at some point experienced housing discrimination reported being currently housed (Grant et al., 2011). Transgender people were pioneers of the modern LGBTQ rights movement in the United States, many recognizing gender non-conforming drag queen Marsha P. Johnson as a key player in the Stonewall Riots, the turning point leading to the modern struggle for gay liberation in the US Johnson was joined by Sylvia Rivera, a self-described transvestite and founding member of the pioneering gay rights organizations the Gay Liberation Front and the Gay Activists Alliance (Feinberg 1996). Today's openly transgender movers and shakers include advocate and star of the hit series *Orange is the New Black* Laverne Cox; writers of *The Matrix* film series and the film adaptation of *V for Vendetta* the Wachowskis; and front-woman of the top punk-rock band Against Me!, Laura Jane Grace.

The National School Climate Survey (NSCS), a survey of US secondary school students who identify as gay, lesbian, bisexual, and/or transgender (GLBT) is the largest source of data on transgender students in the US. While the survey is conducted biennially, the most recent large-scale analysis of data collected on transgender students in particular occurred in 2009 (Greytak et al., 2009). This analysis found a number of concerning trends around transgender students' experiences in school. 87% of transgender students surveyed reported being the targets of verbal harassment, over half reported physical harassment (e.g., pushing or shoving), and just over a quarter reported physical assault (e.g., injury with weapon, punching) at school in response to their gender identities. Transgender students did not, for the most part, report these incidents to school staff, and among those who did report, only a third believed the situation was addressed effectively. These hostile learning conditions seem to take a toll on trans students' educational outcomes, those who experience high levels of harassment reporting significantly lowered grade point averages and educational aspirations than those experiencing less harassment. Transgender students report that the curricula in their classrooms are not particularly supportive of their experiences either, only 11% of them being exposed to curricula which included positive representations of LGTBQ people (Greytak et al., 2009).

Transgender Student Voices:

While the quantitative research on transgender students points to a number of noteworthy trends, quantitative data, by its nature, fails to capture the idiosyncrasies and complexities of the fullness of human experience. However, while a growing body of qualitative research on gay, lesbian, and bisexual students is now available, little qualitative study of transgender students has been performed. As Johnson et al note (2014), even when journal articles purport to address LGBT students, transgender students are often not actually represented in the data, despite the presence of the “T” in the acronym. A few small-scope studies featuring qualitative data collection from transgender young people have nonetheless sought to address this gap.

Gutierrez (2004) interviewed four transgender students under the age of 21, identifying and amplifying trends that emerged. The students were all Black and/or Latinx transgender women who at some point attended an alternative public school for LGBT youth in the Northeast. Unsurprisingly, given the qualitative data mentioned earlier, all of the students interviewed faced extensive harassment in school due to their gender identities. Strikingly, all of the students described their school staff as active and/or complicit in the harassment they experienced. In response to the danger they faced, all of the students felt they needed to learn to fight to defend themselves, three of the four being kicked out of one of the schools they attended for injuring someone in response to attacks on their transgender identities. The students also spoke about their struggles with the term “transgender” and wanting to be seen and talked about primarily as women, rather than transgender women. The author additionally notes the ways in which the students’ trans histories did not exist in isolation from, but rather alongside their racial and class identities to shape their experiences of not fitting in and being teased in school (Guitierrez 2004).

Johnson, Singh, and Gonzalez (2014) utilized a Youth Participatory Action Research (Y-PAR) model to generate qualitative data and analysis alongside 9 transgender and gender-questioning young adults, aged 18-22. Five of the students identified as White and four identified as African-American. Six of the students identified as transgender men while three identified as genderqueer. The students described both their gender identities and the words they used to describe these identities as shifting depending on time and situation, noting that this did not mean they were confused, but that those around them should be careful to pay attention to the words and pronouns they used to describe themselves. Similarly to previous studies, hostile school environments of exclusion, harassment, and assault emerged as common threads across the students' experiences. The students described bathrooms as particularly frightening places in their school environments, noting that the bullying and violence that occurred there could not be seen by school staff. Many students expressed a desire to be able to share their transgender identities with an adult at school, even when they were not comfortable doing so with a family member. Yet, the participants were nonetheless unsure of who at school could be safe to share with. While some students had witnessed teachers intervening in the targeting of transgender students, others had not.

Amidst the challenging circumstances described by the students in the above studies, transgender young people also find solace in their identities. Despite the hardships they face, trans individuals also note the pride and pleasure that can be found in their communities. Author and activist S. Bear Bergman decries the ubiquity of tragic narratives of trans people and a desire to offer an alternative:

> I am frankly tired of showing up for trans events and listening to people talk about how hard it is to be trans. I am tired of being invited to come and Tell My Story, when I know that what the nice, well-meaning white lady on the other end of the phone means is "come and make yourself an object of pity, reveal all your secret hurts, and let us use them to find you blameless in your condition and therefore

> have sympathy for you, and give you some rights… So instead of Telling My Story, I want to talk about what's great about being trans. (191)

The author goes on to describe many potential benefits of the transgender experience, including having thought deeply about one's identity and its impacts on the wider world, independent medical research skills, an increased sense of freedom to make difficult choices, and the ability to sift through government bureaucracy. While Bergman recognizes the harsh realities faced by transgender people, the author asserts that these aspects of transgender experience are not the full story. In the spirit of autoethnography, I offer the following excerpt from an e-journal entry I wrote at age 17, a few months after coming out as transgender in high school:

> Despite the fact that being queer means I have to constantly worry whether I'll be kicked out of my house, beat up on the subway, or denied a job simply because of my identity, I'm still f***ing glad I'm queer. Because it's forced me to do some seriously rewarding soul searching. Because it's allowed me to understand how oppression works. Because queer groups have exposed me to so many beautiful people who come from totally different places (literally and figuratively) than myself (Schwalb 2012)

While describing a daily reality shaped by discrimination against transgender people, I nonetheless express joy and gratitude at the opportunities for personal growth, community-building, and political understanding that this identity afforded me.

Recommendations for the Classroom Environment

While the focus of this paper is on biology curricula, the literature on transgender students has yielded recommendations for the broader classroom and school contexts that are worth noting. Institutionally, schools can support transgender students by providing faculty with professional development on the fair and equitable treatment of transgender students, and by adopting comprehensive anti-harassment policies (Johnson et al., 2014; Greytak et al., 2009). Such policies should "enumerate categories, including sexual orientation and gender identity and expression, and have clear and effective systems for reporting and addressing incidents that students experience" (Greytak et al., 2009). Gutierrez also notes that schools can support trans students in their hiring practices by hiring trans staff whom students can look to as mentors (2004). More locally, the students interviewed in Johnson et al. declared that they need support from teachers in sorting out their use of gendered facilities like locker rooms and bathrooms, and in asserting their preferred names and gender pronouns (2014). Based on statistics indicating the positive impact that mentorship of young transgender people can have on educational outcomes, Greytak et al. suggest teachers make themselves known and available as being supportive of transgender students, particularly through helping students start or continue to lead support groups like Gay-Straight Alliances (2009).

