

Submit originals and one copy and electronic copy to **Governance/Faculty Senate Office**
(email electronic copy to fysenat@uaf.edu)

REQUEST FOR CORE NATURAL SCIENCE DESIGNATOR

SUBMITTED BY:

Department	Biology and Wildlife	College/School	CNSM
Prepared by	Laura Conner	Phone	X 6950
Email Contact	ldconner@alaska.edu	Faculty Contact	Laura Conner

See <http://www.uaf.edu/uafgov/faculty/cd> for a complete description of the rules governing curriculum & course changes.

1. COURSE IDENTIFICATION:

Dept	BIOL	Course #	102	No. of Credits	4
------	-------------	----------	------------	----------------	----------

COURSE TITLE	Biology of Sex
---------------------	----------------

CONTACT HOURS PER WEEK:	<input type="text" value="3"/>	LECTURE	<input type="text" value="3"/>	LAB	<input type="text"/>	OTHER	<input type="text"/>
		hours/weeks		hours /week		specify type	

Note: To meet the natural science requirement, courses must have 4 credit hours and include a laboratory.
See <http://www.uaf.edu/uafgov/faculty/cd/credits.html> for more information on number of credits.

Existing Course	<input type="text"/>	New Course Pending Approval*	<input checked="" type="text" value="X"/>
-----------------	----------------------	------------------------------	---

*Must be approved by appropriate Curriculum Council.)

2. CURRENT CATALOG DESCRIPTION AS IT APPEARS IN THE CATALOG: including dept., number, title and credits

BIOL 102
4 credits
Offered Spring

What is sex, and why is it important? This course explores the biological basis of sexual reproduction and sexual behavior among animals (including humans) and other organisms. Topics include mating systems, sperm competition, gender, courtship, and deception. The class will also examine the nature of science, including the process of posing and testing hypotheses.

JUSTIFICATION FOR ACTION REQUESTED

The purpose of the department and campus-wide curriculum committees is to scrutinize course designator applications to make sure that the quality of UAF education is not lowered as a result of the proposed change. Please address this in your response. This section needs to be self-explanatory. Use as much space as needed to fully justify the proposed change and explain what has been done to ensure that the quality of the course is not compromised as a result.

This course is intended as a non-majors course. The focus of the course, the biology of sex, is an ideal and interesting platform from which to explore evolutionary theory and other foundational concepts in biology. We expect that the course will be a draw for students, and may ultimately entice some to switch majors. The course instructor, Laura Conner, holds a PhD in Ecology and Evolutionary Biology and has a publication record in the area of mating behavior and sperm competition. The course is envisioned as a core natural science course that, along with a nutrition course, will ultimately replace BIOL 103X.

RECEIVED

Governance
10/4/12 TCF


OCT - 3 2012


Dean's Office
College of Natural Science & Mathematics

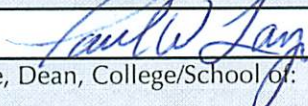
ALONG WITH THIS FORM PLEASE SUBMIT THE FOLLOWING:

A	A course syllabus (see page 24)
B	Titles of all laboratory exercises.
C	Title of a representative textbook.
D	Detailed outline of 3 laboratory exercises. Please attach an explanation of how these laboratory exercises have been designed to familiarize students with methods for the acquisition and expansion of scientific knowledge, including: a) data collection and analysis, b) hypothesis building, and c) experimentation.
E	A list of the major scientific concepts that the course will convey. The attached syllabus should make it clear that the course is organized around these major concepts rather than their application.
F	An explanation of how the relationship between science and society will be explored in the course. Identify where the course public science policy and its development are discussed.
G	A plan for its effectiveness evaluation.

APPROVALS:

	Date	10/2/12
Signature, Chair, Program/Department of:		

	Date	10/2/2012
Signature, Chair, College/School Curriculum Council for: CNSM		

	Date	10/3/12
Signature, Dean, College/School of: CNSM		

ALL SIGNATURES MUST BE OBTAINED PRIOR TO SUBMISSION TO THE GOVERNANCE OFFICE

	Date	
Signature, Chair, Senate Core Review Committee		

Supplementary information for the proposed “Biology of Sex” course

- A. A syllabus is attached.
- B. Titles of all laboratory exercises are included in the syllabus.
- C. Titles of textbooks are included in syllabus.
- D. Three laboratory exercises are attached.
- E. This course intends to explore the biology of sex and sexual behavior through the lens of evolution. Evolutionary theory will be explored in depth throughout the course, including both natural and sexual selection. See the syllabus for a complete description of learning outcomes.
- F. This course will explore the relationship between science and society in several ways. Central to a consideration of sex is the question of gender—what does it mean to be male or female (Feb. 11th lecture)? What are societal and legal implications that result from chromosomal abnormalities? The course will also explore questions of animal and human homosexual behavior (Feb. 13th), looking at such behaviors through the lens of evolution, and discussing societal implications of homosexuality (e.g., same sex marriage). The course will also explore the historical development of scientific knowledge with respect to sexual selection theory and consider how human morals and societal norms have affected the development of knowledge about mating systems (Mar 25-27). Additionally, a section in late April (17th-29th) will explore questions of human mate choice and mating systems, relating biology to human societies across the globe. Finally, an activities-based lab adopted from the Annenberg foundation (attached) will allow students to explore societal questions related to gender in more depth.
- G. We will evaluate the course effectiveness through student pre and post-tests that explore student ideas about evolution, the nature of science, and other course topics.

COURSE SYLLABUS
Biology of Sex
BIOL 102
4 credits

Meeting times: Tuesday/Thursday (time TBA)

Lab meeting times and place: TBA

Meeting place: TBA

Prerequisites: High school algebra; Placement in ENG F111X. This course is intended for non-biology majors.

Instructor: Dr. Laura Carsten Conner
907-474-6950
ldconner@alaska.edu
Bunnell 307B

Office hours: Tues 12-2 or by appt.

Lab instructors: TBA

Course description

What is sex, and why is it important? This course explores the biological basis of sexual reproduction and sexual behavior among animals (including humans) and other organisms. Topics include mating systems, sperm competition, gender, courtship, and deception. The class will also examine the nature of science, including the process of posing and testing hypotheses.

Course goals

Sex is fascinating. A survey of the animal kingdom reveals an astonishing numbers of strategies used to woo mates, compete with rivals, choose the best mate, or to fertilize eggs. Plants, fungi, and other organisms are equally as fascinating—some have eschewed sex completely, while others are both male and female. This course aims to examine this diversity through the

lens of evolution. We will also explore the mechanistic basis of this diversity, as well as what it means to “do science.”

