

Facts of Life — Gender Determination

Secrets of the Sequence Video Series on the Life Sciences • Grades 9 — 12
Teaching materials developed by VCU Life Sciences

V i r g i n i a C o m m o n w e a l t h U n i v e r s i t y

Classroom Tested Lesson

Video Description

“Secrets of the Sequence,” Show 106, Episode 1

“Facts of Life: Gender Determination” – approximately 8 minutes viewing time

David Page at the Whitehead Institute is studying the Y chromosome – the one that’ll make a man out of you. The study of the “Y” reveals much more than maleness – including why only men are prone to certain diseases, and how the set number of genes on the “Y” seems to be responsible for a lot of very “male” behavior.

Ward Television

Producer: Paul Gasek

Featuring: David Page, Biology at Massachusetts Institute of Technology

Lesson Authors; Reviewers: Marilyn Elder and Catherine Dahl; Dick Rezba, Kieron Torres, and Tarynn M. Witten

Trial Testing Teachers: Michael Comet, Brooke Williams

National and State Science Standards of Learning

National Science Education Standards Connection

Content Standard C: Life Science

As a result of their activities in grades 9-12, all students should develop understanding of

- Molecular basis of heredity
- Behavior of organisms

Selected State Science Standards Connections

Use <http://www.eduhound.com> (click on “Standards by State”) or a search engine to access additional state science standards.

Virginia

- BIO.4 The student will investigate and understand relationships between cell structure and function. Key concepts include
- c. similarities between the activities of a single cell and a whole organism
- BIO.5 The student will investigate and understand life functions of archaebacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include
- e. human health issues, human anatomy, body systems, and life functions
- BIO.6 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include
- a. cell growth and division
 - b. gamete formation

- c. cell *specialization*
- e. genetic variation (mutation, recombination, deletions, additions to DNA)
- i. exploration of the impact of DNA technologies

California

Grades Nine - Twelve
 Biology/Life Sciences
 Science Content Standards
 Genetics

2. Mutation and sexual reproduction lead to genetic variation in a population. As a basis for understanding this concept:
 - a. *Students know* meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
 - b. *Students know* only certain cells in a multicellular organism undergo meiosis.
 - d. *Students know* new combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
 - e. *Students know* why approximately half of an individual's DNA sequence comes from each parent.
 - f. *Students know* the role of chromosomes in determining an individual's sex.

4. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept:
 - d. *Students know* specialization of cells in multicellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.

5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells. As a basis for understanding this concept:
 - d. *Students know* how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.

Overview

This video explains how the X and Y versions of the 23rd chromosome are related to the development of male or female sex organs. Of the 40-50 male genes on the Y chromosome, the 23rd chromosome, only one, named SRY (from 'Sex Determining Region of the Y-chromosome'), actually determines the sex of a fertilized egg. If the SRY gene is present in the male, the offspring's reproductive organs will be male and if the SRY gene is not present, the reproductive organs of the offspring will be female "by default". However, since there are multiple characteristics associated with maleness, it is clear that the effect of SRY is more far reaching than just instructing the production of testes. Even though the SRY gene disappears after its instruction phase, male hormones produced by the testes then affect the development of characteristics and traits associated with maleness.

Note: One reviewer suggested that clear distinctions be made between the definition of "gender" and "birth sex". "Gender" refers to a mental perception or cultural perception of masculine/feminine/other while "birth sex" refers to male/female reproductive organs.

Testing: A sample related multiple choice item from State Standardized Exams

In fruit flies, the gene for red eyes (R) is dominant and the gene for sepia eyes (r) is recessive. What are the possible combinations of genes in the offspring of two red-eyed heterozygous flies (Rr)?

1. RR only
2. rr only
3. Rr and rr only
4. RR, Rr, and rr only *

Source: California State Standards

Video Preparation

Preview the video and make note of the locations at which you will later pause the video for discussion.