Similarly, the literature on science identity development for students from historically underrepresented backgrounds should inform the ways educators approach building relationships with their students. In order for students to be successful and persist in science, they must see themselves as "science people" (Brickhouse et al. 2000). One critical way to support students in building these science identities is through curricular representation. If students are not exposed to images or narratives of people in the context of science, they can begin see themselves and the groups they belong to as destined to not be "science people." As such, curricula should reflect the identities of the students in the classroom, including trans students. This might involve highlighting the work of trans scientists, including images of trans people in presentations, or discussing biological topics related to gender and sexual diversity, as is the subject of much of this paper. Beyond the curriculum though, teachers can support their trans students by examining their biases around who a scientists must be and look like. Carlone and Johnson (2007) found that recognition by meaningful others is a key predictor of students' science identity formation. Yet, unexamined biases against trans and gender nonconforming people can prevent instructors from recognizing and thus being able to affirm their trans students' science competence. In order to prevent this lack of recognition that can so negatively impact a student's performance, teachers must humbly consider what and who they see as competent, and why.

Curricular Connections for Biology

The recommendation that teachers devote class time to discussions related to gender identity and transgenderism is a common thread throughout much of the literature surrounding trans students (Gutierrez, 2004; Johnson 2013; Greytak et al., 2009). Two of the students interviewed by Gutierrez suggested this take place in a dedicated gender studies course aimed at increasing all students' knowledge and understanding of their trans and queer peers (2004). Natalya, a of the student who participated in Johnson et al.'s (2013) survey, was similarly insistent that these discussions occur in classrooms, though whether this occurred inside or outside of traditional subject categories did not seem to be a top priority for her:

> Teachers should talk about how gender is fabricated….Our [transgender] existence shows that the gender system isn't based in dual reality. It has real

material effects but there's nothing natural about it. You know what I mean? Maybe they should talk a little about that.

Placed in the context of Natalya's straightforward assertion that the construction of gender is plainly apparent, and an initially direct call for this more complex understanding of gender to be addressed in the classroom, her closing statement of, "Maybe they should talk a little about that" takes on an air of incredulousness. To Natalya, it's surprising or bizarre that to her gender is obliviously constructed, yet it doesn't get discussed as such in the classroom. Her sense of incredulousness indicates that when educators fail to address a more complex understanding of gender in the classroom, thereby reinforcing more traditional perceptions of gender, transgender students can feel as if their teachers are teaching content inaccurately.

In order to support biology teachers to address content related to transgender issues in the classroom, I offer a brief rationale of instructional approach followed by resources on biological background information and sample instructional goals and activities. As previously discussed, much of the literature surrounding trans students recommends teachers devote class time to discussions related to gender identity and transgenderism in order to best support these often vulnerable students (Gutierrez, 2004; Johnson 2013; Greytak et al., 2009). Thus, I provide summaries of recent biological research into phenomenon such as sex determination, intersex conditions, and hormone replacement therapies, which can serve to spark discussion around gender issues in the biology classroom. These summaries provide teachers with the background information they need to appropriately facilitate such activities and discussions. Given the research supporting inquiry science instruction, suggested objectives and activities are informed by inquiry principles and techniques (Minner et al., 2009)

The inquiry model of education is descended from constructivist theories of learning, The constructivist approach was pioneered by psychologists Jean Piaget, David Ausubel, and Lev Vygotsky. Both Piaget and Ausubel conceived of the absorption of new information as highly mediated by one's existing understanding (Cakir 2008). According to Piaget, existing knowledge is stored according to mental patterns called schemes. Ausubel similarly formulated existing understanding as networks of connected concepts called schemata. Learning, for Ausubel and Piaget, involves some sort of change in these systems of organization. As a student is exposed to new information, they make sense of it by modifying existing schemes and concepts to account for the new knowledge (Cakir 2008). For Vygotsky, a student's existing knowledge in part determines the appropriate area of learning for a student, called the zone of proximal development (ZPD). The ZPD is defined as that which a learner is capable of doing assisted, but not unassisted (Valsiner 1984). Thus, the ZPD is bound by that which a learner is already capable of doing independently and by that which is out of reach for the learner (Figure 1). Since, according to Vygotsky, learning happens in one's ZPD, and tasks within the ZPD can only happen with the aid of another, for Vygotsky, learning is fundamentally social. For all of these early constructivists, learning involves some sort of active change in cognitive organization to accommodate new information, and for Vygotsky, this can only happen in a context that is in some way social.

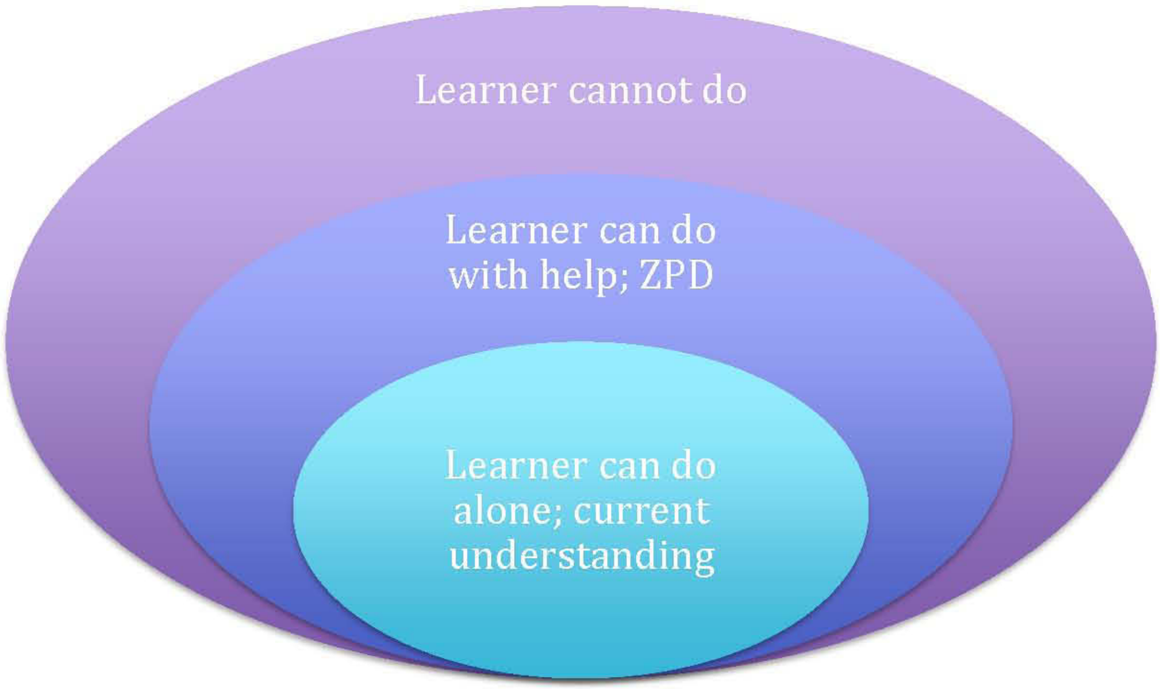

Figure 1. Lev Vygotsky's zone of proximal development (ZPD)

Inquiry approaches to education vary greatly, however the core of the approach is inspired by the constructivists' emphasis on students actively constructing their knowledge in social or collaborative context. Seeking to operationalize the term "inquiry science instruction" in their review of research on the subject, Minner et al (2010) define inquiry science instruction as being characterized by three essential components:

> (1) the presence of science content, (2) student engagement with science content, and (3) student responsibility for learning, student active thinking, or student motivation within at least one component of instruction— question, design, data, conclusion, or communication.