Student Learning outcomes

Upon completion of the course, students will be able to do the following:

- Compare and contrast science with other ways of knowing
- Create hypotheses and devise experiments to test hypotheses
- Distinguish between proximate and ultimate explanations for behaviors
- Describe the features of diverse mating systems, such as polygyny and polyandry
- Compare and contrast mitosis with meiosis
- Describe the principles of natural selection, including sexual selection
- Explain why monogamy is rare in nature
- Compare and contrast asexual and sexual reproduction
- Apply evolutionary principles to explain sexual behaviors, including human behaviors
- Explain why female promiscuity is common in nature
- Describe the features of diverse parental care strategies and why they have evolved
- Demonstrate ability to organize and communicate ideas about scientific knowledge
- Explain certain human societal features through the lens of evolution

Required Textbooks

Alcock, J. 2009. *Animal Behavior, 9th Edition*. Sinauer Associates. 546 pp.

Judson, O. 2002. *Dr. Tatiana's Sex Advice to all Creation*. Metropolitan Books. New York. 308 pp.

I will distribute **Reading Packets** at the beginning of class that contain select chapters from other publications, case studies, and readings from the primary literature.

Instructional Methods and Assignments

This is a lecture and laboratory course. I use active learning techniques in class, including think-pair-share, case studies, hands-on demonstrations and activities, and clicker questions. Science education research has demonstrated that active learning techniques increase grasp and retention of content. Course grades will be based on 3 middle-of-term exams, the final examination, completion of four case studies in class, and participation (see point breakdown below, under “Grading”). Lecture notes will be posted on Blackboard within 24 hours of a lecture; however, because of the active nature of the class, many in-class activities will not be reflected in the lecture notes.

Exams

Course exams will use a combination of multiple choice, short answer, and essay questions. In order to do well, you will need to understand the principles underlying major concepts, rather than simply memorizing facts. Exams must be taken at the scheduled time except in the case of university sanctioned events (such as participation in UAF athletic events) or emergencies. In the case of sanctioned events, you must contact me at least 1 week prior to the exam to notify me of your absence, and the exam must be taken prior to the absence. In the case of emergencies, you must notify me as soon as possible via email or phone about the absence. Make-up exams in the case of emergencies must be taken within 48 hours of the emergency if possible. Expect to provide documentation of the emergency.

Case studies

There will be 4 graded case studies during the semester which ask students to evaluate a data set or a scenario and answer questions. Case studies will generally be assigned as in class activities, and will be completed in pairs or small groups.

Participation

I expect you to attend class and participate actively. As mentioned above, I will use many active learning techniques in class. During class, you may be asked to devise hypotheses and simple experiments to test your hypotheses in small groups or pairs. You may be asked to turn in written, 1-minute responses to questions posed in class, or to participate in other in-class activities. We will also use whole-class discussion as a learning tool. Your participation grade will be based on regular participation in these activities.

Clickers

I will use the i-clicker response system to monitor learning and to identify points of misunderstanding. There is no need to purchase an i-clicker; they will be passed out and collected at the end of a class period when they are used. Note that the i-clicker is not the same clicker that is used in the Chemistry Department or in some other departments at UAF. The i-clicker is now being used in other classes in the Biology & Wildlife department and the Geology & Geophysics department. If you wish to purchase the i-clicker, the cost is about \$40.

Laboratories

The course laboratories are arenas in which to become familiar with tools and approaches used in science. Students will start with guided experiments and gradually move toward creating and testing student-generated hypotheses. We will explore societal implications of questions related to gender and sex determination. In the first half of lab (prior to spring break), students will receive a lab handout for each lab period. Each lab exercise will be graded. After spring break, students will work in pairs or groups to develop and complete a student-devised experiment, including presenting results to the class. In total, the lab makes up ~25% of your overall grade.

Attendance in lab is mandatory. If you are absent from your lab section, you may participate in another lab section during that same week with permission from both your T.A. and the T.A. of

the other lab. If you miss a lab experience, you will receive a zero for the lab assignment for that week.

Grading

Assignment	Points
Case Studies (complete 4)	100
Exam 1	100
Exam 2	100
Exam 3	100
Final Exam	100
Participation	50
Lab	250
TOTAL	800

Grades will be calculated as a percentage of the 800 points possible in the course.

90-100% = A	60-69% = D
80-89% = B	Below 60 = F
70-79% = C	

Attendance Policy

I expect you to attend class and participate. Science education research has demonstrated that students who take an active role in their learning learn more and retain that knowledge longer. In other words, participation will help you get the most out of the course. Ultimately, you are in charge of your own learning. If you choose not to attend lecture, you will not get the most out of your education. It is also difficult to participate if you are absent; thus, regular absences will negatively impact your participation grade. As noted above, lab attendance is mandatory.

Plagiarism/Academic Honesty

Disciplinary action may be initiated in cases of plagiarism, cheating, and/or academic dishonesty. Please refer to the student code of conduct:

http://www.uaf.edu/catalog/current/academics/regs3.html#Student_Rights

Student Support

Students with special needs or concerns can contact Student Support Services (474-6844). Please let us know at the beginning of the semester if you will require accommodations due to a documented disability, and we will work with you in conjunction with the Office of Disability Services (203 WHIT, 474-7043).

Lecture schedule

<u>Date</u>	<u>Topic</u>	<u>Readings</u>
16-Jan	Introduction:	Judson preface
21-Jan	What is sex? Asexual vs. sexual reproduction	Reading 1 in packet
23-Jan	The Nature of Science	Reading 2 in packet
28-Jan	Darwinian Theory and levels of analysis	Alcock Ch. 1
30-Jan	Advantages of sex	CASE STUDY 1
4-Feb	Nature vs. Nurture?	Alcock Ch 3.
6-Feb	EXAM 1	
11-Feb	What does it mean to be male or female?	Judson Ch. 1 & 2
13-Feb	Gender and behavior: what is "normal"?	Judson Ch. 9
18-Feb	Hermaphrodites: animals	Judson Ch. 12
20-Feb	Hermaphrodites: plants	Reading 3 in packet
25-Feb	Sex determination	CASE STUDY 2
27-Feb	Sex ratios	Reading 4 in packet
4-Mar	EXAM 2	
6-Mar	Mate competition and sperm competition	Alcock Ch. 10
11-Mar	Mate choice and cryptic female choice	Judson Ch. 3
13-Mar	Courtship and deception	CASE STUDY 3
18-Mar	Spring Break—no class	
20-Mar	Spring Break—no class	
25-Mar	Mating systems I	Alcock Ch. 11
27-Mar	Mating Systems II	Judson Ch. 10
1-Apr	Parental care: before birth	Alcock Ch. 12
3-Apr	Parental care: after birth	
8-Apr	EXAM 3	
10-Apr	Parent/offspring conflict	
15-Apr	Parental conflict: Mom vs. Dad	
17-Apr	Humans: attracting and assessing mates	Alcock Ch. 14
22-Apr	Humans: manipulation and deception	CASE STUDY 4
24-Apr	Humans: mating systems	

