COMPARING MENDELIAN AND SEX-LINKED TRAITS OF

DROSOPHILA MELANOGASTER

By

JAMES BESS	ANGELA KHONG
DAMIAL FLETCHER	TIMOTHY PINDELL
MARCUS GAINES	JASMINE VAUGHN
JESSICA HARLIN	MICHAEL VILLENA
DAVID HUFFER	WAHLIA WALKER

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Teacher: Ms. Ashli Myers

INTRODUCTION

Genetics is the study of how parents pass genes to offspring through a process known as genetic inheritance. The two basic types of inheritance are Mendelian and sex-linked. The type of inheritance depends on where genes are physically located. Sex-linked inheritance occurs when genes are found on the sex chromosomes. Mendelian inheritance occurs when genes are found on the autosomes (Klug, Cummings, and Spencer, 2006).

A gene is a section of DNA that controls a trait in an organism. Genes are located on DNA, which is compacted to form chromosomes (Fig. 1). Organisms inherit one set of chromosomes from each parent; therefore, they inherit one set of genes from each parent (Joseph, Miller, and Kenneth, 1998). The inherited genes have multiple forms, which are called alleles. For example, the gene for height can have one of two alleles, a tall allele (T) which is dominant, or a short allele (t) which is recessive. Traits expressed by the offspring depend on the alleles inherited from the parents (Joseph, Miller, and Kenneth, 1998).

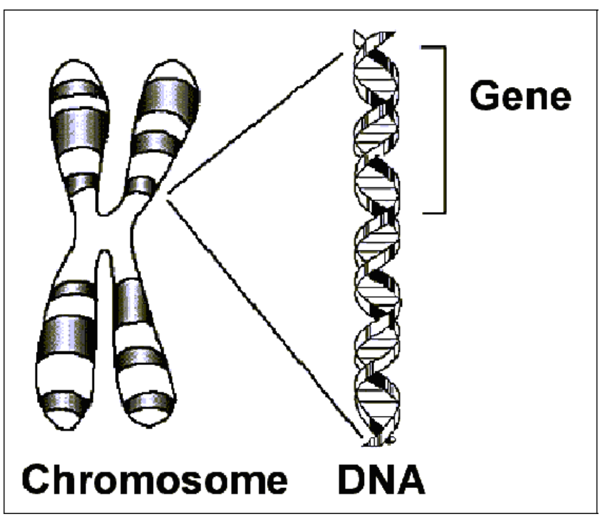


Fig. 1 – Figure 1 shows a picture of a chromosome, DNA, and a gene.

An organism receives one allele from its mother and one allele from its father. The dominant allele masks or hides the recessive allele. As can be seen in Fig 2, individual A will express the dominant trait because it is heterozygous; it has one dominant (T) and one recessive (t) allele. Individual B will express the dominant trait because it is a homozygous dominant; it has two dominant alleles (TT). Individual C is a homozygous recessive organism because it has two recessive alleles (tt). Individual C will express the recessive trait (Schraer and Stoltze, 1999).

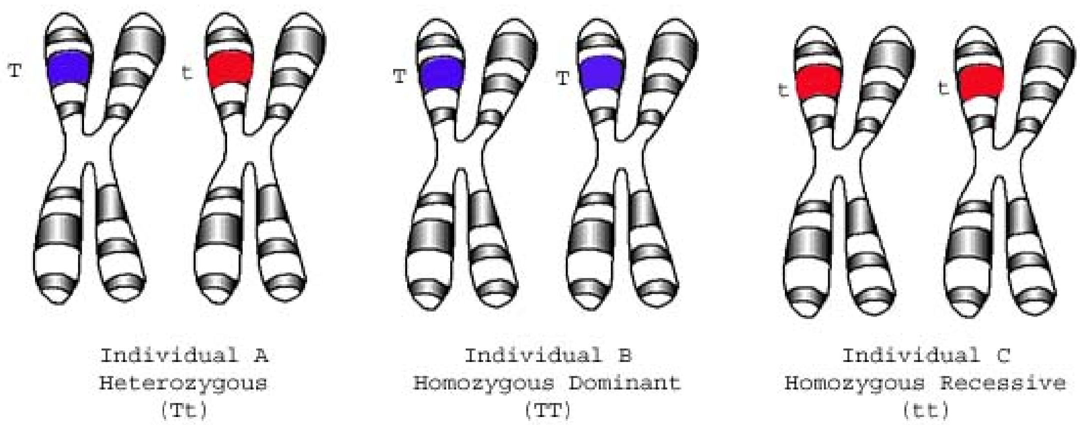
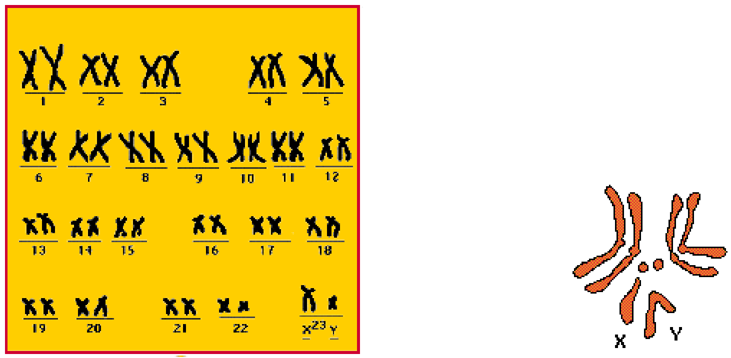


Fig. 2 – Figure 2 shows the difference between heterozygous and homozygous

Genes are found on chromosomes; the two types of chromosomes are sex chromosomes and autosomes (Solomon, Berg and Martin; 2002). All organisms have one set of sex chromosomes. The number of autosomes varies per organism. For example, fruit flies and humans have one sex chromosome, but fruit flies have three autosomes while humans have twenty-two (Fig.3). Sex chromosomes determine the gender of the organism; autosomes do not determine gender but do determine traits. The genes that are located on autosomes are transferred through Mendelian inheritance. Genes that are located on sex chromosomes are transferred through sex-linked inheritance (Mittwoch, 1967).