It's worth noting that according to the authors, student responsibility for learning refers to expectations that students to contribute to group knowledge and make decisions about what and how they learn. Active thinking centers on a student's individual engagement with the content, including making connections to prior knowledge, using logic, and thinking creatively. Finally, motivation refers to a careful attention in instructional design to increasing students' curiosity and enthusiasm about the subject matter.

In their review of the research on inquiry science instruction conducted between 1984 and 2002, Minner et al. found that such instruction was associated with improved student content learning. The review also examined the impact of specific components of inquiry instruction. Students' active thinking was a significant predictor of understanding, while drawing on data to make conclusions was a marginal predictor. With regards to the use of hands-on activities, five of the six studies reviewed involving such instructional strategies displayed significant improvement in student conceptual learning for treatments with more emphasis on inquiry practices. It should be noted that one of these studies, Dalton et al. (1997), found that hands-on activities alone did not result in conceptual change, but that these activities had to be processed for meaning in the context of a class discussion in order to result in understanding. The broader results of the review were not overwhelmingly positive, 51% of the 138 studies examined showing positive impacts of inquiry science instruction on student outcomes. However, these modest results in combination with the more significant results around specific inquiry practices point to a consistent trend that inquiry-based instruction is associated with enhanced content learning. The results of analyses of specific inquiry practices suggest that learning activities involving students' active thinking, drawing on data to make conclusions, and hands on activities with adequate discussion are particularly likely to result in student understanding.

What follows are sample topics, objectives, texts, and learning activities for tying transgender issues into existing biology curricula. For each topic, relevant NGSS standards are identified, briefs on core biological subjects are provided, and examples of biological cases related to sexual diversity are explained. In these explanations, I model the use of the trans-sensitive language discussed in my recommendations. Objectives and activities are designed to take advantage of best practices in inquiry science education. Wherever possible, the following core scientific practices of NGSS are utilized (National Research Council 2012):

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

By addressing transgender topics and inviting transgender voices into the classroom, transgender students are supported to recognize themselves as possible scientists.

Inheritance & Sex Determination

<u>NGSS Standards:</u>

- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)
- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2)
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (MS-LS3-2)

Background Biology:

Sexually reproducing organisms pass on their genes to their offspring. This is how families come to share traits like hair color, height, and disease. Humans and most other animals are diploid, meaning most human cells contain two copies of each of the 23 chromosomes (chunks of DNA wound together) that are characteristic of human cells. Individuals inherit one set of chromosome copies from one parent, and the other set of copies from the other parent. The pairs of analogous chromosomes derived from the two parents are called homologous, which means that they're copies of one another, rather than containing completely different information. Examining an individual gene can help to illustrate how exactly this all fits together. OR6A2 is a gene connected to how one tastes cilantro. There are two main versions of the gene. Depending on what versions of the gene one possess, cilantro tastes deliciously minty and tangy, or it tastes like soap (Eriksson et al. 2012). An individual could have 1 copy of the "yay cilantro" version from parent 1, and another copy of the "yay cilantro" version from parent 2. Or one could have 1 copy of "boo cilantro" from parent 1, and 1 copy of "yay cilantro" from parent 2. OR6A2, the cilantro gene, is located on chromosome 11. Like any gene, if it's on one of an individual's copies of chromosome 11, it's also found on the other one. One might have the "yay cilantro" gene on one copy of chromosome 11, and the "boo cilantro" gene on their other copy, but both genes are found on chromosome 11 and at the same location on the chromosome. Possessing versions of the same genes in the same locations is what qualifies chromosome copies as homologous.

44 of the 46 (2 x 23) chromosomes in human cells have a buddy, a.k.a. a homolog. The exception to this rule is sex chromosomes. Some people have homologous sex chromosomes and some don't. People who have homologous sex chromosomes usually have two X chromosomes. The presence of these two X chromosomes usually determines a body will be typically female, including having a vagina, ovaries, and elevated levels of female hormones like estrogen. Some people have sex chromosomes that are not homologous, which usually looks like 1 having only 1 copy of an X chromosome and 1 copy of a Y chromosome to go along with it. This XY chromosome combination usually causes typically male characteristics, including a penis, testes, and elevated levels of testosterone. But how do some people end up with the XX chromosome combination and other people with the XY chromosome combination?

While most of your somatic (body) cells are diploid (2 copies of each chromosome), your gametes (also called sex cells), either sperm or eggs, contain just one copy of the 23 chromosomes, meaning they are haploid. This is due to meiosis, a process of cell divisions that results in daughter cells with half the chromosomes of the parent cell. But meiosis doesn't mean that these daughter cells end up missing half of the genes that are out there for humans. This is because when you have a cell that has 2 copies of each chromosome, when that cell splits, each of the 2 new cells has 1 copy of each chromosome. This gets more complicated with people who have 1 X and 1 Y chromosome. When their diploid cells split up and become haploid during meiosis, some cells usually end up with X chromosomes, and others with Y chromosomes. So you end up with a bunch of haploid sperm cells that have 1 X chromosome, and a bunch of other haploid sperm cells that have 1 Y chromosome.

In human sexual reproduction, a haploid sperm cell and a haploid egg cell meet creating what's called a zygote. That's the cell that divides to become an entire person! Sometimes a sperm cell with an X chromosome meets an egg cell with an X chromosome, and the zygote has 2 X's. Sometimes a sperm cell with a Y chromosome meets an egg cell with an X chromosome. Aha! So that's how we end up with some people having the XX chromosome combination and other people having the XY chromosome combinations.

<u>Sexual Diversity:</u>

Klinefelter's syndrome is characterized by the presence of two or more X chromosomes in addition to one or more Y chromosomes. For the most part (80%) individuals with Kleinfelter's have 2 X chromosomes and one Y chromosome (Frühmesser and Kotzot, 2010). Kleinfelter's occurs in 0.1-0.2% of the general population, and is the most common genetic cause of infertility for humans with testes (Lanfranco et al. 2004). The extra sex chromosomes present in individuals with Klinefelter's most often arise due to issues in meiosis resulting in sperm cells that have both an X and a Y chromosome. During meiosis, the X and Y chromosomes get stuck together rather than pulling apart during cell division to end up in different cells (Visootsak et al. 2001). Thus, some daughter cells end up with extra sex chromosomes, while others end up missing them (Figure 2). Sperm cells containing multiple sex chromosomes then meet egg cells with another sex chromosome, resulting in daughter cells with three or more sex chromosomes. The condition can also arise due to meiotic issues in egg production, but this is less common (Visootsak et al. 2001).

