LESSON PLAN & TEACHER'S GUIDE

Sex, Genetics & Athletics

Aim

Athletics are often divided into men's and women's categories to provide fair competition, but efforts to define who qualifies to compete in the women's events have been fraught with controversy. How might the history of sex testing in elite women's athletics help us explore the complexity of human sex variation?

Guiding Questions

- How do we define sex?
- What does sex have to do with how athletic competitions are often organized?
- How do sex and athletics intersect?
- What genetic variations exist in humans that lead to differences in sexual development?
- How does genetic testing and our understanding of sex chromosomes impact our ideas about athletes?
- How are concepts of fairness in sports challenged by human genetic variations?

Learning Objectives

By the end of this lesson, students will be able to:

- Describe some of the genetic variations in humans that lead to differences in sexual development.
- Recognize that personal genetic testing might reveal unexpected genetic differences in oneself.
- Discuss how competitive athletes have been treated in the past and present related to sex.
- List several methods that have been used to verify the sex of elite competitors in women's athletics.
- Illustrate human genetic variation and show how it can impact people and communities.
- Describe the challenges faced by athletes and athletic governing organizations as sex chromosome variation becomes more widely understood.

Materials

Articles, handouts, laptop, projector or SMART board

Time/Classroom Implementation

This lesson can be completed in one to two class periods. We have organized this lesson plan into sections (listed below). We hope this model gives teachers the flexibility to teach the entire lesson in one class period or to identify natural breaking spots to split the lesson over two class periods.

Section 1: Background (slides 1-8)

Section 2: History of sex testing (slides 9-42)

Section 2a: Anatomy-based sex tests (slides 11-13)

Section 2b: DNA-based sex tests (slides 14-29)

Section 2c: Hormone-based sex tests (slides 30-41)

Section 3: Activity & conclusion (slides 42-45)

Standards Alignment

Common Core Standards

CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

CCSS.ELA-LITERACY.RST.11-12.2 Determine the central idea or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Next Generation Science Standards

This pgEd lesson integrates some of the NGSS practices and cross cutting concepts associated with the following disciplinary core ideas. The relevant portion of each disciplinary core idea is written out below.

HS-LS3: Inheritance and Variation of Traits

LS3.A: Inheritance of Traits

- The instructions for forming species' characteristics are carried in DNA.

LS3.B: Variation of Traits

- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

Background Information

Many students are interested in sports, and this lesson uses athletics (referred to as "track and field" in the US) as a lens to examine the biology of sex differences. This lesson also looks at the ways societies react to individuals with these differences. Through readings, slides and discussion, students will examine the history of sex confirmation in elite athletic competition and learn why dividing people into two sexes is not as clear-cut as it seems. Students will examine the practice of defining sex by anatomy, DNA, and hormones and will be asked to consider various viewpoints on fairness, diversity and inclusion in sports and society. The lesson culminates in an activity that asks students to imagine being a doctor responsible for verifying the sex of athletes in an international track and field competition. By increasing the student's understanding of human genetic variation, this lesson illustrates the limitations of a system that only officially recognizes two sexes.

As genetic analysis becomes more widespread, whether it be in healthcare or for "recreational" purposes like genealogy, some people are receiving surprising results – including sex chromosomes that do not match the sex with which they identify. Direct-to-consumer genetic testing is playing a role in people becoming more aware of differences in sex development. One leading company, 23andme, has a page dedicated to explaining why people might get results about their sex that do not align with their

identity and lived experience, entitled "How 23andme Uses Your Self-reported Sex". This experience of "surprising" outcomes of tests related to sex is one that has been experienced for decades by a small number of elite athletes competing on the world stage.

The biology of sex differences is in the news because of international court cases related to particular athletes' performance and participation in elite sports – specifically in track and field. Students will consider the experiences of two runners – Caster Semenya and Dutee Chand. Both athletes failed "sex tests" (examinations of anatomy, DNA, or hormones used to confirm the sex of athletes in women's competitions) and were banned at various times from their respective events as a result. Some people believe they were treated unjustly. Semenya and Chand have insisted they were unfairly persecuted for having atypical physical traits, that, in combination with training and hard work, allowed them to succeed at the highest levels. Others argue that these differences of sex development – while not a form of "illegal doping" or intentional cheating – are nonetheless an advantage that is unfair to the other runners in the women's category. pgEd does not offer an opinion on what the outcome of these court cases should have been; rather, we aim to highlight the complexity behind what many people perceive to be a simple genetic trait. Additionally, having a foundation in the biological underpinnings of sex and chromosome variation may be useful to students as they play and watch sports or participate in discussions about sex, equity, competition and athletics. Finally, it is pgEd's mission to encourage discussion about genetics and society, and this topic is an example of an issue in the public discourse where an understanding of genetics is key to informed discussion and policymaking.

Different societies, communities or groups may have divergent views on sex and gender. While pgEd does not aim to pass value judgment or prescribe how different individuals or communities should think about these topics, we hold a basic belief in the dignity and worth of all people and their rights to personal security and respect.

Interdisciplinary Connections

The material presented crosses into multiple subjects, including biology, health, physical education, social studies, law, and sociology. If you have not done a full unit on genetics, you might first explain to students some fundamental concepts in genetics, specifically that (1) traits can be passed down from parent to child through their genes and (2) complex human traits are often the result of multiple genes in combination with environmental factors. You can also remind students that some genetic traits are unique to an individual and not inherited. Students can learn more at the award-winning website from the Genetic Science Learning Center at the University of Utah. In particular, we recommend that students watch the “What is heredity?” and “What is a trait?” videos found on the Learn.Genetics website.

Foundational Concepts

There are several foundational genetic concepts in this lesson, all related to complexity and variation of human sex chromosomes.