29-Apr TBD (student choice)
1-May REVIEW
TBA FINAL EXAM

Lab Schedule

<u>Week of:</u>	<u>Topic</u>
Jan 27-31	Observation and ethograms: crickets
Feb 3-7	IACUC and the ethical treatment of animals
Feb 10-14	Designing testable hypotheses: isopods
Feb 17-21	Gender, sex determination, and society
Feb 24-28	Operational Sex Ratio: walnut flies
Mar 3-7	Territoriality: crayfish
Mar 10-14	Courtship display: crickets
Mar 17-21	Spring Break- no lab
Mar 24-28	Student project formulation
Mar 31-Apr 4	Student Project data collection
Apr 7-11	Student Project data collection
Apr 14-18	Analysis and interpretation
Apr 21-25	Creation of presentations
Apr 28-May 2	Oral presentations of projects

CRAYFISH TERRITORIALITY LAB

BIOL 102

Summary

Today, we will examine territory defense by male Crayfish. Territories have one common theme: they are defended areas which provide a valuable resource such as nesting sites, food, or shelter to the territorial resident. Possession of a territory enables that resident (the territory owner) to survive and reproduce better than an intruder, or non-territory owner. We will use scientific methods to explore how territoriality functions in the Crayfish.

Background

A) Territory Defense

Animals must compete for critical resources such as food or mates, but the form of this competition can differ from one kind of animal to another. The circumstances under which territory defense is advantageous to defending individuals have been studied by many animal behaviorists. In general, the resources being defended must be in short supply. There would be no advantage to spending time and energy defending something that was so common everyone could get enough. And it would be too difficult to sequester resources that moved from place to place, or whose distribution was unpredictable in time (here today, gone tomorrow). Territory defense, then, is a sort of economic practice. Individuals attempt to defend specific areas and maintain exclusive access to them only when the benefits of doing so outweigh any costs.

B) Natural History

Crayfish, common in streams and lakes, often conceal themselves under rocks or logs. They are most active at night, when they feed largely on snails, algae, insect larvae, worms, and tadpoles; some eat vegetation (various water plants). Adults (one year old) become most active at dusk and continue heavy feeding activity until daybreak. Young crayfish are more likely to be the ones out during bright sunny days, while the older crayfish are more active on cloudy days and during the night. General movement is always a slow walk, but if startled, crayfish use rapid flips of their tail to swim backwards and escape danger.

Crayfish Territorial Behavior Lab Instructions

<p>Setup</p>	<ul style="list-style-type: none">• Set up two watchglasses containing water and sand. One is the “resident” tank and the other is the “invader” tank.• Handle Crayfish carefully and keep them moist!
<p>Observation period 1</p>	<ul style="list-style-type: none">• Put one male in each arena.• Observe crabs for 5 minutes. Record all behaviors below:

Experiment 2

- Make a change in the animal's social environment or habitat. Make a hypothesis for how the behavior might change in this new situation and observe any changes in behavior. Record your hypothesis and procedures you will use here:

- Test your hypothesis, observing for 20 minutes to get a large sample of behaviors. Record behaviors here:

Questions:

1) What are the characteristics of territory defense, and do the crayfish exhibit these characteristics (that is, are they really territorial)?

2) How do crayfish attempt to defend their territories?

3) Do you see evidence of exclusive occupation or that intruders avoid territory owners?

4) Does the resident always successfully defend his territory?

5) Is fighting always the ultimate resolution to conflicts over territory, or can encounters be settled without fighting?

6) Is there any way to predict who will win an encounter between two males before the encounter is staged?

7) What additional insights did your 2 experiments reveal?

Operational Sex Ratio, Walnut flies

BIOL 102

Summary

Mating behavior is one of the most frequently studied areas of animal behavior. This is not only because of the fascinating variety of behaviors associated with mating, but because it is so closely tied to fitness and thus natural selection. In this lab, we will focus on male-male competition patterns as they relate to operational sex ratio. We will experimentally test hypotheses you generate from the background information provided.

Background

A) Mating Behavior

All else being equal, the more abundant gender competes against each other for access to the less abundant gender. The less abundant gender, in turn, will be able to take advantage of the abundance of the other gender by being choosy in whom they mate with. So, the abundant ones will compete, and the less abundant ones will be choosy.

Energy investment is also important in predicting mating behavior. Females produce large gametes, and because they have so much invested in each egg, they often spend more time and resources on those eggs and/or offspring, including parental care. Females often spend extra time and effort in creating, birthing and caring for their offspring. While females are engaged in these parental activities, they are either unreceptive or not fertile. Therefore, in many cases, there are fewer sexually fertile and receptive females than males. For this reason, the most common setup in nature is that females are choosy, and males compete against each other (but not always!).

B) Territoriality and Male-Male Competition

Male-male competition can lead to extravagant male characters and sexual size dimorphism. Males compete with each other for access to females in a variety of ways including ritualized displays, sperm competition, fighting and territoriality. Typically, males will compete for territory (in which body size or ornament characteristics will determine their ability to compete) and females will choose males based on the territory they possess. Males that are able to maintain larger territories of good quality tend to acquire more mates and will therefore be more represented in the next generation. It is important, however, that differences in the ability to compete are genetically determined (heritable). Likewise, female preference for males/territories must also have heritable variation. Females choose territories that will maximize their reproductive output. Territory quality is often correlated with size per female.

C) Mate Guarding and Sex Ratio

Sperm competition is the physical competition between the sperm of two separate males to fertilize the eggs of a female. A male's fitness is usually measured as a function of the number of females inseminated; however, in many animal species, fertile females mate with many male partners. Males in many species have evolved mechanisms to give their own sperm a special advantage after deposition in the female reproductive regions. Some males, instead of or in addition to their own mechanisms of sperm competition, will guard their female partners to prevent further copulation after sperm deposition. Mate guarding exists in a variety of forms including prolonged copulations, mating plugs, and mate grasping.