The presence of these extra X chromosomes leads individuals with Klinefelter's to develop feminized qualities as compared to typical males who have just 1 X and 1 Y chromosome. How exactly the extra X copy accomplishes this is not well understood (Lanfranco et al. 2004). However, the preliminary research on the mechanisms underlying Klinefelter's has focused on the duplication of genes on the X chromosomes and their impacts, rather than interference with genes on the Y chromosome (Rocca et al 2016). For individuals with Klinefelter's, sexual development is often normal preceding puberty, however during adolescence, Klinefelter's patients begin to display small, firm testes, and many grow breasts (Lanfranco et al. 2004). Reduced muscle strength, lack of beard growth, and infertility are all common long-term symptoms (Lanfranco et al. 2004).

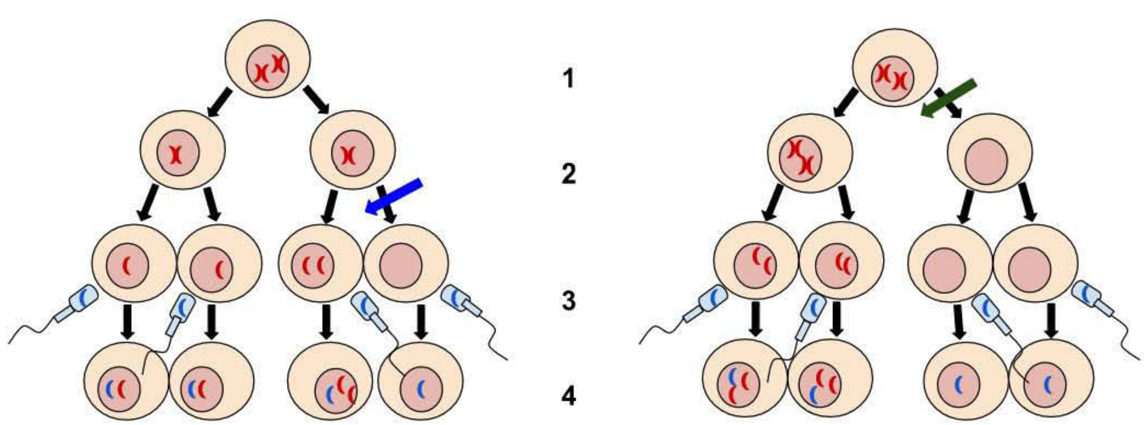

Figure 2. Nondisjunction is when homologous chromosomes or sister chromatids fail to separate properly during cell division, resulting in daughter cells with abnormal numbers of chromosomes. Image source: Wikimedia user Tweety207

Sample Objectives:

Students will be able to…

- determine a human's sex based off of an image of their karyotype
- construct an explanation for how a particular error in meiosis could result in Klinefelter's syndrome, referring the phases of meiosis and the causes of Klinfelter's syndrome.
- argue that biological sex is not a simple binary using incidence data for intersex syndromes in humans as evidence.
- use the biology of intersex conditions and incidence data for intersex syndromes to evaluate arguments against variant gender identities and expressions which claim a biological sexual binary as their basis.

Sample Learning Activities:

- Act it out: meiosis
    - Each student is a single copy of a chromosome.
    - Begin the simulation with half of the class standing up, in pairs. Pairs of students are given notecards with the same chromosome number on them, and either Parent 1 or Parent 2 indicating the parental source of the homolog. So, one partner would have Parent 1, Chromosome 4 on their card and the other Parent 2, Chromosome 4. Another pair would be Parent 1, Chromosome 6 and Parent 2, Chromosome 6.
    - The other half of the class which is sitting down is given blank notecards.

  - Interphase: siting students stand up and partner with one of the standing students. The standing student copies down what is on their card onto their new partner's card.
  - Meiosis 1: groups of 4 students who share the same chromosome number line up in the middle of the classroom. For each group of 4, the 2 pairs of students holding hands go to opposite sides of the room.
  - Meiosis 2: within each ½ of the room, pairs of students who are holding hands line up and then each pair splits to opposite sides of that portion of the room. what should result are 4 quadrants of the classroom, each of which has a single copy of each chromosome that was started out with.
  - To illustrate Klinefelter's syndrome, include an initial pair that is X and Y. certain pairs can be instructed to not come apart during a given division.
- Tag
  - ½ of students are given red notecards and other ½ of students are given green notecards. All red notecards have an X written on them, and ½ of green cards have an X while ½ of green cards have a Y. Students play a tag game in which each red card holder is allowed to tag and pair up with a green card holder, but not a red card holder. Students can tally how many XY and XX pairs there are at the end to see how this system of sex determination results in approximately even numbers of XX and XY individuals.
  - Note: the purpose of this exercise is for students to be able to grasp the connections between parental meiosis and sex determination in

fertilization. It can be tempting for teachers and students alike to further link this material to the social world by saying things like, "It's a boy!" when students with X and Y cards get together, for example. However, these statements reduce the complexity of the biology underlying sexual determination which this curriculum seeks to give prominence to. Such statements can also serve to marginalize trans students who might have XY or XX chromosomes, but don't identify as men or women, respectively.

- Stations
    - In a small group or independently, students explore encounter texts, responding to writing, drawing, or discussion prompts and/or completing a task at each station.
    - This activity allows students to move between texts concerned with the biological and social features of sexual determination, drawing connections between the two as the go along.
    - See below text section for possible resources to be featured at each station.
    - This activity functions well as an introduction to the scientific and social issues under discussion, or as a closing activity in which students apply their scientific understanding to the social issues. For the latter, stations could simply consist of the tasks outlined in the sample objectives and any associated input needed (data, e.g.).

<u>Texts:</u>

- Dreger, A. (December 2010). Is anatomy destiny? Retrieved from https://www.ted.com/talks/alice_dreger_is_anatomy_destiny?language=en
    - "We now know that sex is complicated enough that we have to admit nature doesn't draw the line between male and female, or between male and intersex and female and intersex. We actually draw that line on nature. So what we have is a sort of situation where the farther our science goes, the more we have to admit to ourselves that these categories that we thought of as stable anatomical categories, that mapped very simply to stable identity categories are a lot more fuzzy than we thought."
- Blackless, M., Charuvastra, A., Derryck, A., Fausto-Sterling, A., Lauzanne, K., & Lee, E. (2000). How sexually dimorphic are we? Review and synthesis. *American Journal of Human Biology*, *12*(2), 151–166. https://doi.org/10.1002/(SICI)1520-6300(200003/04)12:2<151::AID-AJHB1>3.0.CO;2-F
    - contains tables of incidence statistics of various intersex conditions, including Klinefelter's Syndrome
- Kuklin, S. (2014). Nat: Something Else. In *Beyond Magenta: Transgender Teens Speak Out* (First edition, pp. 121–145). Somerville, MA: Candlewick Press.
    - "I started to notice that my body was changing, but I wasn't developing like girls. When I tried to compare myself to boys, I wasn't like them, either. So where the hell should I go?"
    - "When the doctors confirmed that I was intersex, I thought, *Wow, I'm that whole other gender!* It proved what I had been feeling all along. I was not

only emotionally, psychologically, and spiritually both sexes; I was physically both sexes too. This is who I am."