Athletic governing bodies and elite athletes are struggling to reconcile competitions divided into “men's” and “women's” categories with the realities of human sex variation that leave some athletes unable to fit neatly into either category. Athletic competitions are often segregated by sex (although, confusingly, the categories are called “men’s” and “women’s”, which are terms that refer not to sex, but gender). This may seem to be a sensible and straightforward division instituted to promote fairness of competition and increase opportunities for athletic participation among women. Anatomical and physiological differences between typical male and female bodies give males a competitive advantage in most (but not all) athletic events. Without this division, especially at the most elite levels, the strongest male competitor would likely always be stronger than the strongest female and the fastest male would likely be faster than the fastest female. These differences are what have driven the policies designed to provide equitable opportunities to compete against fairly-matched competitors.

While the tools of "sex testing" for sports have changed, problems remain. Throughout the history of women's sports, there has been speculation that men pose as women to compete. In response to these accusations, sports governing bodies such as the International Olympic Committee (IOC) and World Athletics (formerly the International Association of Athletics Federations (IAAF)) have subjected competitors in women's events to various forms of sex confirmation. Since it is assumed that women would not be at a competitive advantage in the men's division, governing bodies have not required those in men's competitions to prove their sex.

Sex confirmation tests have included an examination of athletes' genitals, DNA testing, and measuring the level of testosterone in the blood. They are all controversial. This is because the complexities of the human body mean that there is no single way to definitively determine a person's sex. While typical males and females have obvious physical, chromosomal, and hormonal differences, there is a small but significant portion of the population whose sex does not fit neatly into this male-female binary. These individuals are referred to as "intersex". Some studies estimate that, when all the categories of intersex are combined, nearly 2% of all people are intersex.

A note about genetics and sexual orientation: *Since this lesson discusses the genetics of sex, it may prompt students to ask about whether sexual orientation is determined by genetics. The full answer to that question is beyond the scope of this lesson, but put briefly, while no single "gay gene" or "straight gene" has been identified, weak correlations have been found between many genes and sexual orientation. Like most complex human behaviors and traits, sexual orientation is likely the result of the interaction of multiple factors, both genetic and environmental. Research is ongoing, and our understanding of the genetic link to sexual orientation continues to evolve. More information can be found in this Washington Post article.*

This is not a lesson about transgender athletes. *Intersex individuals do not fit easily into the male/female binary due to differences in sexual development. That is different than being transgender - having a gender identity that is different than the gender typically*

associated with one's sex assigned at birth. An intersex person may also be transgender, but the majority are not. While intersex and transgender athletes face many of the same issues, this lesson focuses on the experience of intersex athletes and how genetic differences in sex chromosomes or in the production and metabolism of sex hormones can impact athletic participation.

Note: We have included a number of news articles and videos throughout this lesson plan. However, as technology evolves at a rapid pace, we recommend visiting www.pged.org for regular updates related to this lesson.

Outline of Resources and Activities in this Lesson

Student handouts, including the vocabulary list, quiz, and worksheets are on pages 34-39, if teachers are planning to print these items and share them as paper handouts.

1. PART 1: Overview for Students (includes links to articles to share or print) (page 10)
2. PART 2: Slideshow Teacher Notes (pages 11-29)
3. PART 3: Classroom Activity Teacher's Guide (pages 30-32)
4. PART 4: Assessments and Handouts (pages 33-39)
    a. Quiz Answer Key (page 33)
    b. Student Handout: Vocabulary (pages 34-36)
    c. Student Handout: Classroom Activity (pages 37-38)
    d. Quiz (page 39)
5. List of Additional Resources (pages 40-42)

Guide for Using this Lesson Plan

This lesson includes a Do Now activity, a slideshow, and a worksheet, and concludes with a teacher-led class discussion.

The slideshow is located at http://www.pged.org/lesson-plans/ along with this lesson. Accompanying explanatory notes for the slideshow are provided in the sections below. You may want students to take notes to help evaluate their understanding, particularly if this material is new or if you plan to extend this lesson with additional readings or writing activities. We have found this guide from Facing History and Ourselves to be helpful: Two Column Note Taking.

PART 1: OVERVIEW FOR STUDENTS

Reading for Students

In advance of the lesson, we suggest asking students to read one or more of the following articles. Teachers can decide which ones are the best fit in terms of class reading level and science background. Teachers may find the video from SciShow helpful to assign in advance of the lesson, or as a resource to show during class: "Intersex Across the Animal Kingdom," October 2016, SciShow.

1. The first 9 paragraphs of "The Humiliating Practice of Sex-testing Female Athletes" by Ruth Padawar, June 2016, New York Times. Students should read until the paragraph that ends with the sentence, "The media asked, 'Did you have a gender test?' And I said, 'What is a gender test?'"

2. "In the 1930s, Intersex Athletics Worried Olympic Officials about the Future of Women's Sports," by Isaac Eger, March 2017, Timeline.

Vocabulary

Some vocabulary used in this lesson may be unfamiliar. We recommend you provide students with the vocabulary list on pages 34-36 before beginning the lesson.

PART 2: SLIDESHOW (45 minutes)

This slideshow introduces students to three major concepts: 1) human sex chromosomes vary beyond the familiar categories of XX and XY, 2) some individuals with XX or XY chromosomes have other genetic traits that affect sexual development, and 3) the growing awareness of these genetic variations presents challenges for elite sports that typically divide athletes into male and female categories.

The slideshow is located on the pgEd website along with this lesson and accompanying explanatory notes for the slideshow are below. The slides provide a great deal of information, while posing many unanswered questions. In the classroom activity, students will be asked to apply the material presented in the slides as they consider how varied, and even confusing, markers associated with male or female sex can be.

Section 1: Introduction

Section 1 of the slideshow provides background information on sex determination in humans. The slides introduce students to the complex interactions leading to a person developing as male, intersex, or female.

Slide 2

In this "Do Now" activity, students are asked to consider how it might feel to have your peers question your sex in response to exceptional athletic performance.