Assuming the male controls copulation duration, the relative benefits of long versus short copulations can depend on the operational sex ratio (OSR). If the OSR is female-biased, then the male fertilizes the most eggs by mating for a short time and then immediately mating with a different female. However, if the OSR is male-biased, the time it takes the male to find another unoccupied female increases, and it may be more advantageous, reproductively speaking, for the male to prolong the copulation.

D) Mating Basics of the Walnut Fly

Like other members of this genus, the walnut fly (*Rhagoletis juglandis*: Tephrididae) is characterized by a resource-defense mating system in which the males engage in territorial contests over walnut fruit. Females oviposit and larvae develop solely in the fruit. Females arriving at the fruit often mate during oviposition attempts in what sometimes appear to be "forced" copulations. Females mate with multiple males, and last male sperm precedence has been demonstrated. Copulation duration is variable in this species.

Lab Instructions

- 1) Given the background information provided, create hypotheses and predictions related to how OSR may affect male-male competition
- 2) Perform the experiment testing your hypotheses
- 3) Graph your data
- 4) Make new hypotheses and predictions based on your observations and develop an experiment to test these hypotheses

OSR WORKSHEET

1. Hypothesis:

2. Predictions:

3. Experimental steps needed to test this hypothesis:

4. Data collected (ethogram or other. Use additional pages if needed):

5. Graph of data

6. Explain how your results support or do not support your hypothesis:

7. Do your results suggest any new hypotheses?

8. Design a new experiment to test these hypotheses. Write out the steps needed, collect the data, and report the results.

Activity 1: 1 in 4000

Based on video content

15 minutes

Setup

One in approximately 4000 babies is born with intersexuality. In this condition, gender cannot be determined by a visual examination of the genitals. The video for this unit explores the biology of gender and some of the variations that can occur in gender development. Before watching the video, spend a few minutes in pairs, thinking of all the details you can recall about how gender is determined in humans. Then brainstorm as many different causes as you can think of for abnormalities in gender development, either in humans or in other animals. Finally, as a group, collect and categorize the causes you came up with and the effects they would have. Tips and Suggested Answers lists some ideas that your group may have thought of.

Materials

- Tips and Suggested Answers

Potential Answers

A few causes your group may have thought of are:

1. abnormalities of entire chromosomes
 - a. missing chromosomes

XO (Turner's syndrome, result is female development with some mental and physical differences)
 - b. extra sex chromosomes
 - i. more than two X (XXY, XXX, etc): viable, although more than two X chromosomes causes some physical differences and any Y causes mostly male development
 - ii. more than one Y (XYY etc): viable as long as there is an X; results in male development
2. abnormalities of parts of chromosomes or defects in single genes on sex chromosomes
 - a. translocation of parts of Y to X (or another chromosome)

inheritance of the male-determining gene SRY causes mainly male development, although some abnormalities can result if there is only the SRY gene without the rest of Y
 - b. mutations in single genes on Y

depending on the gene, can cause male development with sterility or other effects; or if SRY is affected, can cause female development, even though a Y chromosome is present
3. single gene mutations on non-sex chromosomes
 - a. defects in hormones, receptors, or enzymes can cause syndromes like androgen insensitivity, in which an XY develops as a female
4. other
 - a. some people may know about "freemartins" in cows: if a cow has twins, one male and one female, the female will be sterile because of the hormones produced by the male during their in utero development

Activity 2: Birds Do It, Bees Do It

Based on video content

15 minutes

Setup

Biology has a variety of ways to create different genders. In pairs, take a few minutes to brainstorm as many different sex-determination mechanisms as you can think of. Use specific examples if you can think of any. Then, as a group, list all the different mechanisms the pairs thought of and categorize them. Tips and Suggested Answers lists some ideas that your group may have thought of.

Materials

- Tips and Suggested Answers

Potential Answers

A few different mechanisms that your group may have thought of are:

1. chromosomal determination
 - a. Humans and other mammals have XX females and XY males. In humans, the gene *SRY* on the Y is primarily responsible for male development.
 - b. *Drosophila* fruit flies also have XX females and XY males, but sex is not determined by a specific gene on one of the sex chromosomes; it is determined by the ratio of X chromosomes to autosomes (non-sex chromosomes). In *Drosophila*, an X:autosome ratio of 1:0 is a female, so a diploid set of autosomes and XX is female. An X:autosome ratio of 1:2 is male, so a diploid set of autosomes and XY is male. Therefore, in humans, XO is a female; in *Drosophila*, XO is a male. In humans, XXY is male; in *Drosophila*, XXY is female.
 - c. In birds, males are the homogametic sex, meaning one type of sex chromosome, with the ZZ combination; females are heterogametic (or heteromorphic) with ZW.
 - d. Some, but not all, plants that have separate male and female plants (dioecious) have an XY sex chromosome system.
 - e. In *Caenorhabditis elegans*, a soil worm used in genetic and developmental research, most individuals are hermaphrodites with two X chromosomes. Rare males are XO.
 - f. In some insects, like grasshoppers, females are XX and males are XO.
 - g. In bees and some other insects, males come from unfertilized eggs so they are haploid (one set of chromosomes). Females come from fertilized eggs and are diploid (two sets of chromosomes).
2. environmental cues
 - a. In turtles and some other reptiles, temperature of the egg during development determines male or female development.
 - b. In some fish, the presence of other males and females determines sex. If the group loses a male, a female will change gender and become a male.

Activity 3: What About Meiosis?

Based on video and online text content

15–30 minutes, depending on the experience of the participants

Setup

The sex chromosomes represent a special situation in meiosis. In meiosis I, autosomes pair with their homologs, cross-over, and segregate. The pairing and crossing-over is an essential step; meiosis cannot proceed without it. However, in an XY male, the X and the Y do not have a homologous chromosome with which to pair. So what do they do?

Homologous chromosomes are necessary for repairing damaged chromosomes. Every time an X chromosome finds itself in a female, it has a chance to repair mutations from a homolog; however, the Y chromosome is nearly always by itself because a normal male is XY. So how does the Y undergo recombinational repair?