Before Viewing

1. Ask: Which chromosome determines our birth sex? How is sex determined by that chromosome?
The 23rd chromosome. Females contribute an X chromosome in the egg. Male sperm either have an X chromosome or a Y chromosome. If the Y chromosome is present, the embryo is male (XY). If the X chromosome is present, the embryo is female, because both of the 23rd chromosomes are the same (XX).
2. Was Henry VIII's strategy of changing wives in order to produce a male heir a correct one? *No. Males produce sperm that carry either X or Y chromosomes while eggs always have X chromosomes. Although sperm vitality can be affected by pH and temperature of a woman's body, birth sex is ultimately determined by the male so the lack of a male heir was Henry VIII's problem, not his wives'.*

During Viewing

1. **START** the video.
2. **PAUSE** the video (5:10 minutes into the video) on the table showing the 3 classes of genes.

There are only 40-50 genes on the Y chromosome that are divided into 3 classes or families of genes. Review the classifications and the functions involved in each.

- *SRY single gene – if present this gene instructs other genes to start making testes*
- *16 genes – housekeeping genes for basic cell functioning*
- *9 genes or gene families – for sperm production*

If the Y-chromosome and its SRY gene are present, the gene will instruct other genes to start making testes 7 weeks after fertilization. After triggering that function, the SRY gene turns off and is never heard from again.

Ask: If the only gene that determines birth sex turns off, how do all of the characteristics associated with gender develop?

The presence or absence of the SRY gene results in testes or ovaries that in turn produce the male and female hormones that cause changes in the body, including the brain.

One field test suggested pausing the video at 5:20 to also discuss lab research as a career.

3. **RESUME** the video and play to the end.

After Viewing

Following the video, you may wish to do one or more of the following:

1. Review the statistics on infertility and list other possible reasons for male infertility.
Note: A field test teacher suggests contacting a local university research center or reproductive endocrinologist for additional resources and information.

Ask: Can males modify their behaviors to influence their fertility?

One sixth of all couples are infertile and 1/3 of this infertility is caused by the male. About 1 in 4000 males is infertile because of a "hole" in the Y-chromosome, but that is only one cause of male infertility. Other reasons for male infertility are

*Restrictive clothing
Hot tub use; excessive heat
Smoking
Alcohol use
Marijuana use*

2. Ask: What determines sex traits and characteristics?
Testes and ovaries produce hormones that influence the body's development: e.g., amount of facial and body hair, physique, aggressiveness.
3. **Optional:** Depending on community mores and school policies, you may wish to discuss the following:

The narrator states that the most frequently question asked of him is, "What do the X and Y chromosomes have to do with sexual orientation?" He said that the role of the X and Y chromosomes in sexual orientation is still unclear.

Among the questions you might ask are:

- What do you think... Is sexual orientation genetically based or is it a choice?
- What do you know about the nature versus nurture argument?
- What do the X and Y chromosomes have to do with sexual identity?
- What do the X and Y chromosomes have to do with sexual choice of partner?
- Do you think that sexual identity can change over the lifespan or is it fixed?

Teacher Notes for the Student Activities I and II

Materials

- Student Handout 1: Sex Chromosomes and Inheritance
- Student Handout 2: Gender Determination at the Olympics
- Appendix A: Background Information on Sex Chromosomes and Inheritance
- Appendix B: Background information on Gender Determination and Androgen Insensitivity Syndrome

- Appendix C: History of Olympic Rulings on Gender Determination

Note: One reviewer pointed out that in the Appendices taken from the Internet, where the word "gender" is used, a better technical usage would be "birth sex".

Procedure

Activity 1: Sex Chromosomes

1. Give each student a copy of Appendix A and ask them to carefully read the background information on sex-linked chromosomes. Provide sufficient time and encourage students to ask questions about the material.
2. Distribute a copy of the Student Handout 1: Sex Chromosomes and Inheritance to each student.
 - Review Meiosis with the students.
 - Emphasize that meiosis occurs only in gametes - the egg and sperm cells. In humans the chromosome number is 23 after meiosis instead of the 46 chromosomes in somatic cells.
 - Direct them to the Web site on their handout (http://www.biology.arizona.edu/cell_bio/tutorials/meiosis/main.html) and have them read this tutorial on line (Under 'Contents', click on Reproduction, at the bottom of this page, click on 'next', after reading this page click on 'next'. On this page, play both animations – Meiosis I and Meiosis II, and then click on 'next' to read the final page called, "A Review of Meiosis")
 - Have students answer the questions on the Activity 1 Handout:

Answer Key to questions on Activity 1 Handout:

1. Where does meiosis take place?
In ovaries and testes that produce eggs and sperm.
2. How many chromosomes are in the cells in the beginning of meiosis I?
Diploid - 46
3. How many chromosomes are there in the cells at the end of meiosis I?
Haploid -23
4. How many chromosomes are there in the cells at the end of meiosis II?
Haploid -23

Activity 2: Gender Determination and Androgen Insensitivity Syndrome and History of Olympic Rulings on Gender Determination

This activity is on an unusual sports-related genetic topic that will interest many students and require of them a level of maturity that may be challenging. You may wish to consider trying this activity first with your most mature or advanced class.

1. Give each student a copy of Appendix B and ask them to read the background information on gender determination and the Androgen Insensitivity Syndrome.
2. Discuss the sensitive nature of this topic and your expectations for a mature discussion on the implications of genetic abnormalities.
3. Give each student a copy of the Student Handout Activity 2 on Gender Determination at the Olympics. The activity can be done individually as homework or in class in groups of 2-3.
4. Discuss the questions in groups or as a whole class.

5. Encourage interested students to research current Olympic gender-related policies and procedures or on other sex related conditions such as Klinefelter's syndrome. (A trial test teacher suggested that students may confuse intersexuality with homosexuality, and that the differences should be discussed to help maintain the integrity of your discussions. A useful website is <http://www.isna.org>)

Answer Key to Student Handout 2: Gender Determination at the Olympics

	Phenotype			Genotype		
	Hair	Height	Weight in pounds	Inferred <i>(will vary)</i>	Self-reported	Actual
1	Long, blond	5'11"	175	XX	XX	XY
2	Short, brown	5'10"	160	XX	XY	XY
3	Long, black	5'9"	155	XX	XX	XX
4	Medium, black	5'11"	180	XY	XX	XY
5	Short, blond	5'8"	160	XX	XX	XX
6	Shaved	6'2"	190	XY	XY	XY
7	Short, black	6'1"	175	XY	XY	XY
8	Long, brown	5'9"	185	XX	XX	XX
9	Medium, black, dreadlocks	5'11"	185	XY	XX	XX
10	Long, blond, dreadlocks	5'10"	155	XY	XY	XY

Student Handout 1: Sex-Linked Chromosomes and Inheritance

Procedure

1. Carefully read *Appendix A: Background Information on Sex Chromosomes and Inheritance*. Your teacher will allow time for questions to make sure you understand this background information
2. Go to the following website, read the tutorial and watch the animations of Meiosis I and II. http://www.biology.arizona.edu/cell_bio/tutorials/meiosis/main.html
 - Under contents, click on 'Reproduction'
 - Read this page and at the bottom of this webpage, click 'next'
 - Read this page and at the bottom of this webpage, click 'next'
 - Read this page and watch both animations of meiosis I and II by clicking on them. When through, click on 'next'
 - Read this page, 'A Review of Meiosis' that includes a section on 'meiotic errors'.
3. Answer the following questions.
 - a) Where does meiosis take place?
 - b) How many chromosomes are in the cells at the beginning of meiosis I?
 - c) How many chromosomes are there in the cells at the end of meiosis I?
 - d) How many chromosomes are there in the cells at the end of meiosis II?

Student Handout 2: Gender Determination at the Olympics

Imagine that you and your group are organizing a new Olympic event. You must establish criteria for your athletes in order to make the competition fair. Although you have the phenotype information given below, you do not have information on the athletes' birth sex. Complete the table by reading the steps below.