Slide 3

This might seem like an invented scenario, but it is based on the real-life experience of world champion middle-distance runner Caster Semenya. Students are asked to consider a question they may have never thought about – what was Caster Semenya's experience like when she learned someone was questioning her sex?

Caster Semenya is a world champion runner who experienced her competitors questioning if she was a "real woman," in part because of her running victories, her rapid improvement in performance, and her muscular appearance. The group referenced in the slide represents the International Association of Athletics Federations (IAAF) (now called World Athletics) and the International Olympic Committee (IOC), two organizations that make decisions about who is allowed to participate in sporting events, set policies that apply to all athletes, and are often seen as models for other organizations. Teachers can expect students' answers to run the gamut, from students who have never considered such a question, to others who have had their own sex or gender identity questioned in some way, to others who are firm in their belief that designating people as male or female is a simple task. This may be a sensitive topic for students to talk about. We recommend the guide "Facilitating Challenging Conversations in the Classroom" from Washington University in St. Louis if you are looking for resources about establishing classroom norms and expectations.

Slide 4

Learning unexpected information about one's biological sex is not just the purview of elite athletics – direct-to-consumer (DTC) genetic testing can also reveal previously unknown differences of sex development. Many people take genetic tests to learn about their ancestry, health risks or carrier status. Some individuals are surprised when their test results reveal that they have a different complement of sex chromosomes than expected. It is common enough for people to receive results that don't align with their self-reported sex that DTC test providers have created a landing page for questions. Overall, learning about our DNA means we are learning a lot about the breadth of variation in human populations.

Slide 5

To understand this situation, we need to understand how sex is determined. For many, it's a lot more complicated than is often taught.

Slide 6

What most of us learn in biology class is that in humans, sex is determined by the X and Y chromosomes with females having XX chromosomes and males having XY. A person with XX chromosomes will develop ovaries, a uterus and a vagina; estrogen will be the dominant sex hormone, and at puberty breasts will develop. A person with XY chromosomes will develop a penis and testes, testosterone will be the dominant sex hormone, and facial hair will begin to appear at puberty. It all seems very straightforward.

Slide 7

The reality of human sex determination is complicated, as is illustrated in this infographic from Scientific American. Without going into all the details, the far-right column that has a dotted line circling it is the typical XY male as described in the previous slide. The column second from the left is the typical XX female. Everything in between illustrates differences in sex development that are often left out of the discussion. People whose sexual development follows one of these other pathways are called intersex. Intersex people account for approximately 1.7% of the population, making intersex variations about as common as having red hair or green eyes. (Teachers or students interested in exploring this infographic in more detail can find it at "Beyond XX and XY: The Extraordinary Complexity of Sex Determination").

Slide 8

The terms "sex" and "gender" are often confused, but these two words have separate and distinct meanings and are not interchangeable. "Sex" refers to the classification of people into "male", "intersex", and "female" based on physical characteristics, including chromosomes, sex hormones, and reproductive organs. "Gender" refers to behavioral, social and other factors pertaining to the meaning or role of being a "man", "woman", both, or neither. A person's gender identity may be different than the one typically associated with their sex assigned at birth.

In this lesson, the focus is on sex as it relates to athletics – specifically the division of athletics into men's and women's events (see note below on confusing language) and the history of sex testing of athletes in the women's events. This is not a lesson on transgender athletes.

Note: Students may notice that while sports are divided by sex (male vs. female), the categories are named using gendered terms (men's vs. women's events). This is an example of the confusion that is caused by using these terms interchangeably.

Section 2: History of Sex Testing in Athletics

The increase in opportunities for women to compete in elite athletic competitions starting in the early 20th century led to fears of non-female competitors entering women's competitions to claim victory for their country. The slides in Section 2 discuss attempts to verify competitors' sex using a) anatomical, b) DNA-based, and c) hormone-based tests.

Slide 9

In an effort to provide fair competition and increased athletic opportunities for women, sports are often divided into separate categories by sex. Elite sports, such as the Olympics or "world championship" races are overseen by international organizations that set rules and guidelines for athletes and include The International Olympic Committee (IOC) and World Athletics (formerly the International Association of Athletics Federations (IAAF)). Since the mid-20th century, these organizations have used various methods for verifying the sex of athletes competing in women's events, including examining athletes' a) anatomy, b) DNA, and c) hormones.

Slide 10

Since women were first allowed to compete in track and field events in the 1928 Olympic Games, there have been voices suspicious of "un-feminine" levels of

performance. After the 1936 Berlin games, the president of the US Olympic Committee, Avery Brundage, was worried about the threat of "hermaphrodite" athletes compromising the "integrity" of women's sports, and "demanded examination for sex ambiguities in all women competitors." (The word "hermaphrodite", used here because it is a direct quote, is now considered to be pejorative. "Intersex" is the accepted word to refer to individuals who do not easily fit into the male/female sex binary.)

The next three Olympic Games were canceled due to World War II. By the time they returned in 1946, international sports organizations had begun sex testing competitors in women's events. The slides that follow provide an overview of the 70-year history of "sex/gender tests" for female athletes in international sporting events. (Historically, these were referred to as "gender tests".) For more background on this era, see, "In the 1930's, Intersex Athletes Worried Olympic Officials about the Future of Women's Sport," by Isaac Eger in Timeline. This article is part of the pre-reading for students.

Section 2a: Anatomy-based Tests

Slide 11

Let's look at the various ways sports governing bodies have tried to define sex, starting with anatomy.

Slide 12

Beginning in 1944, the IAAF required competitors in women's events to submit a medical certificate from their home country verifying their sex. (The IOC did the same in the first post-war Olympic Games in 1946.)

Slide 13

Suspicions about certain countries falsifying their tests resulted in the 1966 decision from the IAAF to examine the genitals of athletes in women's events. In some cases, the athletes were required to take part in a "nude parade", in which they walked in front

of a panel of doctors at international competitions. “Nude parades” caused a controversy and were abandoned by the IOC in favor of what they considered to be a more scientific effort to assess sex.