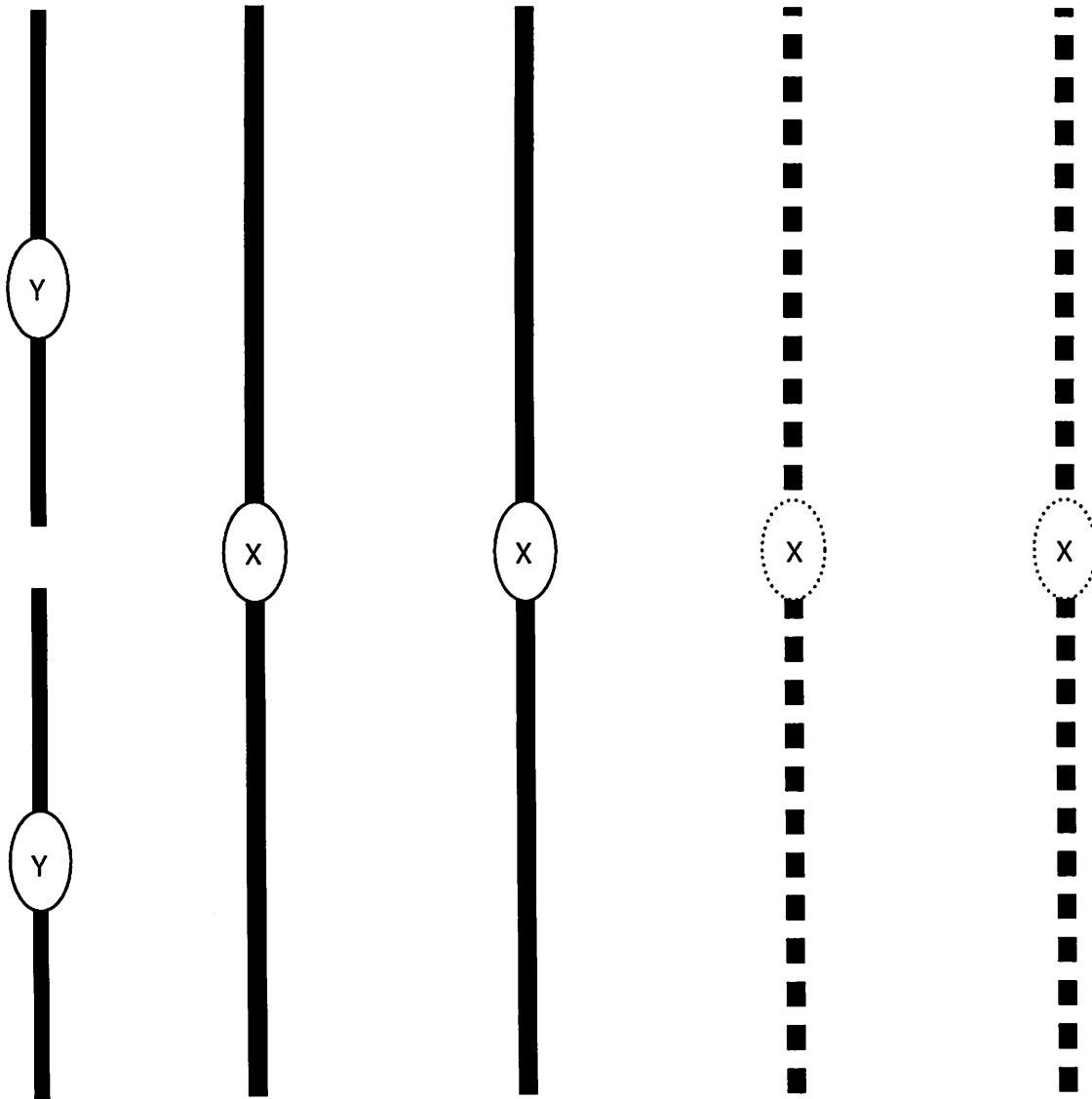
Although someone with a sex-chromosome abnormality may be infertile, there may still be germ line cells that go through meiosis—even if viable eggs and sperm are not produced. What happens if there are extra sex chromosomes or missing sex chromosomes?

We often do labs or demonstrations of meiosis using pipe cleaners or pieces of paper to represent chromosomes; we can use them here to show some of the exceptional meiotic situations of the sex chromosomes. Work through each situation in pairs. If you are used to working with demonstration chromosomes in this way and don't want a warm-up, you can skip the first few exercises.

Materials

- One set of Paper Chromosomes per two people (master copy provided; to make a set, cut after copying, so that each chromosome is separate)
- One copy of the Instructions and Situations per two people (master copy provided)
- A box of small- to medium-sized paper clips
- A roll of tape
- Tips and Suggested Answers

Paper Chromosomes



Instructions and Situations

For answers, see Tips and Suggested Answers.

Instructions:

Make sure your chromosomes have been cut so that each chromosome is separate. To make duplicated sister chromatids, paper-clip them together at the circle, which represents the centromere. There are four copies of autosome 1, so you can make paired, duplicated chromosomes during meiosis I. For meiosis II, remove the paper clips binding the duplicated chromosomes to show how they will separate, and what combinations of chromosomes can end up in the gametes.

There are four copies of X and two of Y, so all the situations can be represented. The arrows on one of the Y chromosomes show palindromic sequences needed for Situation 5.

Situation 1: Normal male

(A warm-up, so skip this one if you are used to showing X and Y segregation using demonstration chromosomes.)

To warm up and get used to using the paper chromosomes, show meiosis I and meiosis II using the sex chromosomes and one autosome from a normal male. For the autosomes, take one solid-line and one dotted-line version of chromosome 1. What is the probability of a gamete with a Y chromosome and a "dotted" chromosome 1?

Situation 2: Androgen Insensitivity Syndrome (AIS)

(A warm-up, so skip this one if you are used to showing X and Y segregation using demonstration chromosomes, and determining probabilities of segregation outcomes.)

A person with this condition is XY. The recessive mutation that causes AIS is on the X chromosome. Show all the relevant chromosomes pairing and then segregating in meiosis I; then show the sister chromatids separating in meiosis II. If a person with AIS was not infertile, what would be the chances that they would pass on a chromosome with the AIS mutation?

Situation 3: 45, XO (Turner syndrome, O stands for no other sex chromosome)

(A warm-up, so skip this one if you are used to showing X and Y segregation using demonstration chromosomes, and determining probabilities of segregation outcomes.)

In a person who is XO, there is only one X chromosome. Show what you think happens in meiosis I and II. What are the chances of a gamete that, if fused with normal sperm from a male, would result in the Turner syndrome genotype? What are the chances of an inviable zygote?