- National Human Genome Research Institute (NHGRI). (October 13, 2011). Learning About Klinefelter Syndrome. Retrieved May 1, 2017, from https://www.genome.gov/19519068/Learning-About-Klinefelter-Syndrome
    - short, simple summary of basic causes and symptoms of Klinefelter Syndrome
- Miller, R. [Roy Miller]. (2016, December 6) My Life With Klinefelter's | Journey to Diagnosis. Retrieved from https://youtu.be/2BTHlnuvluc
    - personal story and testimony of a young adult with Klinefelter's

Mutation and Development

NGSS Standards

- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1)
- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation

produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

- Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2)

Background Biology

Organisms pass on their genes to their offspring, resulting in shared family traits like hair color and disease. But how exactly do genes come to be physically (phenotypically) realized? As discussed in the last module, genes are like directions, and those directions materialize when the genes are turned into proteins. This involves a few steps, though. First, the DNA that makes up a gene is read, and a complementary stretch of RNA gets made based on the DNA's code. RNA is similar to DNA in that it is a code written in molecules. RNA is made up of many of the same basic building blocks as DNA called nucleotides, but it has some slightly different component parts to it, and is made up of one strand of nucleotides while DNA is made up of two. In a process known as translation, specialized cellular structures called ribosomes interpret RNA's code of nucleotides for their meaning: a sequence of amino acids. The ribosomes and their cellular helpers assemble and link the amino acids according to the identity and order specified by the RNA. After translation, these strings of amino acids are often further edited and processed by the cell. As the amino acids in a chain interact with one another and with other amino acid chains, they fold and contort according to predictable patterns. Phew! A protein. Finally. Proteins do most of the stuff in human cells. The patterns that structure proteins give them unique shapes and qualities, allowing them to accomplish particular functions. Your bodily functions only keep happening because the proteins in your cells are doing what they're supposed to.

The structures and cells of a human body are not all alike, and they don't do the same things. Skin is a solid protective coating that selectively lets certain substances in and out of the body. Blood, by contrast, is liquid and delivers nutrients to your organs. These cells are different from one another because they produce different proteins. If DNA makes proteins, and different cells contain very different proteins, how do the different cells share the same DNA? Every human begins as a single cell called a zygote. All of the cells in your body are the result of an enormous number of cell divisions descending from this one cell. Beginning with even the earliest divisions, individual cells and groups of cells start to take on specialized roles and identities in a process known as specification. They do this by producing some proteins from their DNA but not others. This differential expression of DNA occurs in response to some sort of environmental cue. Often, in one way or another, these cues come from other cells. Cells send a wide variety of timed and targeted signals that either indirectly or directly interact with the factors controlling transcription inside of each cell. These factors can turn the production of a protein or a group of proteins on or off. They can also speed up or slow down the rate of transcription for given proteins. As you go from one cell to a functioning human, your cells take on specific functions by being told what proteins to make, and what proteins not to make.

The development of the gonad is at the heart of typical sexual development in humans. Gonads are organs which, when fully mature and functioning, produce gametes (egg or sperm) and secrete sex hormones (like estrogen and testosterone). In humans, gonads begin developing at around 4 weeks post fertilization (Pannetier et al. 2016). They are paired structures, meaning each human has 2 gonads each of which performs the same functions as the other, and they emerge located relatively close to one another in the developing fetus's intermediate mesoderm (Wilhelm, Palmer, & Koopman, 2007). For the first 2 weeks of their existence, the gonads are indifferent, meaning the gonads of an XX individual and an XY individual are structurally identical, and both have the capability of taking on male or female fates down the line (Pannetier et al. 2016; Wilhelm, Palmer, & Koopman, 2007). At around 6 weeks post fertilization, the human gonads begin to undergo sexual differentiation, usually becoming either testes or ovaries (Pannetier et al. 2016).

In the past, investigation into sexual determination has centered almost exclusively on the male-determining factor responsible for testis formation in fetal development. Indeed, the SRY gene serves as a master regulator of male sexual development in mammals, its sole presence being capable of inducing typically male development in XX individuals (Koopman et al. 1991). Scientists have in the past taken this to mean that ovarian development is a default state only overridden by the presence of the SRY gene. However, as Wilhelm, Palmer, & Koopman (2007) point out, the notion that ovarian development is the result of a passive molecular pathway "cannot really be the case," multiple lines of evidence suggesting active control mechanisms in early ovarian development. Fausto-Sterling (2012, p. 17) posits that this conceptualization of ovarian development and the markedly poor understanding of early ovarian development that has resulted from it are consequences of the ways in which patriarchy has colored biological research.

Indeed, the more recently characterized *FoxL2* gene has been shown to serve as a master regulator of ovarian development from the indifferent gonads in numerous vertebrate species (Pannetier et al, 2016). The *FoxL2* gene codes for a transcription factor, which recruits RNA polymerase to bind to a segment of DNA. RNA polymerase is the enzyme that interprets DNA, creating a complementary strand of RNA that can then be translated into a protein. Thus, the transcription factor increases the rate at which the gene is turned into a protein. FoxL2 is a transcription factor that *increases* the rate of transcription, however other transcription factors serve to decrease or even halt transcription entirely. The *FoxL2* gene begins to be expressed in the ovary in its earliest stages of development, as it differentiates from the indifferent gonads, and continues to be expressed until the ovary becomes fully functional in adulthood (Pannetier et al, 2016). Typically, FoxL2 plays a major role in the formation of follicles, which are collections of cells that surround eggs and secrete hormones involved in typically female fertility cycles. Researchers have found that abnormalities in FoxL2 can result in masculinization of XX goats (Pailhoux et al., 2001; Pannetier et al., 2012). Though typically female in their chromosomal makeup, these individuals display more intermediate sexual organs.

