

Sex Verification Testing of Athletes

INTRODUCTION

This handout complements the Click & Learn "Sex Verification Testing of Athletes."

PROCEDURE

As you proceed through the interactive, follow the instructions and answer the questions in the spaces provided.

INTRODUCTION

Select the "Introduction" tab and watch the opening video. After watching the video, scroll down and read the text. As you read, click on the underlined terms to learn more about them. When you have finished, answer questions 1-3 below.

1.	What evidence provided supports the claim that "A high level of testosterone provides an unfair advantage
	in women's athletics"? Is this adequate evidence? Explain your answer.

Click c	n the term	"biological sex."	Describe how	biological sex and	l gender diffe	er from each	າ other.
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3. Are sex verification tests of athletes used to determine biological sex or gender? Explain why you selected sex or gender.

HUMAN DEVELOPMENT

Click the "Human Development" tab. As you navigate through this section, use the information to answer questions 4-20.

4. Rewrite the following statement to be correct regarding human chromosomes: "All chromosomes are autosomes, and some autosomes are allosomes."

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5.	What does	the pre	esence of	f a	Barr	body	indicate?
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- 6. Regarding the SRY gene ...
 - a. What does SRY stand for?
 - b. On which chromosome is the SRY gene normally found?
 - c. What is the function of the SRY gene?
- 7. Think about it. If an embryo made testosterone normally but did not have testosterone receptors in any of its cells, would the embryo develop female reproductive structures, male reproductive structures, or no reproductive structures? Explain your answer.

8. Examine the graph showing blood testosterone levels in elite male and female athletes. Fill in the table below to show the range and mode (highest frequency) of testosterone concentration for females and males in this study.

Cov	Range	Mada		
Sex	Low	High	Mode	
Females	nmol/L	nmol/L	nmol/L	
Males	nmol/L	nmol/L	nmol/L	

9. Based on the data in the graph of blood testosterone levels in elite male and female athletes, is there a testosterone concentration that can reliably divide females from males? Explain your answer.

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10. Secondary sex characteristics arise during puberty. What causes these developmental changes?
11. List two examples of secondary sex characteristics in females and two in males.
12. Are there secondary sex characteristics that could be the basis of a reliable sex determination test? Explain your answer.
13. Regarding DSDs a. What does the abbreviation DSD stand for?
b. How common are DSDs?
Answer the following questions using the table of DSDs.
14. CYP21A2 gene mutationsa. By what mechanism can a mutation in CYP21A2 change testosterone levels?
b. What changes in phenotype are typical in people with a CYP21A2 mutation?
15. SRY gene mutationsa. How can an error in chromosome segregation during meiosis affect inheritance of the SRY gene?



	b.	What is the effect of a nonfunctional SRY gene on the development of primary sex characteristics?
	C.	Which sex is typically assigned at birth to an individual with a mutation that results in a nonfunctional SRY gene?
16.	хо	a. How can an error in chromosome segregation result in Turner syndrome?
		b. Can an individual with Turner syndrome have biological children?
17.		gene mutation Which phenotypes may arise in an individual with a mutation in the AR gene?
	b.	In humans, the AR gene is located on the X chromosome. If a person who is XY has a complete deletion of the AR gene, do you think giving them testosterone injections during puberty would cause an increase in expression of male secondary sex characteristics compared to not receiving injections? Explain your answer.
18.	XXY a.	Which of the following terms describes the process of homologous chromosomes failing to separate correctly during meiosis? A. Chromatid adhesion syndrome B. Nondisjunction C. Ametaphasia D. Anti-anaphase
	b.	If a person with Klinefelter's syndrome wanted to look more like an average male, what medical treatment could help accomplish this?

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19. SRD5A2 gene mutation

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A mutation of the *SRD5A2* gene causes a deficiency in the enzyme 5-alpha reductase. Describe how this affects ...

- a. embryonic development
- b. external reproductive anatomy at birth
- c. secondary sex characteristics at puberty

20. AMH or AMHR2 gene mutations

- a. What typically happens to the Müllerian ducts in females during development?
- b. What typically happens to the Müllerian ducts in males during development?
- c. Which internal reproductive structures would a person with a mutation in the AMH or AMHR2 gene have?

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CASE STUDIES

Click the "Case Studies" tab, read about the two athletes and the history of sex verification tests, and then use the information to answer questions 21-22.

- 21. Click the "Sprinter" tab.
 - a. Which four tests have historically been performed to determine an athlete's biological sex?
 - b. What is a genotype that would explain the sprinter's phenotype? Explain.
- 22. Click the "Swimmer" tab.

Under current regulations, would the swimmer be allowed to compete? Explain.

EXTENSION ACTIVITY DSD TABLE

The table on the following page provides additional information on the DSDs shown at the bottom of the Human Development tab. Complete the table to indicate whether a "sex verification test" of a person with each listed DSD would show Barr bodies or the *SRY* gene, whether their testosterone level would be low (typical of a female) or high (typical of a male), and whether they are likely to menstruate or be fertile (able to have biological children without in vitro fertilization or other medical interventions).

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Chromosomes	Genetic mutation	Syndrome	Internal reproductive anatomy	External genitalia	Secondary sex characteristics	Sex typically assigned at birth	Barr body (Y/N)	SRY gene (Y/N)	Testosterone (Low/High)	Menstruation (Y/N)	Fertile (Y/N)
46,XX	None	None	Female	Female	Female	Female					
46,XX	CYP21A2 mutation or deletion	Congenital adrenal hyperplasia	Female	Ambiguous	Male but reduced	Female					
46,XY	SRY mutation or deletion	Swyer syndrome	Female but nonfunctional ovaries	Female	Absent or female, but reduced	Female					
45,X	Complete or partial loss of X chromosome	Turner syndrome	Female but absent or nonfunctional ovaries	Female	Absent or female, but reduced	Female					
46,XY	Androgen receptor (AR) deletion	Complete androgen insensitivity syndrome	Shortened vaginal canal and testes, no fallopian tubes or uterus.	Female	Female	Female					
47,XXY	Extra X chromosome	Klinefelter syndrome	Male	Male	Male but reduced. Breast growth may occur	Male					
46,XX	SRY gene translocation to X	XX male syndrome	Male	Male but small testes	Male but reduced	Male					
46,XY	SRD5A2 mutation or deletion	5-alpha reductase deficiency	Male	Female or ambiguous	Male	Female					No
46,XY	Mutation or deletion of the genes for AMH or AMH receptor (AMHR2)	Persistent Müllerian duct syndrome	Male reproductive organs plus uterus and fallopian tubes	Male, but one or both testes may be undescended	Male	Male					No
46,XY	None	None	Male	Male genitalia	Male	Male					



EXTENSION ACTIVITY

Four factors are considered when determining a person's biological sex: 1) chromosomes, 2) hormones, 3) primary sex characteristics that are features essential for sexual reproduction (internal reproductive structures and external genitalia), and 4) secondary sex characteristics, features that typically appear during puberty and are different between the sexes, but are not directly involved in reproduction (for example, females typically have enlarged breasts and widened hips; and males typically have increased facial and body hair, increased muscle mass, and a larger Adam's apple). Given that the top male athletes outcompete the top female athletes by about 10% in most sports, provide a justification for how each of these four factors is or is not likely to contribute to performance differences between sexes.

Factor that helps determine biological sex	Likely to affect athletic performance? (Y/N)	Justification
Chromosomes		
Hormones		
Primary sex characteristics		
Secondary sex characteristics		