Situation 4: 47, XXY (Klinefelter syndrome)

Show what would happen to the sex chromosomes during meiosis of a cell that was XXY. What are the chances of a gamete that, if fused with normal gametes from a female, would result in the Klinefelter syndrome genotype?

Situation 5: X and Y

When the sequence of the Y chromosome was determined, investigators discovered that it contained several palindromic repeat sequences. These are regions with similar sequence but oriented in the opposite direction. The investigators suggested these regions could be used for recombinational repair by the Y chromosome, essentially allowing the Y chromosome to undergo crossing over with itself.

Start by showing exactly how the X and Y pair during meiosis and where crossing over can occur. What conformation does the X chromosome have to assume?

Next, use the Y chromosome with the white arrows to show how Y can use its palindromic regions to undergo recombinational repair. What conformation does it have to assume?

Situation 6: 46, XX male

Some males have two X chromosomes, but with part of the Y chromosome translocated onto one of the X's. The translocation mutation may occur during meiosis in the father of the 46, XX male. The father would be normal XY, but would produce a sperm that, when combined with an egg, produced the 46, XX male genotype.

Start with the normal XY chromosome combination, as they would be in meiosis I. Show how the translocation would occur by ripping off a little bit of one Y chromatid, transferring it to one X chromatid, and then securing it with tape. Then show how the rest of meiosis would proceed. What gametes are produced in the end? What part of Y has to be translocated in order to direct male development? Because translocations often occur through errors in crossing-over—and you have shown in Situation 5 how X and Y cross-over in meiosis—where do you think the critical part of Y is located?

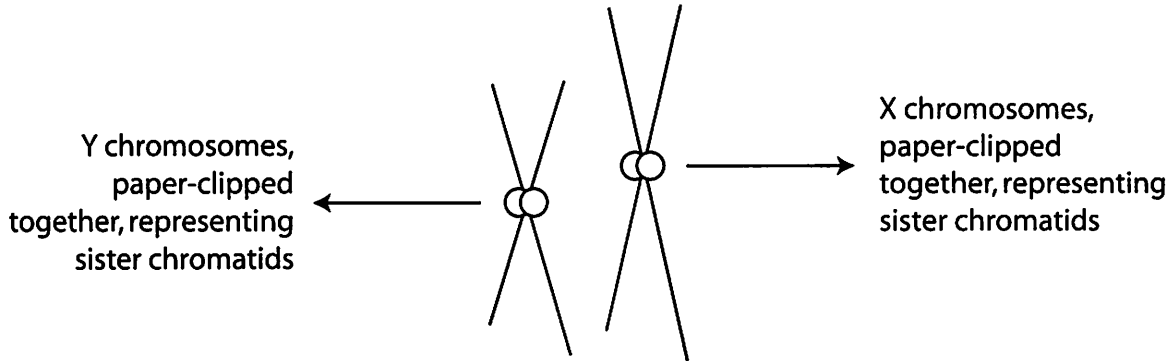
Answers

Situation 1:

The chance of gamete with Y is 1/2. The chance of a dotted chromosome is 1/2. $1/2 \times 1/2 = 1/4$.

meiosis I

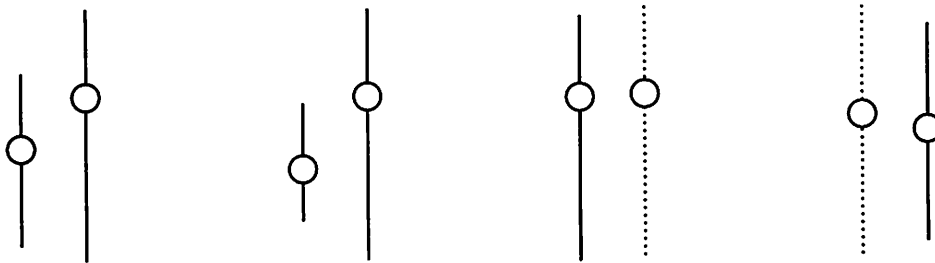
uplicated X and duplicated Y pair and then segregate, just like the homologous autosomes, even though they are not true homologs



meiosis II

sister chromatids separate

(Of course, independent assortment says these are not the only combinations of chromosomes that are possible!)



Situation 2:

Diagrams look like the sex chromosomes in Situation 1, but both copies of the X carry a recessive AIS allele, so the chance of a gamete with this allele is 1/2.

Situation 3:

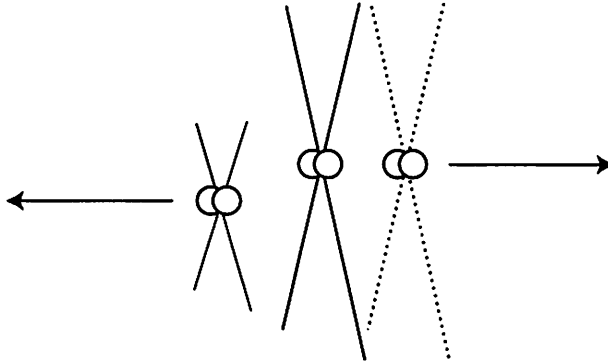
In meiosis I, there is no X or Y for the duplicated X to pair with; it segregates to one cell or the other. So at the start of meiosis II, one cell is normal and the other will give rise to two gametes with no sex chromosomes.

The chance of a gamete with no sex chromosome is 1/2. Gametes from a male would have either an X or a Y. In order to result in a zygote with the Turner syndrome genotype, a gamete with no sex chromosome would have to fuse with a sperm with an X. The chance of a gamete with no sex chromosome from the XO person is 1/2. The chance of a sperm with an X is 1/2. $1/2 \times 1/2 = 1/4$.

At least one X chromosome is essential, so an inviable zygote would result from the fusing of a gamete with no sex chromosome with a sperm with a Y. The chances are $1/2 \times 1/2 = 1/4$.