SRY is a gene usually found on the Y chromosome whose presence is sufficient to induce testes development from the indifferent gonads (Koopman et al. 1991). Like FoxL2, SRY is a transcription factor, binding to particular stretches of DNA to increase the expression of genes linked to those regions. SRY's primary target is Sox9 (Bhandari et al. 2012). Sox9 in turn binds to regions of DNA which promote the transcription of Anti-Müllerian hormone (AMH) (SOX9, National Center for Biotechnology Information, 2017). As the name suggests, AMH prevents the formation of the Müllerian ducts, precursors to the uterus that typically develop in XX individuals. So, to piece it back together, SRY activates SOX9 which activates AMH. AMH stops the gonads from developing towards uterus structures. Thus, the presence of SRY in XY individuals stops these individuals from developing uteruses. Both SOX9 and SRY have numerous other target genes, though the influence of these genes on testes differentiation is less understood (Bhandari et al. 2012).

Testes begin to secrete androgens at 9 weeks of gestation. Androgens are a category of hormones associated with the development and maintenance of typically male characteristics. They are signals generated by the testes and transported through the circulatory system, allowing them to influence far away organs. Androgens exert their influence by modulating transcription, which they do with the help of androgen receptors (AR). In the presence of androgens, the AR protein's shape changes, allowing it to enter the nucleus of a cell, where it starts transcription of particular genes (Galani et al. 2008). These particular genes code for proteins associated with typically male sexual characteristics. The androgens produced by the fetal testes influence genes related to the transition of the primordial external genitalia to penis and scrotum. At puberty, the androgens result in the development of the secondary sexual characteristics of adult males, such as increased muscle mass, square face, deepening of voice, and increased stature.

As discussed in the previous module, organisms pass on their genes to their offspring, resulting in shared family traits like hair color and disease. But the genes that our parents pass on to us aren't the exact same genes that we give to our offspring. Though we get lots of the genetic information that makes us us from our birth parents and grandparents, some of our genetic information is also the result of a broken copy machine. These "copy machines" are really enzymes (proteins), which copy DNA so that reproduction can occur. They are impressively good at what they do, making very few mistakes. They do, however, occasionally make mistakes. These are called mutations. When a mistake happens and isn't fixed, it gets passed into daughter cells. As discussed previously in this module, DNA serves as the body's directions for making the proteins that are the physical building blocks of life. If I make a copy of driving directions, but the copier malfunctions and now the copy of the directions is a little bit off, whoever uses those directions is going to have a different navigating experience than the person with the original for the directions. Certain mistakes would result in the driver getting completely lost (deleting a whole segment, for example), and others wouldn't change much at all. Still others would result in the driver taking a different route but ending up in the same place alright. Mutations are just like this. Some result in a completely nonfunctional protein, others result in no change at all, and still others result in a different protein that can serve lots of the same functions as the original one.

<u>Sexual Diversity</u>

The gene for AR is found on the X chromosome, meaning most humans have functional ARs (AR, National Center for Biotechnology Information, 2017). It is not the lack of ARs but the difference in the amount of androgens in the bloodstream that results in sexual differences between XY and XX individuals. Thus, for XX individuals, the presence of elevated levels of androgens results in the development of certain typically male characteristics. Which characteristics develop depends on the time of exposure relative to developmental stage. For an adult XX individual, exposure to androgens would slightly change the appearance of the external genitalia, but have a greater impact on traits typically acquired by XY men at puberty, such as tone of voice, facial hair, and muscle mass. AR's location on the X chromosome thus enables hormone treatment therapies for XX individuals seeking to acquire a more male phenotype (transgender men, for example). Because XX individuals have the capability of processing androgens much like XY individuals typically do, increasing the levels of androgens in the bloodstream through regular injection of synthetic androgens allows transgender men to acquire male sexual characteristics.

Some XY individuals have mutations in the AR gene which result in a partial or complete inability to process and respond to androgens. With the genetic directions telling the AR protein to diverge from its typical structure, it can no longer fully function to mediate the effects of androgens. This condition is known as androgen insensitivity syndrome (AIS), and results in feminized features in XY individuals. Mutations in AR that are associated with AIS vary widely, including insertions, deletions, and substitutions. Accordingly, AIS phenotypes vary greatly as well. Some individuals with AIS are completely incapable of responding to androgens, resulting in totally female-appearing external characteristics (Ahmed et al. 2000). Others have partial AIS, resulting in ambiguous external genitalia. Because the gonads are developed prior to the secretion of androgens in humans, almost all individuals with AIS have internal testes and lack uteruses (Galani et al. 2008).

Sample Objectives

Students will be able to…

- construct an explanation for how AIS can result in a primarily female phenotype for XY individuals, drawing upon knowledge of mutations and development
- design a hypothetical study of the effects of androgen injection on humans at different developmental stages
- argue for or against surgical intervention in children with AIS using the biological basis of the condition as evidence.
- develop a model or metaphor for how mutations impact development, drawing on their learning about the case of AIS
- given a particular gene and mutation, ask generative questions about how the change in genotype results in phenotypic change

Sample Learning Activities

- Student generated mutations
    - this activity requires students have knowledge of DNA base pairing and differences in bases between DNA and RNA. As such, it is best suited for an honors or AP biology course.
    - groups of students given DNA sequences for different segments of AR
    - each group of students gets to chose a kind of mutation to apply: insertion, deletion, or substitution

    - with this new mutation, students have to transcribe the DNA into RNA, and then translate the RNA using a genetic code table
    - Questioning strategies: Did your mutation result in a change in amino acid sequence? What might the impact of this change be on AR function? Do you think it would damage AR function significantly or just a little bit? Which kinds of mutations most often resulted in functional changes? Which resulted in these changes least often?
- mutated directions
    - class begins by all looking at complete, step by step instructions for making ice cream
    - after being split into groups, each group of student receives a "mutated" copy of the original directions.
        - Deletion: Some groups are missing a large chunk of their directions
        - insertion: directions are interrupted by unrelated, confusing text
        - duplication: one step of the original directions is repeated four times
    - Groups are then instructed to follow the instructions on the papers they were given, and to try to ignore the instructions they were shown at the beginning of class
    - Following the activity, students reflect:
        1. what happened when you tried to follow the instructions that were given to you? Did you succeed? Why did this happen this way?

2. Which groups had the best results and which had the worst?
3. How was this similar to mutations? How was this different than mutations?
4. What does your answer to number 2 tell you about kinds of mutations?

