

Teacher Preparation Notes for Genetics

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Equipment and Supplies:

Pennies (1 per student)
Sockosomes (1 per student -- optional)
Calculator for converting fractions to percents (optional)

Teaching Points:

- The behavior of chromosomes during meiosis and fertilization provides the basis for understanding the inheritance of genes.
- Meaning of terms, including allele, heterozygous, homozygous, dominant, recessive, genotype, phenotype
- How to use Punnett squares to make predictions about genotypes and phenotypes
- In large samples of offspring, observed frequencies of genotypes and phenotypes will usually be close to predictions based on Punnett squares, but for small samples there may be substantial deviations from predicted due to chance variation.
- Independence of successive fertilization events
- Genetics of sex determination
- How to carry out basic pedigree analysis and interpret pedigrees
- Adaptive advantage for sickle-cell heterozygous individuals where malaria is prevalent

Suggestions for Implementation:

Ideally, this hands-on activity should immediately follow the Mitosis, Meiosis, and Fertilization hands-on activity, and students can use the sockosomes from that activity for the review of relevant material on p. 1 of the student protocol.

For the coin toss activity, some teachers prefer having the students shake checkers in a paper cup (may be quieter, result in more random tossing, and higher return rate than coins). Also, you may want to prepare a table that compiles the outcomes of the coin tosses for the entire class, which should provide a close approximation to the predicted percents (which is not always observed in the 16 coin tosses made by each pair of students). Discussion of random variation will help your students to reconcile the precise predictions of Punnett squares in their classroom learning with their experience of variation in outcomes in real world families.

For the genetics of sex determination part of this activity, we post a chart on the board with columns for number of males and total number of children, so students can enter the data for their family or group in order to compile the data needed to answer questions 5-6 on page 6. If your class is sex-biased, you will probably want to modify the instructions to prevent biased results due to whatever factors have resulted in a preponderance of males or females in your class. Specifically, the students should exclude themselves from the analysis for questions 5-6 on page 6 and just count all of their siblings (and step-siblings), each of whom represents an independent fertilization event and thus should be unaffected by whatever bias has affected enrollment in your class.

If you do not have enough class time to complete all the activities, you can use page 1 through the top of page 5 as an introduction to the first five teaching points above. Each of the subsequent sections can be used independently or added to the introductory sections, according to your teaching needs.

¹ These teacher preparation notes and the related student handout are available at http://serendip.brynmawr.edu/sci_edu/waldron/.

Statistical Information for Interpreting Results

For the Coin Genetics activity, one of the teaching points is that the results for larger samples usually are close to the predicted distribution, in contrast to results for small samples, which often deviate substantially from the predictions of the Punnett Square. This does not mean that results from larger samples are more likely to show exactly the predicted distribution, but only that result from larger samples are more likely to be close to the predicted distribution. For example, for many repetitions of 4 pairs of coin tosses, 18.75% would be expected to show exactly the predicted 1:2:1 ratio for AA, Aa, aa genotypes. In contrast, for many repetitions of 16 pairs of coin tosses, 5.37% would be expected to show this exact predicted ratio, but 23.51% would be expected to be within 10% of the expected frequencies for each genotype (see table below). The most striking change with increasing sample size is the decrease in the frequency of extreme deviations from predicted. For example, a finding of all Aa would be expected in 6.25% of repetitions of 4 pairs of coin tosses, but only 2 times in 100,000 repetitions of 16 pairs of coin tosses.

Observed Distribution in the Coin Genetics Activity			Probability of this Distribution for:	
AA	Aa	aa	4 coin tosses	16 coin tosses
25%	50%	25%	.1875	.0537
15-35%	40-60%	15-35%	.1875	.2351
	100%		.0625	.00002
100%			.0039	.00000

(Calculated using the multinomial calculator available at <http://stattrek.com/Tables/Multinomial.aspx>)

For the Genetics of Sex Determination activity, the following table shows the expected ranges of results for different sample sizes. Even with relatively large samples, rather substantial variation from one class to the next will be relatively common.

Number of Children For All the Mothers in a Class	If data were collected for a large number of classes,	
	68% of results expected to be in this range:	95% of results expected to be in this range:
20	39%-61% males	28%-72% males
40	42%-58% males	34%-66% males
60	43.5%-56.5% males	37%-63% males
80	44.4%-55.6% males	39%-61% males

(Calculated based on normal approximation to binomial distribution)

It should be mentioned that these ranges have been calculated based on several simplifications. Specifically, we have not taken into account the fact that slightly more males than females are born (51% males in US, slightly lower for African-Americans and slightly higher for Asian-Americans). Also, there appears to be some biological tendency for some couples to produce more female or more male offspring; this would increase expected variation in results. As discussed in Suggestions for Implementation, if you have a preponderance of males or females in your class, you should use only the siblings and omit the students in your class in order to avoid biased results.

Background Biology:

As shown in the first pedigree, the allele for albinism is recessive, since two unaffected parents have an affected offspring. (This pedigree also indicates that the allele for albinism is autosomal

recessive and not X-linked recessive, since the affected daughter, E, presumably inherited one allele for albinism from her unaffected father, B.) The allele for albinism is recessive because it codes for a defective enzyme for producing melanin, while the normal allele codes for the functioning enzyme; even when there is only one copy of the normal allele there is enough of this functioning enzyme to produce enough melanin to prevent albinism. Recessive alleles often code for a non-functional protein, while dominant alleles often code for a functional protein.