Section 2b: DNA-based Tests

Slide 14

Thus, began the era of DNA-based sex tests in women’s athletics.

Slide 15

In 1967, the IOC and IAAF switched to lab tests to check the sex chromosomes. These tests were used until the 1990s. What were these tests looking for?

Slide 16

The challenges of sex testing in sports can be illuminated by examining the biology of sex. At a genetic level, “sex” in humans – the physical and reproductive differences between males and females – is primarily correlated with the sex chromosomes. In typical females, cells contain two X chromosomes, while in typical males, there is one X and one Y chromosome. The X and Y chromosomes share a small number of genes. However, the Y is about one-third the size of the X and has less than one-tenth the number of genes.

Slide 17

One DNA-based test looked for the presence of a Barr body – an inactivated X chromosome – in the athletes’ cells. In individuals with two X chromosomes, one of the X chromosomes in each cell is inactivated and condensed. The inactivated X chromosome appears as a dark spot, called a Barr body, near the edge of the nuclear membrane when viewed under a microscope. In this era, the presence of a Barr body

was generally considered to confirm female sex – and allowed the athlete to participate in the women's events.

Note: As XX individuals carry more genetic material than XY individuals, one X in each cell undergoes X-chromosome inactivation (because excessive or inadequate function of genes may lead to developmental issues in the fetus as well as diseases such as cancer).

Slide 18

Another DNA-based test looked for the presence of the SRY gene. Many genes, on the sex chromosomes as well as the other 22 pairs, play important roles in forming the testes and the ovaries (the reproductive organs, or gonads, where sperm and egg cells mature). Some of these genes, such as the SRY gene typically found on the Y chromosome, actively suppress the development of the ovaries and promote the development of the testes. Other genes do the opposite and encourage the growth of ovaries and suppress the development of testes. From 1967 to the 1990s, any athlete having an SRY gene would be deemed male and ineligible to compete in women's competitions.

For more, please see, "How Sex Development Works," from The University Health Network and The Hospital for Sick Children.

Slide 19

Although we often think of sex in humans as binary – existing in two distinct and mutually-exclusive categories of male and female – this over-generalization does not accurately represent the genetic and biological complexity of sex determination. While typical males and females have physical and chromosomal differences, there is a small but significant portion of the population whose sex does not conform to the commonly understood categories. These individuals with differences in sexual development (DSDs) are referred to as "intersex."

Note: It is important to note that this spectrum of sex does not map neatly onto the spectrum of gender identity. Like individuals who are chromosomally male or female, intersex individuals may identify as a man, woman, both or neither. In fact, the varying gender identities of intersex individuals reinforce the complexity of how human gender is matched onto sex. Intersex people with biological features that do not match their chromosomal sex are more likely than the average population to identify as a different gender than the one they are assigned to or raised as. At the same time, their gender identity usually cannot be predicted from the "maleness" or "femaleness" of their sexual features.

Slide 20

Broadly, there are two categories of biological bases for intersex traits: (1) having an atypical number of sex chromosomes (sex chromosome aneuploidy), or (2) having a typical combination of sex chromosomes but possessing other genetic variants that affect how the reproductive system develops. We will explore examples of each on the following slides.

Slide 21

Intersex traits caused by having an atypical number of sex chromosomes (sex chromosome aneuploidy) are fairly common. Examples include Turner syndrome (X), Klinefelter syndrome (XXY), XYY syndrome (XYY) and triple X syndrome (XXX). Individuals with sex chromosome aneuploidy have a wide range of physical, cognitive, and reproductive characteristics.

It is also possible for certain groups of cells in the developing fetus to lose one of the sex chromosomes, resulting in a "mosaic" individual who has some cells that contain XY (or XX) while others contain only a single X. Other mosaic individuals may have some cells with XX chromosomes and others with XXY. An athlete with XX/XXY mosaicism may develop as a typical female and have no idea they have a Y

chromosome until they fail a sex verification test based on the presence of the SRY gene.

Aneuploidies and mosaicism often develop in the course of gamete formation or early embryonic development, and typically are not inherited from one's biological parents.

Slide 22

Ewa Kłobukowska, a Polish Olympic sprinter, had an intersex variation called "genetic mosaicism" in which some cells contain XX chromosomes and others contain XXY. This is considered a type of sex chromosome aneuploidy. In 1967, she was the first athlete to fail the genetic "gender verification tests" of athletics authorities, due to her extra chromosome, and was stripped of her medals and world records.

Slide 23

Another group of intersex individuals have typical combinations of sex chromosomes (XX or XY) but possess genetic variants that affect how the reproductive system develops. Individuals with these genetic variations often have gonads that are nonfunctional (called "streak gonads") or, in very rare cases, have both testicular and ovarian tissues (an "ovotestis"). External sex organs and secondary sexual features may take a range of forms - typical for what might be expected from their sex chromosomes, opposite of what might be expected, or ambiguous.

Of these intersex variations, Androgen Insensitivity Syndrome (AIS) is one of the most common. Androgens are hormones that promote male sexual development and masculinization of the body. Testosterone is an example of an androgen. In AIS, genetic variation in the androgen receptor gene decreases the body's ability to respond to androgens. Because of this decreased ability to respond to androgens, AIS causes individuals with XY chromosomes to have less-developed male features than typical males. This can occur even if they have high levels of androgens circulating in their

bloodstream. In cases of complete AIS (CAIS), a person with XY chromosomes would have sexual features of a typical female, but internal testes in place of ovaries.

Slide 24

In 1986, Spanish hurdler María José Martínez-Patiño was disqualified after a sex verification test showed she had XY chromosomes. She protested the disqualification based on having androgen insensitivity syndrome (AIS) and was eventually reinstated. She is now a professor of sports science and has written extensively on AIS and sex testing in sports. This is an example of a person who has a typical number of chromosomes (meaning, no evidence of aneuploidy) but possesses other genetic variants that affect how the reproductive system develops.