- diagram
  - create a Venn diagram comparing and contrasting a biological article on AIS to a personal account of it

Texts

- Graham, S. (2006, August 8). The secret of my sex. *The Independent*. London, UK. Retrieved from http://www.independent.co.uk/life-style/health-and-families/health-news/the-secret-of-my-sex-411032.html
  - "Even though I was knowledgeable about the cultural construction of sexuality, nothing prepared me to deal with the facts about my rare genetic condition - which is now called Androgen Insensitivity Syndrome (AIS). Being told that on a chromosomal level I am male (XY, not XX) and that the "ovaries" that were removed from me were in fact undescended "testes" was a complete shock. (No, really! On a good day, I can laugh about it now). My body is a 1 in 30,000 genetic fluke and I am nearly completely insensitive to testosterone, so even though I have male chromosomes I didn't develop properly along male lines."
- Ahmed, S. F., Cheng, A., Dovey, L., Hawkins, J. R., Martin, H., Rowland, J., … Hughes, I. A. (2000). Phenotypic Features, Androgen Receptor Binding, and Mutational Analysis in 278 Clinical Cases Reported as Androgen Insensitivity

Syndrome. *The Journal of Clinical Endocrinology & Metabolism*, *85*(2), 658–665. https://doi.org/10.1210/jcem.85.2.6337

  - contains data tables on mutations in AIS patients, including position, base change, and amino acid change

- Dreger, A. (December 2010). Is anatomy destiny? Retrieved from https://www.ted.com/talks/alice_dreger_is_anatomy_destiny?language=en
  - "We now know that sex is complicated enough that we have to admit nature doesn't draw the line between male and female, or between male and intersex and female and intersex. We actually draw that line on nature. So what we have is a sort of situation where the farther our science goes, the more we have to admit to ourselves that these categories that we thought of as stable anatomical categories, that mapped very simply to stable identity categories are a lot more fuzzy than we thought."
- Strudwick, P. (2015, October 7). This Trans Guy Took A Selfie Every Day For Three Years To Show How His Face Changed. Retrieved May 2, 2017, from https://www.buzzfeed.com/patrickstrudwick/this-trans-guy-took-a-selfie-every-day-for-3-years-to-show-h
  - "I was taking testosterone so I could go through the correct puberty for me – and I tried not to have expectations, because testosterone affects everyone differently and different changes come in at different points. Some people get loads of facial hair within the first six months, and some people never get it. I didn't pin too many hopes on T [testosterone] changing me drastically and just took the changes as they came.

- Quinn, E. [Emilord]. (2016, October 26) INTERSEX: Complete Androgen Insensitivity • Explained!. Retrieved from https://youtu.be/5vDVUPjBJiM
    - individual with CAIS describes biological basis for and symptoms of AIS as they relate to her personal experiences

Works Cited

Ahmed, S. F., Cheng, A., Dovey, L., Hawkins, J. R., Martin, H., Rowland, J., … Hughes, I. A. (2000). Phenotypic Features, Androgen Receptor Binding, and Mutational Analysis in 278 Clinical Cases Reported as Androgen Insensitivity Syndrome. *The Journal of Clinical Endocrinology & Metabolism*, *85*(2), 658–665. https://doi.org/10.1210/jcem.85.2.6337

Bergman, S. B. (2009). Sing if You're Glad to Be Trans. In *The Nearest Exit May Be Behind You* (pp. 191–192). Vancouver, B.C: Arsenal Pulp Press.

Bhandari, R. K., Haque, M. M., & Skinner, M. K. (2012). Global Genome Analysis of the Downstream Binding Targets of Testis Determining Factor SRY and SOX9. *PLOS ONE*, *7*(9), e43380. https://doi.org/10.1371/journal.pone.0043380

Blackless, M., Charuvastra, A., Derryck, A., Fausto-Sterling, A., Lauzanne, K., & Lee, E. (2000). How sexually dimorphic are we? Review and synthesis. *American Journal of Human Biology*, *12*(2), 151–166. https://doi.org/10.1002/(SICI)1520-6300(200003/04)12:2<151::AID-AJHB1>3.0.CO;2-F

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What Kind of a Girl Does Science? The Construction of School Science Identities. *Journal of Research in Science Teaching*, *37*(5), 441–458. https://doi.org/10.1002/(SICI)1098-2736(200005)37:5<441::AID-TEA4>3.0.CO;2-3

Brickhouse, N. W., & Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching*, *38*(8), 965–980. https://doi.org/10.1002/tea.1041

Cakir, M. (2008). Constructivist Approaches to Learning in Science and Their Implications for Science Pedagogy: A Literature Review. *International Journal of Environmental and Science Education*, *3*(4), 193–206.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218. https://doi.org/10.1002/tea.20237

Clancy, S. (2008) Genetic recombination. Nature Education 1(1):40

Dalton, B., Morocco, C. C., Tivnan, T., & Mead, P. L. (1997). Supported inquiry science: teaching for conceptual change in urban and suburban science classrooms. *Journal of Learning Disabilities*, *30*(6), 670–684. https://doi.org/10.1177/002221949703000611

Dreger, A. (December 2010). Is anatomy destiny? Retrieved from https://www.ted.com/talks/alice_dreger_is_anatomy_destiny?language=en

Eriksson, N., Wu, S., Do, C. B., Kiefer, A. K., Tung, J. Y., Mountain, J. L., … Francke, U. (2012). A genetic variant near olfactory receptor genes influences cilantro preference. *Flavour*, *1*, 22. https://doi.org/10.1186/2044-7248-1-22

Fae, J. (2012, July 9). Newspaper declines to apologize for terminology in intersex story. *Pink News*. London, UK. Retrieved from http://www.pinknews.co.uk/2012/07/09/newspaper-declines-to-apologise-for-terminology-in-intersex-story/

Fausto-Sterling, A. (2012). *Sex/Gender: Biology in a Social World* (1st edition). New York: Routledge.

Feinberg, L. (1996). *Transgender warriors: making history from Joan of Arc to RuPaul*. Boston: Beacon Press.

Frühmesser, A., & Kotzot, D. (2011). Chromosomal variants in klinefelter syndrome. Sexual Development: Genetics, Molecular Biology, Evolution, Endocrinology, Embryology, and Pathology of Sex Determination and Differentiation, 5(3), 109–123. https://doi.org/10.1159/000327324

Galani, A., Kitsiou-Tzeli, S., Sofokleous, C., Kanavakis, E., & Kalpini-Mavrou, A. (2008). Androgen insensitivity syndrome: clinical features and molecular defects. *Hormones (Athens, Greece)*, *7*(3), 217–229.

Graham, S. (2006, August 8). The secret of my sex. *The Independent*. London, UK. Retrieved from http://www.independent.co.uk/life-style/health-and-families/health-news/the-secret-of-my-sex-411032.html

Grant, J. M., Mottet, L. A., Tanis, J., Harrison, J., Herman, J. L., & Keisling, M. (2011). *Injustice at Every Turn: A Report of the National Transgender Discrimination Survey* (p. 220). Washington, DC: The National Center for Trasngender Equality and The National Gay and Lesbian Task Force. Retrieved from http://www.transequality.org/sites/default/files/docs/resources/NTDS_Report.pdf

Greytak, E. A., Kosciw, J. G., & Díaz, E. M. (2009). *Harsh Realities: The Experiences of Transgender Youth in Our Nation's Schools*. New York: Gay, Lesbian and Straight Education Network (GLSEN). Retrieved from https://eric.ed.gov/?id=ED505687

Gutierrez, N. (2004). Resisting Fragmentation, Living Whole. *Journal of Gay & Lesbian Social Services*, *16*(3-4), 69–79. https://doi.org/10.1300/J041v16n03_05