	Phenotype			Genotype		
	Hair	Height	Weight in pounds	Inferred	Self-reported	Actual
1	Long, blond	5'11"	175			
2	Short, brown	5'10"	160			
3	Long, black	5'9"	155			
4	Medium, black	5'11"	180			
5	Short, blond	5'8"	160			
6	Shaved	6'2"	190			
7	Short, black	6'1"	175			
8	Long, brown	5'9"	185			
9	Medium, black, dreadlocks	5'11"	185			
10	Long, blond, dreadlocks	5'10"	155			

Complete and discuss the following:

1. Infer the athletes' genotype based solely on the phenotype information provided in the table. Put an XX if you think that the athlete is female and XY if you think the athlete is probably male. Do this now before continuing.
2. When the athletes arrive for the contest, athletes 1, 3, 4, 5, 8, and 9 enter the female category. Athletes 2, 6, 7 and 10 enter the male category. Put an XX if the athlete entered as a female and XY if the athlete entered as a male.
3. Athletes 1 and 4 are found to have the Y-linked SRY. They have partial androgen insensitivity syndrome. Read APPENDIX B: Background Information on Gender Determination and

Androgen Insensitivity Syndrome, and then enter the actual genotypes in the column labeled 'Actual'?

4. In your opinion, should these athletes be allowed to compete as women? Read APPENDIX C: History of Olympic Rulings on Gender Determination

5. Which of the following do you think is important in defining gender identity?
 - Birthsex
 - Chromosomes
 - Hormones
 - Internal organs

6. Should all athletes be tested for sex? Which kind of sex? (see above in question #5)

Note: If you would like to know more about the complexity of these sex and gender issues go to either www.transciences.org or www.glsen.org

APPENDIX A: Background Information on Sex Chromosomes and Inheritance

The X and Y chromosomes do not just determine sex; they contain many other genes that have nothing to do with sex determination. The Y chromosome is very small and seems to contain very few genes, but the X chromosome is large and contains thousands of genes for important products such as rhodopsin (a protein in the membrane of a photoreceptor cell in the retina of the eye, basically a light absorbing pigment), blood clotting proteins and muscle proteins.

Females have two copies of each gene on the X chromosome (i.e. they are diploid), but males only have one copy of each gene on the X chromosome (i.e. they are haploid). This means that the inheritance of these genes is different for males and females, therefore they are called *sex linked characteristics*. Some researchers refer to those conditions found on the X chromosome as X-linked conditions.

X-linked conditions are those for which the gene is present on the X chromosome. X-linked conditions show inheritance patterns that differ from autosomal conditions and abnormalities. This occurs because males only have one copy of the X chromosome (plus their Y chromosome) and females have two X chromosomes. Because of this, males and females show different patterns of inheritance and severity of manifestation. While there are both dominant and recessive X-linked conditions, there are some characteristics that are common to X-linked conditions in general.

These include:

- X-linked genes are never passed from father to son. The Y chromosome is the only sex chromosome that passes from father to son.
- Males are never carriers. If they have an X-linked condition, it will be expressed. Males are termed hemizygous for genes on the X chromosome.

X-linked dominant conditions are very rare while X-linked recessive conditions are fairly common. X-linked recessive conditions are those in which a female must have two copies of the allele in order for the phenotype to be expressed as a female. Only one allele is needed to be expressed for a male. Many X-linked recessive conditions are well-known, including color blindness, hemophilia, and Duchene muscular dystrophy. Typical features of X-linked recessive inheritance include:

- Never passed from father to son.
- Males are much more likely to be affected because they only need one copy of the allele to express the phenotype.
- Affected males get the condition from their mothers and all of his daughters are obligate carriers.
- All that an affected male can pass on to his daughters is his X chromosome with the affected allele.
- Sons of heterozygous females have a 50% chance of receiving the affected allele. These conditions are typically passed from an affected grandfather to 50% of his grandsons.

APPENDIX B: Background Information on Gender Determination and Androgen Insensitivity Syndrome

Normal Development of Reproductive Organs

Every fetus, whether genetically male (XY) or female (XX), starts life with the capacity to develop either a male or female reproductive system. All fetuses have non-specific genitals for the first 8 weeks or so after conception. After a few weeks, in a male XY fetus, the Y sex chromosome initiates the formation of these non-specific genitals into male genitals (testes) which produce masculinizing hormones (androgens) in large quantities whose job is also to suppress female internal organ development.