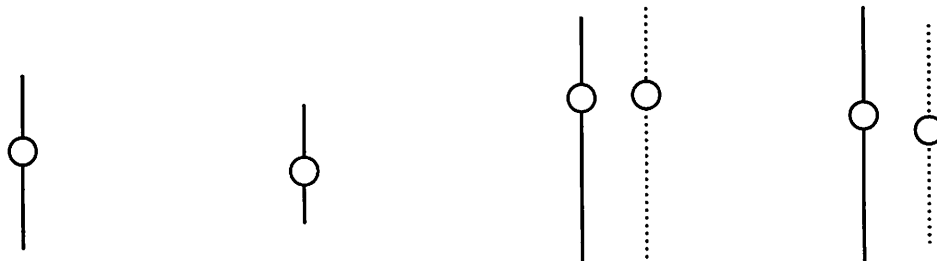
Situation 4:

XX and Y all pair, so meiosis I looks like this:



During segregation, the two duplicated X's could go into one cell, with the duplicated Y segregating into the other. Alternately, an X and a Y could segregate together into one cell, with the other X segregating into the other cell.

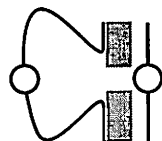
In meiosis II, sister chromatids segregate; a cell that had received two, duplicated sex chromosomes would divide into two cells, each with an extra sex chromosome. Here's one possibility for the end of meiosis II: If the chromosomes shown during meiosis I segregated so that the two duplicated X's segregated away from the Y, the end of meiosis would produce two gametes that each have 1Y, and two gametes that each have 2 X's.



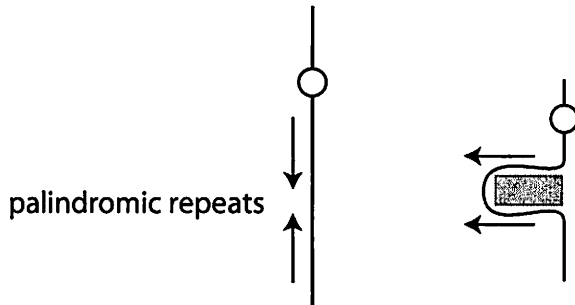
The XXY cell would produce the following gametes (with the X's marked so they can be followed separately): X^1 , Y, X^2 , X^1Y , X^1X^2 , X^2Y . Normal gametes from a female would all contain one X. The probability of a XY gamete from an XXY person is $2/6$. $1 \times 2/6 = 2/6 = 1/3$.

Situation 5:

The Y chromosome is much shorter than X, yet the homologous regions that pair and cross-over are at the ends of the chromosomes. Therefore, the X chromosome has to assume a looped conformation to pair with Y in meiosis. Crossing-over can occur in the shaded area.

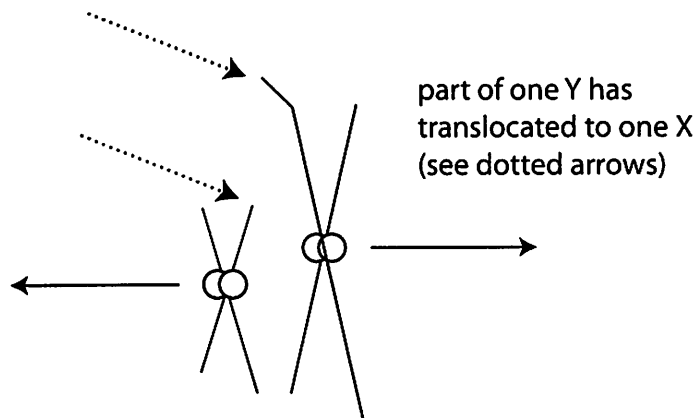


If the Y chromosome uses its palindromic repeat sequences to undergo recombinational repair, the sequences have to align along their homologous (or similar) regions. A conformation like this would have to occur. As above, regions where crossing over can occur are shown in gray.

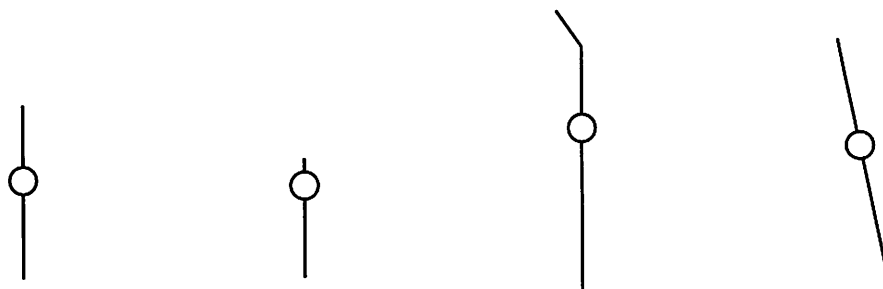


Situation 6:

In meiosis I, after the translocation, the chromosomes would look like this:



After meiosis II, they look like this:



As long as all the autosomes segregated correctly, there are two completely normal gametes: one with a X and one with a Y. There are two abnormal gametes—one with an X that has a portion of Y. If this portion contains the gene SRY, which determines maleness, this chromosome will direct male development. In fact, the SRY gene is located toward the end of the Y chromosome, close to the region where crossing over occurs with X. A slight misalignment of X and Y in meiosis can transfer SRY, and possibly more of Y to the X chromosome. The extent to which the development produces a normal, fertile male depends on how much of Y was translocated. The other gamete has a Y that is missing a segment. The viability and gender of a zygote from this sperm depends on how much of Y is missing.

Activity 4: What Are Our Roles?

Based on video and online text content

30 minutes

Setup

One of the ramifications of gender assignment is how parents, teachers, counselors, and school administrators will treat intersex children. In 2001, the television show *Friends* offended the Intersex Society of North America by treating this situation comically. Guest star Brad Pitt played a former high-school colleague who made up a rumor that Jennifer Aniston character was intersex.

In real life, the issue can create difficult situations, which this exercise will explore. Working in teams of three or four, choose at least three different roles to explore—such as mother, father, doctor, principal, the child’s teacher, the school counselor, or the child. Suggested topics for role-playing or discussion are listed below. Choose either a situation in which parents are first confronted with the birth of an intersex child, or a situation in which the child has grown and is adjusting to life in school. If a school situation is chosen, each group can choose the grade they have the most experience with, or different groups can portray the same situation at different grade levels.

As a group, discuss afterwards how the viewpoints of different parties varied or were the same. Were there some fundamental principles or ground rules that everyone agreed on?

Materials

- One copy of the Situations and Discussion Topics per person (master copy provided)

Situations and Discussion Topics

1. How might a health care professional approach parents who will give birth to, or have given birth to, an intersex baby? How might the parents react, what might their options be, and how would they make their decision?