Hauser, C. (2016, May 13). Transgender Directives for Schools Draw Reaction From Across the Country. *The New York Times*. Retrieved from https://www.nytimes.com/2016/05/14/us/transgender-students-and-new-rules-in-public-schools.html

Hoffman, J. (2016a, May 17). As Attention Grows, Transgender Children's Numbers Are Elusive. *The New York Times*. Retrieved from https://www.nytimes.com/2016/05/18/science/transgender-children.html

Hoffman, J. (2016b, June 30). Estimate of U.S. Transgender Population Doubles to 1.4 Million Adults. *The New York Times*. Retrieved from https://www.nytimes.com/2016/07/01/health/transgender-population.html

Hull, C. L., & Fausto-Sterling, A. (2003). Letter to the Editor. *American Journal of Human Biology*, *15*(1), 112–116. https://doi.org/10.1002/ajhb.10122

Johnson, C. W., Singh, A. A., & Gonzalez, M. (2014). "It's Complicated": Collective Memories of Transgender, Queer, and Questioning Youth in High School. *Journal of Homosexuality*, *61*(3), 419–434. https://doi.org/10.1080/00918369.2013.842436

Koopman, P., Gubbay, J., Vivian, N., Goodfellow, P., & Lovell-Badge, R. (1991). Male development of chromosomally female mice transgenic for Sry. *Nature*, *351*(6322), 117–121. https://doi.org/10.1038/351117a0

Kuklin, S. (2014). Nat: Something Else. In Beyond Magenta: Transgender Teens Speak Out (First edition, pp. 121–145). Somerville, MA: Candlewick Press.

Lanfranco, F., Kamischke, A., Zitzmann, M., & Nieschlag, E. (2004). Klinefelter's syndrome. *The Lancet*, *364*(9430), 273–283. https://doi.org/10.1016/S0140-6736(04)16678-6

Lave, J. (1991). Situating learning in communities of practice. *Perspectives on socially shared cognition*, *2*, 63-82.

Lharmon, C., & Gupta, V. (2016, May 13). Dear Colleague Letter on Transgender Students. Retrieved from https://www2.ed.gov/about/offices/list/ocr/letters/colleague-201605-title-ix-transgender.pdf

Miller, C. C. (2015, June 8). The Search for the Best Estimate of the Transgender Population. *The New York Times*. Retrieved from https://www.nytimes.com/2015/06/09/upshot/the-search-for-the-best-estimate-of-the-transgender-population.html

Miller, R. [Roy Miller]. (2016, December 6) My Life With Klinefelter's | Journey to Diagnosis. Retrieved from https://youtu.be/2BTHlnuvluc

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474–496. https://doi.org/10.1002/tea.20347

National Center for Biotechnology Information. (2017, April 29). AR androgen receptor [Homo sapiens (human)] Gene. Retrieved May 2, 2017, from https://www.ncbi.nlm.nih.gov/gene/367

National Center for Biotechnology Information. (2017, May 8). SOX9 SRY-box 9 [Homo sapiens (human)] Gene. Retrieved May 2, 2017, from https://www.ncbi.nlm.nih.gov/gene?Db=gene&Cmd=ShowDetailView&TermToSearch=6662

National Human Genome Research Institute (NHGRI). (October 13, 2011). Learning About Klinefelter Syndrome. Retrieved May 1, 2017, from https://www.genome.gov/19519068/Learning-About-Klinefelter-Syndrome

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. HS.Inheritance and Variation of Traits. Retrieved March 20, 2017, from http://www.nextgenscience.org/topic-arrangement/hsinheritance-and-variation-traits

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Pailhoux, E., Vigier, B., Chaffaux, S., Servel, N., Taourit, S., Furet, J. P., … Vaiman, D. (2001). A 11.7-kb deletion triggers intersexuality and polledness in goats. *Nature Genetics*, *29*(4), 453–458. https://doi.org/10.1038/ng769

Pannetier, M., Elzaiat, M., Thépot, D., & Pailhoux, E. (2012). Telling the story of XX sex reversal in the goat: highlighting the sex-crossroad in domestic mammals. *Sexual Development: Genetics, Molecular Biology, Evolution, Endocrinology, Embryology, and Pathology of Sex Determination and Differentiation*, *6*(1-3), 33–45. https://doi.org/10.1159/000334056

Pannetier, M., Chassot, A.A., Chaboissier, M.C., & Pailhoux, E. (2016). Involvement of FOXL2 and RSPO1 in Ovarian Determination, Development, and Maintenance in Mammals. *Sexual Development: Genetics, Molecular Biology, Evolution, Endocrinology, Embryology, and Pathology of Sex Determination and Differentiation*, *10*(4), 167–184. https://doi.org/10.1159/000448667

Rocca, M. S., Pecile, V., Cleva, L., Speltra, E., Selice, R., Di Mambro, A., Ferlin, A. (2016). The Klinefelter syndrome is associated with high recurrence of copy number variations on the X chromosome with a potential role in the clinical phenotype. *Andrology*, *4*(2), 328–334. https://doi.org/10.1111/andr.12146

Schwalb, A. (2012, February 16). schwalb's profane addendum to "up your butler."

Serano, J. (2007). *Whipping Girl: A Transsexual Woman on Sexism and the Scapegoating of Femininity*. Emeryville, CA: Seal Press.

Serano, J. (2010). Performance Piece. In K. Bornstein & S. B. Bergman (Eds.), *Gender Outlaws: The Next Generation* (p. 85). Berkeley, CA: Seal Press.

Strudwick, P. (2015, October 7). This Trans Guy Took A Selfie Every Day For Three Years To Show How His Face Changed. Retrieved May 2, 2017, from https://www.buzzfeed.com/patrickstrudwick/this-trans-guy-took-a-selfie-every-day-for-3-years-to-show-h

Teede, H., Deeks, A., & Moran, L. (2010). Polycystic ovary syndrome: a complex condition with psychological, reproductive and metabolic manifestations that impacts on health across the lifespan. *BMC Medicine*, *8*, 41. https://doi.org/10.1186/1741-7015-8-41

Valsiner, J. (1984). Construction of the zone of proximal development in adult-child joint action: The socialization of meals. *New Directions for Child and Adolescent Development*, *1984*(23), 65–76. https://doi.org/10.1002/cd.23219842307

Veitia, R. A. (2010). FOXL2 versus SOX9: A lifelong "battle of the sexes." *BioEssays*, *32*(5), 375–380. https://doi.org/10.1002/bies.200900193

Visootsak, J., Aylstock, M., & Graham, J. M. (2001). Kilnefelter Syndrome and Its Variants: An Update and Review for the Primary Pediatrician. *Clinical Pediatrics*, *40*(12), 639–651. https://doi.org/10.1177/000992280104001201

Wilhelm, D., Palmer, S., & Koopman, P. (2007). Sex Determination and Gonadal Development in Mammals. *Physiological Reviews*, *87*(1), 1–28. https://doi.org/10.1152/physrev.00009.2006