In the most common form of albinism, the lack of the pigment melanin affects not only skin and hair color, but also the appearance and function of the eyes. Further information about the various forms of albinism, as well as additional information concerning many of the conditions discussed below and a great deal of information on other aspects of human genetics, is available from OMIM, Online Mendelian Inheritance in Man (www.ncbi.nlm.nih.gov/omim/).

Students may ask questions concerning the distinction between inherited albinism and vitiligo. Albinism is the inability of the body's cells to produce melanin and affects the whole body. Vitiligo is a patterned loss of melanin pigment resulting from the destruction of melanocytes; the hypopigmented areas appear on the skin of a person with normal pigmentation. (Additional information from the National Vitiligo Foundation is available at www.nvfi.org.)

Students often ask questions concerning the various sex determination anomalies. Klinefelter and Turner Syndromes are two of the sex chromosome anomalies which are described in many biology textbooks. In addition, there are several syndromes that result from defective hormone receptors or defective enzymes to produce hormones.

Androgen Insensitivity Syndrome results from lack of functional molecular receptors for testosterone and dihydrotestosterone, so these hormones have no effect on the body. Consequently, a 46XY fetus develops female external genitalia. These individuals are raised and live as females, but they are infertile due to the lack of ovaries and a uterus. This syndrome is typically detected when a teenage female fails to menstruate.

Congenital Adrenal Hyperplasia (also called Adrenogenital Syndrome) develops when an enzyme needed to produce cortisol is defective or missing, resulting in abnormal hormonal feedback which leads to excessive production of androgens by the adrenal cortex. The elevated androgen levels in a 46XX fetus result in varying degrees of masculinization of the external genitalia. As a result, the baby's sex may appear ambiguous or even be mistaken for male.

Sickle cell hemoglobin is less soluble in the watery cytosol of the red blood cells than normal hemoglobin, particularly when oxygen concentrations are low. Thus, sickle cell hemoglobin tends to form long stacks or rods of hemoglobin molecules, and this results in the sickled shape of red blood cells. The sickled red blood cells tend to clog the capillaries, blocking the circulation in different parts of the body. Also, the sickled red blood cells do not survive as long as normal red blood cells, contributing to a tendency to anemia. Resulting symptoms include pain, physical weakness, impaired mental functioning, and damage to organs such as the heart and kidneys.

For the challenge question, when two affected parents have a normal child, this indicates that the allele for this particular condition is dominant. (This allele must be autosomal dominant and not X-linked dominant, since an affected father (A) has an unaffected daughter.) The allele for achondroplasia is considered dominant because an individual who is heterozygous for this allele and the normal allele has the dwarf phenotype. However, it is of interest that, while heterozygous individuals have an increased risk of infant death (estimated at about 7%), the homozygous condition is lethal (due to difficulty breathing as a result of a small rib cage and

brain problems resulting from abnormalities of the skull). The specific mutation responsible for achondroplasia results in a protein that is overactive in inhibiting bone growth.

Achondroplasia provides the opportunity to discuss two additional interesting points. Achondroplasia is an example of a condition caused by an allele which is dominant, but rare in the population; 99.99% of the population is homozygous for the normal recessive allele for this gene. Also, achondroplasia is a good example of a condition which is genetic, but generally not hereditary; in more than 80% of cases neither parent has the allele for achondroplasia and the child has achondroplasia due to a new mutation which occurred during production of the sperm.

Additional Possible Activities

Helpful activities for learning more genetics include:

- Two versions of Dragon Genetics, available at <http://serendip.brynmawr.edu/sci/waldron/>
- Genetics Practice Problems available at <http://biology.clc.uc.edu/courses/bio105/geneprob.htm>
- Learning Mendelian Genetics through a Simple Coin Toss Game at <http://www.wsu.edu/~omoto/papers/cointoss.html>
- Learning Genetics with Paper Pets, available from Science Scope, March, 2006, pp. 18-23 or http://www.nsta.org/main/news/stories/science_scope.php?news_story_ID=51647

We also have had good success with the following **Genetics Web Search Activity**.

Work in pairs to find out more about one of the following topics:

- Turner syndrome, Klinefelter syndrome, or another sex chromosome disorder
- androgen insensitivity syndrome or another intersex condition
- hemophilia or another X-linked recessive disorder
- blood type
- another genetic disease or trait.

Use reliable sources to answer questions such as:

- What is the genetic basis and mode of inheritance for this condition?
- What are the molecular, cellular, physiological and anatomical effects?

The specific information available will vary, but be sure to include fundamental biological information in your report. After 30 minutes, you and your partner will split up to report your findings to students who have investigated other conditions.

Suggested sources include:

- National Human Genome Research Institute, Specific Genetic Disorders (<http://www.genome.gov/10001204>)
- MEDLINEplus Health Topics, including Genetics/Birth Defects (www.nlm.nih.gov/medlineplus/healthtopics.html)
- Learn.Genetics, Understanding Genetic Disorders (<http://learn.genetics.utah.edu/units/disorders/index.cfm>)
- Your Genes, Your Health (<http://www.ygyh.org/>)
- Mayo Clinic Diseases and Conditions (www.mayoclinic.com)
- OMIM (Online Mendelian Inheritance in Man; www.ncbi.nlm.nih.gov/omim/)
- MEDLINE, PubMed, Medscape or ISI Web of Science
- textbooks