For a first-hand account of what this experience was like for Martínez-Patiño, see "A Woman Tried and Tested", by Martínez-Patiño, MJ, Lancet 2005;366:S38.

Slide 25

Congenital adrenal hyperplasia (CAH) is an intersex variation in which production of androgens is increased. Elevated androgen levels can lead to a range of typically male sexual features in XX individuals. (While CAH can also affect individuals with XY chromosomes, it does not result in intersex traits.) Teachers will note there is not an athlete featured in this lesson to highlight CAH, but that does not mean there are no athletes with this condition competing and impacted by sex testing.

Slide 26

There are many other variations that may affect sexual development, but we are focusing here on those that are relevant to women in athletics. For that reason, we are not discussing differences of sex development (DSDs) that affect individuals who would likely be identified as male. People competing in men's categories have not be subject to sex verification testing.

To explore other DSDs, see slide 7.

Slide 27

Estimates of the prevalence of individual DSDs vary, and many intersex people may never learn that they are intersex.

Slide 28

While each individual DSD is considered rare, being intersex is fairly common. Intersex traits occur in up to 1.7% of the population (with estimates varying due to differing definitions of what counts as intersex).

However, intersex variations are often considered “invisible”. Many intersex people choose not to share this personal information about themselves. Others are not aware they are intersex, either because they never had outward signs or, because of the common practice of performing surgeries during infancy or early childhood to make intersex bodies conform to the male/female binary. These surgeries are often medically unnecessary and involve parents and/or doctors deciding about whether to make their child appear male or female. Their decision does not always align with the child’s eventual sense of self, and sometimes the child is never told about the surgery or is lied to about the reason for it. This “invisibility” can lead us to think that being intersex is very rare when, in fact, most of us likely know at least one person who is intersex. Teachers may want to help students understand these numbers by thinking about how many people attend their school or live in their town as a reference point.

Slide 29

Both the IAAF and the IOC ended compulsory chromosomal sex testing of all competitors in women’s events in the 1990s. However, they reserved the right to examine athletes if someone were to “challenge” their femaleness.

Section 2c: Hormone-based Tests

Slide 30

Testing hormone levels replaced chromosomal testing as a way to determine eligibility to participate in women's events.

Slide 31

Starting in 2000, athletes' testosterone levels were used to determine eligibility. Like earlier methods of sex testing, this too would be controversial.

Slide 32

Testosterone is a hormone produced in both male and female bodies. Testosterone has many effects on the body, including promoting the growth and strength of bones and muscles and causing many of the puberty-related changes in males. While testosterone is the primary sex hormone in males and estrogen is the primary one in females, both hormones are produced in all humans, with levels varying from one individual to the next. Both testosterone and estrogen are required for the body's overall function in both male and female bodies, and imbalances in the levels of these hormones can affect health.

Slide 33

This slide is animated to allow students to see the distribution of male and female testosterone levels before introducing the 10 nmol/L limit.

a) Testosterone levels vary from one person to the next. This image shows a comparison of testosterone levels between male and female elite athletes. The areas in the shaded boxes show the reference ranges considered "normal" for non-elite athletes (<2.7 nanomoles per liter (nmol/L) for females, 8.4 to 28.7nmol/L for males). While there is a difference in the distribution of testosterone levels between males and

females, notice there is significant overlap of the ranges, with both males and females ranging from nearly 0 to over 30 nmol/L.

b) When hormone testing began to be used to determine eligibility, the IAAF set an initial threshold of 10 nmol/L for competitors in women's competitions. Those with testosterone levels above the cutoff would have to have surgery or take medication to lower and maintain their testosterone level below the 10 nmol/L threshold to compete.

Slide 34

In 2008, Caster Semenya, a South African middle-distance runner specializing in the 400m, 800m and 1500m events, emerged as an international talent. In 2009, the IAAF requested that Semenya be subjected to sex testing due to suspicions raised by her performance and, in particular, her rapid improvement in performance. This led to her disqualification from competition due to her natural testosterone levels being higher than the 10 nmol/L threshold. Feeling she had no other choice, Semenya began taking medication to lower her testosterone levels so she could compete.

In 2014, Dutee Chand, a 100m sprinting champion from India, was also disqualified due to hyperandrogenism, or naturally elevated testosterone. She refused to undergo treatment for her hyperandrogenism, arguing that it was unfair that she was required to undergo medically unnecessary treatments to continue to compete.

Slide 35

In 2014, after being dropped from India's national team, Chand sued the IAAF over the testosterone rule. This was the beginning of a long legal battle over hormone-based sex testing. Chand's lawsuit resulted in the court ruling that the IAAF must suspend the regulation until providing scientific evidence to support the legitimacy of this 10 nmol/L threshold for athletes to compete in the women's division.

Slide 36

At the heart of the lawsuit were three main questions: 1) Do naturally occurring elevated testosterone levels confer an athletic advantage? 2) If so, at what level (of testosterone) does that advantage become unfair? 3) Are testosterone-based eligibility requirements discriminatory? The court gave the IAAF two years to provide scientific evidence to support their claim.

Slide 37

The IAAF hired scientists to study the testosterone levels of elite track-and-field athletes and their results were published in 2017. Of the 21 women's events studied, researchers found that athletes with the highest levels of testosterone performed significantly better than those with the lowest levels in five events – the 400m, 400m hurdles, 800m, hammer throw and pole vault.

The number in parentheses shows how much of an advantage.

1. Hammer throw (4.53% further)
2. Pole vault (2.94% higher)
3. 400m hurdles (2.78% faster)
4. 400m (2.73% faster)
5. 800m (1.78% faster)

This study looked at the testosterone levels of competitors in the IAAF World Championships in 2011 and 2013.

Note: In statistics, a “significant” difference is one that is mathematically determined unlikely to be due to chance.