Both male and female fetuses usually have at least one X sex chromosome, which contains a gene that gives their body tissues the capacity to *recognize* and *react to* androgens. At puberty, girls react to the relatively small quantity of androgens (that come mainly from their adrenal glands) by developing pubic/underarm hair and darkish pigmentation around the nipples.

Androgen Insensitivity Syndrome

The Androgen Insensitivity Syndrome (AIS) is a condition that affects the development of the reproductive and genital organs. People with AIS have a functioning Y sex chromosome (and therefore no female internal organs), but an abnormality on the X sex chromosome that renders the body completely or partially incapable of recognizing the androgens produced.

In AIS, the child is conceived with male (XY) sex chromosomes. Embryonic testes develop inside the body and start to produce androgens. However, these androgens cannot complete the male genital development since the androgens that the testes produce are not effectively recognized. Therefore, the development of the external genitals continues along female lines. However, another hormone produced by the fetal testes suppresses the development of female internal organs.

In the case of *complete* androgen insensitivity (CAIS), the external genital development takes a female form. In the case of *partial* insensitivity (PAIS), the external genital appearance may lie anywhere along the spectrum from male to female. Internally, however, there are testes instead of a uterus and ovaries.

Other related conditions, resulting from changes on different chromosomes, also disrupt the normal pathway of androgen action, resulting again in a feminized phenotype (body form). People with these 'XY conditions' may identify as female, intergendered, or male.

In about two thirds of all cases, AIS is inherited from the mother. In the other third there is a spontaneous mutation in the egg. The mother of the fetus, who does not have AIS, but has the genetic error for AIS on one of her X chromosomes, is called a carrier.

APPENDIX C: History of Olympic Rulings on Gender Determination

For more than 30 years the International Olympic Committee (IOC) has required all female competitors to undergo "gender verification." The purported rationale is to detect male imposters who would have an unfair competitive advantage. In point-of-fact, genuine imposters have not been uncovered. Since genetic testing was instituted for women in the Olympic Games, a number of women have been disqualified as "not women," after winning. However, none of the disqualified women have been man; all have abnormal karyotypes, and one gave birth to a healthy child after having been disqualified. Some women athletes were born with relatively rare genetic abnormalities that affected development of the gonads or the expression of secondary sexual characteristics.

Background:

1896: 0 women competed.

The founder of the modern Olympics, Baron Pierre de Coubertin, was opposed to women competing; thus, reflecting the general cultural attitudes about the "weaker sex" that prevailed in the Victorian era.

1900: 19 women competed

1912: 57 women competed

1960: 610 women competed

1996: 3800 women competed

As women's athletic competition became more acceptable and popular, increasing attention was devoted to the concept of a "level playing field." In a number of instances, questions were raised regarding the "femininity" of highly successful female competitors, in particular during the Cold War era of competition between the United States and the former Soviet Union. These rumors were abetted by anecdotal reports of recognized athletes who were found to have varying degrees of intersexuality (having physical characteristics of both genders). In one case, a Polish sprinter with an apparent chromosomal abnormality was stripped of her medals. Three track and field champions who competed as women before World War II subsequently underwent reconstructive surgery and sex reassignment. These cases led to efforts to ensure that women competing at international events were in fact women, initially with rather crude and demeaning efforts at physical examination. In two instances, women athletes were required to parade nude before a panel of female physicians, and at another event, women athletes were required to undergo direct gynecologic examination.

These initial crude attempts at gender verification were soon replaced by less direct measures: first, the use of a buccal smear for sex chromatin, which was implemented at the 1968 winter games in Grenoble on an experimental basis and formally adopted at the 1968 summer games in Mexico City. Until the last decade, this remained the standard for gender verification, notwithstanding that by the mid-1970s, the test was discarded by medical professionals as technically unreliable. More importantly, the test detected athletes who were unassailably feminine but who happened to have an XY chromosomal pattern. Many of these individuals had variants of androgen resistance, either complete or partial -- in which case, they are naturally resistant to the strength-promoting qualities of testosterone. Others had variants of XY gonadal dysgenesis. Ironically, the sex chromatin test would have permitted recognized males with an XXY karyotype, or Klinefelter's syndrome, and XX males, who have a portion of the testicular determining gene (SRY) transposed onto the X chromosome, to compete.