For this situation, it might help to read the position of the Intersex Society of North America as of 2003 (<http://www.isna.org>):

- Intersexuality is basically a problem of stigma and trauma, not gender.
 - Parents' distress must not be treated by surgery on the child.
 - Professional mental health care is essential.
 - Honest, complete disclosure is good medicine.
 - All children should be assigned as boy or girl, without early surgery.
2. How might a teacher introduce a child of ambiguous gender in a classroom, at several grade levels? What might we tell students who notice that a student is different and treat them differently, or ask about him or her? Should the child have special academic consideration because of his/her personal situation?
 3. How might a teacher or counselor talk to a teenage student who is undergoing personal gender issues—for example, an intersex person whose personal gender assignment does not match the assignment determined by his or her parents? Another example might be a student who is completely male or female physiologically, but feels like a person of the opposite gender and is considering sex change after reaching adulthood. How might a teacher or counselor approach the parents in this situation?
 4. What should teachers and administrators do if an intersex or homosexual student who wants privacy is "outed" by his or her peers? What if a student's peers are uncomfortable with a student who is outspoken about his or her status as an intersexual, a homosexual, or any other sexual or gender status that might make other students or parents uncomfortable?

Activity 6: Y?

Based on video content

15 minutes

Setup

The sequence of the Y chromosome has been determined, and this smallest human chromosome contains more genes than we had previously expected. Take a few moments to consider the implications of this discovery by discussing the provided questions.

Materials

- Optional: Paper Chromosomes (master copy provided in Activity 3)
- One copy of the Discussion Questions per person (master copy provided)
- Tips and Suggested Answers

Discussion Questions

See Tips and Suggested Answers for more information and answers.

1. At one point, the Y chromosome was thought to have a dozen genes or fewer. Now we know that it has 78—meaning that men have 78 genes that women do not have. David Page, one of the researchers who sequenced the Y chromosome, was interviewed for National Public Radio on June 19, 2003. In the interview, he said that while we say that all humans are 99.9 percent identical in DNA sequence, this statement is true only half the time—when comparing two males or two females. If we take into account the 78 genes on the Y chromosome that males have and females do not, males and females are only 98.5 percent alike in DNA sequence. A male chimpanzee and a male human are also 98.5 percent alike in DNA sequence. This leads Page to tell the interviewer "...you are about as similar to your wife as you are to a male chimp."

Do you believe this statement is true? Or, are there other factors that make male and female humans more alike than humans and chimps? In any case, what does this information about the Y chromosome tell us about the differences between sexes?

2. (If you did Activity 3, review the information relevant to this question. If not, skip to the next question.) One of the functions of crossing-over (recombination) in meiosis is to protect against the deleterious effects of mutations. The reshuffling of allele combinations during meiosis means that mutant alleles of several different genes might, by random crossing-over, all end up on one chromosome. This chromosome carrying several lethal alleles would be lost by segregation into a gamete that would be inviable.

However, crossing-over requires homologous chromosomes—that is, two chromosomes with the same genes. Except in rare cases of males with two Y chromosomes, the Y chromosome never has a homolog in meiosis with which to cross-over. What are the implications of this for genes on Y? How does the Y pair with X in meiosis if they are not homologous? Does knowing that the Y chromosome contains large repeated sections give you any clues about how it compensates for the inability to shuffle out mutant alleles?

3. The XY sex chromosome system means that men have genes that women do not. It also means that women, with two X chromosomes, have twice as many copies of the X chromosome genes as men. These include genes that encode carbohydrate metabolism enzymes, blood clotting factors, and color vision receptors.
 - a. Humans are quite sensitive to having too many or too few copies of genes. Think of the consequences of trisomy 21 (Down syndrome). What mechanism balances the difference in X chromosome gene copy number and how does it work?
 - b. What other systems are possible for balancing X chromosome gene copy number? (For example, *Drosophila* also have an XY chromosome sex determination system but they use a different mechanism than humans.)

Additional Information and Answers

1. One caveat to the genetic "differences between the sexes" is that the differences between male and female humans is in discrete genes. The differences between humans and chimps is over the entire genome, at every gene, at gene regulatory regions and in large changes in chromosome structure.
2. X and Y share enough homology at the ends that they can pair in meiosis in an XY male, and undergo limited crossing-over at these terminal regions. However, the bulk of the Y chromosome cannot undergo crossing-over, and is destined to accumulate mutations. The article notes that the Y chromosome has large, repeated regions, and suggests that these regions represent extra material that is available for repairing mutations.
3.
 - a. In mammals, gene dosage of X chromosome genes is regulated by X-inactivation. During early development, both X chromosomes express a gene called *Xist* into *Xist* RNA. This RNA binds the X chromosome. Slight differences in the amount of *Xist* RNA cause one X to be condensed into an inactive Barr body; the other expresses its genes. In effect, female mammals have one functional X, just like males. Regulation is more complex than that, because having only one X chromosome, as in Turner syndrome, is not the same as having one inactivated and one expressed X.
 - b. In other organisms with two different sex chromosomes, like *Drosophila*, dosage compensation can occur by either increasing the expression of X-linked genes in males, or decreasing expression in females.

Activity 7: You Be the Judge

Based on video content

15 minutes

Setup

The video for this unit included a bit of the history of gender testing in the Olympics, and covered some of the issues in human gender determination. Now that you've had a chance to apply and reflect on this information, discuss the following questions in pairs or in a group.

Materials

- One copy of the Discussion Questions per person (master copy provided)

Discussion Questions

1. According to *The Journal of the American Medical Association*, at the 1992 Winter Olympics in Albertville, France, 8 of 3387 (1 per 423) women were found to have the Y-linked gene *SRY*. Seven of the eight had complete or partial androgen insensitivity syndrome, and the eighth probably had a defect in an enzyme in a testosterone biosynthesis pathway.
In your opinion, which, if any, of these people should be allowed to compete in women's events?
2. Do you think it would be fair for a true male who could "pass" as a female—and perhaps had the internal sense that he was more female than male—to compete in women's events in golf? swimming? soccer? basketball? boxing?
3. If you don't think this would be fair, should all athletes be tested for gender? How?
4. In your opinion, which is more important in determining gender: sex chromosome composition? appearance of external genitals? internal anatomy? self-identification? levels of sex-determining hormones?
5. In general, do you think biological or psychological criteria are more important in determining gender?
6. In biological terms, what do you think determines the critical features of maleness and femaleness in humans? What genes might be involved, and what might they encode?

Sources:

- Simpson, J. et al. 2000. *JAMA* 284:1568–69.
Simpson, J.L. 1986. *JAMA* 256(14):1938.

Notes