Slide 38

In 2018, after completing their study, the IAAF decided to reinstate their testosterone regulations, but with a narrower focus. Under the new regulations, testosterone limits only apply to athletes with DSDs participating in certain women’s events – international races with distances between 400m and 1 mile. This includes the 1500m race, which showed no statistically significant advantage to those with elevated testosterone, as well as the 1-mile race, which was not included in the study. As students will note from the slide, the new regulations do not apply to hammer throw or pole vault, both of which did show statistically significant correlation.

This decision to apply the rules to the 1 mile and 1500m, and not the hammer throw or pole vault, was very controversial. Additionally, there are concerns about the study design, implementation and data used. The study has been critiqued for including data from athletes who had been disqualified for doping, and for using duplicated or “phantom” data (e.g., race time data points for which no match was found in the official race times from the events that those data supposedly came from, and the authors of this work themselves admit to “the presence of errors”).

b) They also lowered the testosterone limit for these events from 10 nmol/L to 5 nmol/L.

Note: The study also looked at male athletes in the same World Championship events. No significant difference was found between male athletes in the highest and lowest testosterone tertiles for any event.

Slide 39

Discussion questions give students a chance to wrestle with what will appear to some as a contradiction - the study identified some events where performance is impacted by testosterone, but the list of events covered by the new rules do not align with those in the study. Student answers will vary, but common questions that might come up are: "How meaningful are the <5% advantages in a competition?"; "How would you decide where to set the testosterone level threshold, if one is deemed necessary?"; "Would each event need its own threshold, or can there be one threshold that applies to all events?". Teachers may wish to create an activity where students more deeply examine this particular controversy but it is outside the scope of this lesson.

Slide 40

In 2019, all legal challenges were exhausted and the IAAF ruling took effect.

Slide 41

What do the new IAAF regulations mean for Chand and Semenya? The new IAAF rules for athletes with DSDs apply only to athletes competing in international races between 400m and 1 mile. Since Dutee Chand competes in the 100m, she is free to compete.

Caster Semenya, as an 800m racer, is subject to the regulations. Competitors in these events have several options: 1) lower and maintain their testosterone levels below the threshold for at least 6 months via medication or surgery to remove testicular tissue that may elevate testosterone; 2) participate in an event not covered by the regulation; 3) enter non-international competitions not governed by this rule; 4) compete in the men's division; or 5) possibly compete in another, distinct, third division that does not yet exist.

Semenya, in an article in the Los Angeles Times, responded to the ruling saying, "I am a woman and I am a world-class athlete. The IAAF will not drug me or stop me from being who I am."

For several viewpoints on these questions, see "Track's New Gender Rules Could Exclude Some Female Athletes," by Jeré Longman, April 2018, New York Times. Also: "Sex, Sport, and Why Track and Field's New Rules on Intersex Athletes Are Essential," by Doriane Lambelet Coleman, April 2018, New York Times.

Section 3: Activity & Conclusion

Section 3 of the slideshow introduces the classroom activity in which students imagine being the physician responsible for administering sex verification tests to determine athletes' eligibility for competition in the women's events. The activity is meant to illustrate the limitations of these sex verification tests and show how differences in sexual development may lead to the same athlete being categorized differently depending on which test is used. The lesson ends by questioning current and former methods of sex verification and asks whether in the future we may use something other than sex to divide competitors.

Slide 42

This slide introduces the classroom activity in which students imagine being the medical doctor responsible for determining whether athletes pass sex-verification tests to compete in women's 800m race at an international competition. The exercise is intended to give students the chance to reflect on the complexity of biological sex and increase their knowledge of biological concepts. The classroom activity reinforces the information offered in these slides and requires students to synthesize what they have learned about differences in sexual development and the various methods of sex verification tests used by international athletics organizations.

Slide 43

This slide poses questions for discussion after completing the classroom activity. Debriefing is a critical part of the activity to give students opportunity to discuss 1) how they made their decisions, 2) how categorizing these athletes made them feel, and to 3) process the difficulty of the exercise and limitations of a binary system of sex classification.

Slide 44

Many questions remain about the current and future practice of sex testing in athletics. Critics question the singular focus being placed on testosterone levels, and not other physical characteristics such as height, lean body mass or lung capacity, which are known to confer performance advantage. Others point out that sex verification in sports has always only targeted athletes in the women's division, not those in the men's. Many also note the seeming contradiction in having an upper testosterone-level threshold for women's events, but neither an upper nor lower threshold for men's events. Will testosterone levels remain the metric by which eligibility is decided? Might there be another method by which athletes could be sorted to offer fair competition?

Slide 45

While this lesson highlights the issues of elite athletes, the broader concepts apply to everyone, and can be used to facilitate discussions about fairness and destigmatize differences in sexual development and genetic differences in general. This slide lists resources for further inquiry and support.

Radiolab Presents: Gonads: Dutee

NIH: Numeric Sex Chromosome Variations

AXYS: Association for X and Y Chromosome Variations

[InterAct: Advocates for Intersex Youth]

PART 3: CLASSROOM ACTIVITY (25-35 minutes)

Students are asked to imagine they are a doctor responsible for verifying the sex of competitors in the women's events of an international track and field competition. Students are given profiles of five athletes, with information about their genes and traits (genotype and phenotype) and asked to decide whether they pass or fail the three major types of "sex testing" that have been used historically (anatomy, chromosomes) or currently (hormone levels). Each of the athletes has a difference of sex development that we have discussed in the lesson. The student handout is on pages 37-38 of this lesson.

Before they begin, you may want to reinforce the concepts of Barr bodies and the SRY gene, as they are important to understand for this activity. Students may benefit from revisiting parts of the slide show while completing this activity, especially slides 17 and 18.