Concerns regarding the appropriateness of sex chromatin for gender verification were voiced continuously in the 1970s and 1980s, but their impact was limited because of the absence of information regarding the frequency of positive results and the subsequent diagnoses and follow-up. At virtually every Olympic event, however, abundant rumors circulated; in one instance women athletes who were detected as "positive" were instructed to feign injuries or in some cases were actually fitted with casts. In one celebrated case, a Spanish hurdler was publicly disclosed after failing her femininity test during an event in Tokyo, at the cost of public disgrace and loss of her athletic scholarship. It took 2 years and the active intercession of a number of medical authorities for the athlete, who has androgen resistance, to be reinstated.

In the 1990's the IOC replaced sex chromatin with DNA-based methods to detect Y chromosomal material, principally the SRY sex-determining locus on the Y chromosome, implementing this procedure at the 1992 winter games in Albertville. At the insistence of the organizers, the 1996 Summer Olympic Games in Atlanta included a comprehensive process for screening, confirmation of testing, and counseling of individuals detected. Eight female athletes had positive test results. Of these, 7 had androgen insensitivity, 4 incomplete, and 3 complete; the other athlete had previously undergone gonadectomy and is presumed to have 5-alpha-steroid reductase deficiency. All individuals were given appropriate gender verification certificates and were permitted to compete.

After the Atlanta Olympics, efforts continued to persuade the IOC to abandon gender verification. Indeed, by the time of the 1996 Summer Olympic Games in Atlanta, essentially all of the relevant professional societies had endorsed resolutions that called for elimination of gender verification, including the American Medical Association, the American Academy of Pediatrics, the American College of Physicians, the American College of Obstetrics and Gynecology, the Endocrine Society, the Lawson Wilkins Pediatric Endocrine Society, and the American Society of Human Genetics. It was argued that the current clothing used in athletic competition, as well as the requirement that urine for doping control be voided under direct supervision, made it virtually certain that male impostors could not escape detection; furthermore, gender verification procedures are complex, expensive, and counterproductive.

Still, it was not until the IOC's Athletes' Commission called for discontinuation of the IOC system of gender verification that the IOC's executive board, at its June 1999 meeting in Seoul, decided to discontinue the practice on a trial basis at the summer Olympic games in Sydney which should become permanent.

Adapted from Olympic Gender Testing at:

<http://ai.eecs.umich.edu/people/conway/TS/OlympicGenderTesting.html>

Additional Resources

Because Web sites frequently change, some of these resources may no longer be available. Use a search engine and related key words to locate new Web sites.

Resources for sex-linked characteristics and meiosis

<http://biology.clc.uc.edu/courses/bio105/sex-link.htm>

<http://www.uic.edu/nursing/genetics/Lecture/Types/SingleGene/Sex-linked/sexlinked.htm>

<http://www.biologymad.com/master.html?http://www.biologymad.com/GeneticsInheritance/geneticsinheritance.htm>

Resources for Policies of the International Olympic Committee on Gender Determination

<http://ai.eecs.umich.edu/people/conway/TS/OlympicGenderTesting.html>

http://www.olympic.org/uk/news/olympic_news/full_story_uk.asp?id=841

<http://www.elainerose.freehomepage.com/Words/fmame.htm>

Resources for learning about intersex conditions

<http://www.isna.org/drupal/node/view/91>

<http://www.washingtonsquarenews.com/features/citylife/8080.html>

Gender Identity

<http://www.transcience.org>

<http://www.glsen.org>

Genomic Revolution

http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtml

The Web site to the government-funded Human Genome Project with links about genomics, the history of the project, and more.

Secrets of the Sequence Videos and Lessons

This video and 49 others with their accompanying lessons are available *at no charge* from

www.vcu.edu/lifesci/sosq