Teachers can expect answers to vary and for students to be unsure or confused about deciding whether or not to "pass" or "fail" people on the worksheet. We do not advise using this worksheet as graded work with right or wrong answers. The exercise is intended to give students the chance to reflect on the complexity of biological sex and increase their knowledge of biological concepts. The classroom activity reinforces the information offered in these slides and requires students to synthesize what they have learned about how sex chromosomes can vary in structure and function.

After students complete the worksheet, teachers may lead the class through the worksheet as a group with the following questions: How varied are the answers? Were some of the categorizations difficult to make? Why or why not?

We have included sample discussion questions/writing prompts for use in class or to extend the lesson with a writing assignment.

1. When thinking about whether the athletes in this exercise should compete in the women's division, were there certain traits you felt were more important than others? Did you consider them equally or give one (or more) more weight?
2. How did you make the decision to pass or fail athletes who have traits associated with both male and female sexes? Describe your thought process. Did you wish you had more information or was the information you had enough?
3. If you could offer some advice to the courts making decisions about if and how to include athletes with differences of sex development in elite competition, what would it be?
4. Describe three scientific facts you learned from this lesson that might be helpful to the courts that make decisions impacting athletes such as Caster Semenya, Dutee Chand, and others.

Teacher's Guide to Classroom Activity

Student answers may vary as these tests do not always give a conclusive result (e.g. Barr Body Test result for Athlete 2).

	Anatomical Test	Barr Body Test	SRY Gene Test	Hormone Level Test
Athlete 1	PASS	FAIL	PASS	PASS
Athlete 2	PASS	PASS/FAIL	FAIL	PASS
Athlete 3	PASS/FAIL	PASS	PASS	FAIL
Athlete 4	PASS	FAIL	FAIL	FAIL
Athlete 5	PASS/FAIL	FAIL	FAIL	FAIL

Additional Information

The findings for **Athlete 1** are consistent with Turner syndrome. Individuals with Turner syndrome have a single X chromosome and would have neither a Barr body nor an SRY gene.

Because the genetic tests found Barr bodies present in some cells and absent in others, **Athlete 2** likely has genetic mosaicism. Since some cells have a Barr body and there is an SRY gene present, we would suspect that some cells have XXY while others have XY (although other combinations are possible). Another possibility would be translocation of the SRY gene onto an X chromosome.

The findings for **Athlete 3** are consistent with congenital adrenal hyperplasia (CAH). This athlete has XX chromosomes, slightly elevated testosterone, and ambiguous genitalia.

The findings for **Athlete 4** are consistent with complete androgen insensitivity syndrome (CAIS). Although this athlete appears to have XY chromosomes and testosterone levels considered 'normal' for males, they have female genitals.

Athlete 5 likely also has androgen insensitivity syndrome (AIS), but since the genitals are ambiguous, they may have only partial insensitivity.

PART 4: ASSESSMENTS & HANDOUTS

Quiz Answer Key (see page 39 for quiz)

1. Intersex
2. D
3. Student responses may include statements such as:
   She has elevated testosterone levels that some feel give her an unfair advantage over other women with more typical hormone levels.
   People are divided over whether it is fair for someone with male and female physical traits to compete with athletes who are more clearly one sex or the other.
4. False
5. D
6. True

Student Handout: Vocabulary

Androgen – One of the two major groups of steroidal sex hormones, or chemicals produced by our bodies to regulate the development of the reproductive organs and sexual features. Androgens are typically found in higher levels in males, and estrogens typically higher in females, but both types of hormones are present in all people.

Androgen insensitivity syndrome (AIS) – An intersex variation in which a person with XY chromosomes has limited or no sensitivity to the hormones that "masculinize" the body.

Aneuploidy – In humans, a condition in which an individual has more or fewer than the usual 46 chromosomes.

Barr body – An inactivated X chromosome, present only in cells with more than one X chromosome, that appears as a dark spot near the edge of the nuclear membrane when viewed under a microscope. The presence of a Barr body is a genetic indicator for female sex.

Binary – Something that exists only in one of two mutually exclusive states.

Chromosome – An individual piece or molecule of DNA in the genome. In humans, each cell typically has 23 pairs of chromosomes, 22 pairs called autosomes, and one pair of sex chromosomes (X and/or Y).

Complete androgen insensitivity syndrome (CAIS) – An intersex variation in which a person with XY chromosomes has no sensitivity to the hormones that "masculinize" the body.

Congenital adrenal hyperplasia (CAH) – An of intersex variation in which increased hormone production in the adrenal glands (small glands that rest atop the kidneys), cause masculinization in a person with XX chromosomes.

Estrogen – One of the two major groups of steroidal sex hormones, which are chemicals produced by our bodies to regulate the development of the reproductive organs and sexual features. Androgens are typically found in higher levels in males, and estrogens typically higher in females, but both types of hormones are present in all people.

Gender – Behavioral, social and other factors pertaining to the meaning or role of being a "man", "woman", both, or neither.

Gender identity – A person's internal and individual experience of gender, as man, woman, both or neither. This may or may not be the gender typically associated with their sex assigned at birth.

Genetic test – A procedure that gives some information about the genetic make-up of an individual.

Genetic variant – One of several possible DNA sequences at a particular location in the genome.

Genome – An individual's full set of genetic information, including all genes as well as other sections of DNA that may regulate when genes are turned on or off.

Gonad – An organ in the body (e.g., testis or ovary) whose function is to produce gametes (i.e., reproductive cells, including sperm or egg) and sex hormones.

Intersex – Individuals whose sex (at the levels of chromosomes, gonads, sex chromosomes and/or genitals) does not fit into the male-female binary.

Mosaicism - A genetic condition in which a person has two or more sets of cells with different (differing?) genetic make-up.

Non-binary – General term for gender identities that do not fit the man-woman binary.

Sex – Classification of people into “male”, “intersex”, and “female” based on physical characteristics, including chromosomes, sex hormones, and reproductive organs.

SRY gene – The sex-determining region of the Y chromosome, responsible for initiating male sexual development. The presence of an SRY gene is a genetic indicator for male sex.

Testosterone – An androgen hormone.

Transgender – Individuals whose gender identity differs from the gender typically associated with their physical or chromosomal sex or the gender they were assigned at birth. Cisgender refers to individuals whose gender identity is the same as the gender typically associated with their physical or chromosomal sex.

Student Handout: Classroom Activity

Name: _____ Date: _____

Imagine you are a medical doctor responsible for verifying the sex of competitors in women's events in an international track and field competition. Using the information given in Tables 1 and 2, determine whether each athlete passes or fails each type of sex verification test. (An athlete who *passes* a sex verification test *is allowed* to compete in women's competitions.) Record either "pass" or "fail" for each test in Table 3.

Table 1: Athlete Profiles

Athlete 1	**Physical characteristics:** female genitals fully formed **Genetic test findings:** Barr body absent, SRY gene absent **Hormone test findings:** Testosterone (T): 1.2 nmol/L
Athlete 2	**Physical characteristics:** female genitals fully formed **Genetic test findings:** Barr body present in some cells absent in others, SRY gene present **Hormone test findings:** Testosterone (T): 3 nmol/L
Athlete 3	**Physical characteristics:** genitals neither typically male nor typically female **Genetic test findings:** Barr body present, SRY gene absent **Hormone test findings:** Testosterone (T): 6.3 nmol/L
Athlete 4	**Physical characteristics:** female genitals fully formed **Genetic test findings:** Barr body absent, SRY gene present **Hormone test findings:** Testosterone (T): 25 nmol/L
Athlete 5	**Physical characteristics:** genitals neither typically male nor typically female **Genetic test findings:** Barr body absent, SRY gene present **Hormone test findings:** Testosterone (T): 12 nmol/L

Student Handout: Classroom Activity

Name: _____ Date: _____

Table 2: Criteria for passing each test:

	Pass	Fail
Anatomical Test	Female genitals fully formed	Masculinized genitalia
Barr Body Test	Barr body present	Barr body absent
SRY Gene Test	SRY gene absent	SRY gene present
Hormone Level Test	Testosterone level less than 5 nmol/L	Testosterone level above 5 nmol/L

Table 3: Eligibility Results

	Anatomical Test	Barr Body Test	SRY Gene Test	Hormone Level Test
Athlete 1				
Athlete 2				
Athlete 3				
Athlete 4				
Athlete 5				

Quiz

Name: _____ Date: _____

1. Individuals with differences in sex development, whose sex (at the levels of chromosomes, gonads, sex chromosomes and/or genitals) does not fit into the male-female binary are referred to as _____.

2. Which of the following has been used for sex testing in athletics?
    a. Examination of athletes' anatomy
    b. Chromosome assessment
    c. Hormone levels
    d. All of the above

3. Summarize the controversy surrounding world champion runner Caster Semenya.

4. All humans fit easily and clearly into the biological category of male or female. T/F

5. Androgens are chemicals/hormones that are:
    a. Present only in males
    b. Present only in females
    c. Present only in intersex individuals
    d. Present in all humans

6. Some people may learn they are intersex from the results of direct-to-consumer genetic tests (such as those for DNA ancestry). T/F

Additional Resources for Teachers

These articles and videos highlight the scientific and societal questions related to sex, gender and athletics. Some provide some historical context; others are up-to-the-minute in terms of the publication date of this lesson. They may be useful for teachers who are new to this topic, for extending or differentiating the lesson, or to share with students who want to learn more. This lesson will be updated regularly, therefore we also recommend visiting pged.org for the most up-to-date news articles.

News Articles

"Caster Semenya, Testosterone and the History of Gender Segregation in Sports," by Jaime Schultz, May 2019, *LiveScience*.

"Gender Testing for Athletes Remains a Tough Call" by Eric Vilain, June 2012, *New York Times*.

"Sex Redefined," by Claire Ainsworth, February 2015, *Nature*.

"How Intersex Latina Dalia Rundblad Is Destigmatizing the 'I' in LGBTQIA," by Raquel Reichard, February 2017, *Latina*.

"Sex, Sport, and Why Track and Field's New Rules on Intersex Athletes Are Essential," by Doriane Lambelet Coleman, April 2018, *New York Times*.

"Track's New Gender Rules Could Exclude Some Female Athletes," by Jeré Longman, April 2018, *New York Times*.

"Not by Gender, Not by Sex, but by the Testosterone Saith: The IAAF International Athletics and the New Female Eligibility Regulations" by Ben Koh, Daryl Adair, and Liam

Elphick, May 2018, *Law in Sport.* Note this is a lengthy, legal analysis but could be used selectively with students.

"Caster Semenya Will Challenge Testosterone Rule in Court" by Jere Longman, June 2018, *New York Times.*

"Caster Semenya, Testosterone and the History of Gender Segregation in Sports" by Jaime Schultz, May 2019, *Live Science.*

"Caster Semenya: Olympic 800m Champion Can Compete after Swiss Court Ruling", June 2019, *BBC.*

"Ruling Leaves Caster Semenya with Few Good Options," by Victor Mather and Jeré Longman, July 2019, *The New York Times.*

Videos

"The Problem with Sex Testing in Sports," June 2019, *Vox.*

"Intersex Across the Animal Kingdom," October 2016, *SciShow.*

"Too Fast to Be a Woman? The Story of Caster Semenya", October 2015, by the *Kuchu Times.*

Curriculum

"Sex Verification of Female Athletes" from *HHMI Biointeractive*. A complete lesson plan from the Howard Hughes Medical Institute.

How Sex Development Works," from The University Health Network and The Hospital for Sick Children.

Related pgEd Lesson Plans

Introduction to Personal Genetics

Consumer Genetics

Personalized Medicine

Genetics, Jobs and Your Rights

ACTN3: Can Genetics Tell Me if I Am Going to Be an Olympic Sprinter?