A B

Fig. 3 – Section (A) shows the Human karyotype and Section (B) shows the fruit flies karotype

Most chromosomes are autosomes. Genes located on the autosomes are passed through Mendelian inheritance. Through Mendelian inheritance, each offspring receives two alleles, one from the mother and one from the father. The Punnett square is used to determine the possible allele combinations resulting from a parent cross. A Punnett square is also used to determine the phenotypic ratio of the offspring. A phenotypic ratio is the ratio of visible traits displayed in the offspring. The Punnett square in Figure 4 shows the different allele combination and the phenotypic ratio that will result when two heterozygous parents are crossed. The offspring will either be homozygous dominant (TT) expressing the dominant trait, or heterozygous (Tt) expressing the dominant trait, or homozygous recessive (tt), expressing the recessive trait. The offspring has a 3:1 phenotypic ratio; three dominant and one recessive.

	T	t
T	TT	Tt
t	Tt	tt

Fig. 4- This figure shows the Mendelian parent cross and the offspring

In sex-linked inheritance, however, every offspring does not necessarily get two alleles. There are two types of sex-chromosomes, the X chromosome and Y chromosome. A female has a pair of X chromosomes, one from the mother and one from the father. The male has an X and a Y chromosome. The Punnett square in Figure 5 shows the female with a pair of X chromosomes and a male with an X and Y chromosome. The X chromosome is from the mother and the Y chromosome is from the father. The Y chromosome is very small and does not hold many genes, whereas the X chromosome holds most of the genes. When the gene is found on the X chromosome and not the Y chromosome, then the female offspring receives two X chromosomes which means the female inherits two alleles. The male offspring only receives one allele because the male only has one X chromosome. For example, when a heterozygous female is crossed with a dominant male, the offspring will be females with two alleles and males with one allele. The females will be homozygous dominant ($X^T X^T$), and heterozygous ($X^T X^t$), while the males will be dominant ($X^T y$), and recessive ($X^t y$) (Fig. 6).

	X	X
X	XX	XX
y	Xy	Xy

Fig. 5- This figure shows the possible gender outcomes of a cross between a male and female parent

	X^T	X^t	
X^T	$X^T X^T$	$X^T X^t$	females with two alleles
y	$X^T y$	$X^t y$	males with only one allele

Fig. 6- This figure shows the sex-linked parent cross and the offspring

The purpose of the study was to use the ratios in the F2 generation to determine whether the genes in *Drosophila melanogaster* for eye color and wings are found on the autosomes, resulting in Mendelian inheritance, or the sex chromosomes, resulting in sex-linked inheritance. When a trait is passed through Mendelian inheritance, a cross between a homozygous dominant male (TT) and homozygous recessive female (tt) will result in all offspring being heterozygous in the F1 generation (Fig. 7). The F2 generation is produced by crossing the heterozygous females from theF1 generation with the heterozygous males from the F1 generation. The F2 generation will have a phenotypic ratio of 3(dominant): 1(recessive) (Fig. 8).

	T	T
T	Tt	Tt
T	Tt	Tt

Fig. 7- This figure shows the Mendelain parent cross and the resulting F1 generation.

	T	t
T	TT	Tt
t	Tt	tt

Fig. 8- This figure shows the F1cross and the resulting F2 generation

When a trait is passed through sex-linked inheritance and the gene for the trait is found only on the X chromosome, a cross between a dominant male (X^Ty) and a homozygous recessive female (X^tX^t) will result the F1 generation. The females in the F1 generation will have two alleles and will be heterozygous. The male offspring in the F1 generation will be recessive with only one allele (Fig. 9). The F2 generation is produced when the heterozygous females from the F1 generation are crossed with the recessive males from the F1 generation. The F2 generation will have a phenotypic ratio of 1:1:1:1(one heterozygous female (X^TX^t) to one homozygous recessive female (X^tX^t) to one dominant male (X^Ty) to one recessive male (X^ty) (Fig. 10).

	X^t	X^t
X^T	X^TX^t	X^TX^t
y	X^ty	X^ty

Fig. 9- This figure shows the parent cross and resulting F1 generation

	X^T	X^t
X^T	X^TX^t	X^tX^t
y	X^Ty	X^ty

Fig. 10 – This figure shows the F1 cross and resulting F2 generation.

The difference between sex-linked and Mendelian inheritance is the phenotypic ratio in the F2 generation. Because most genes are found on autosomes, most traits are passed through Mendelian inheritance. The null hypothesis states that the genes for eye color and wings in *Drosophila melanogaster* are passed through Mendelian inheritance and will result in a 3:1 phenotypic ratio in the F2 generation. The alternative hypothesis states that the genes for eyes and wings in *Drosophila melanogaster* are passed through sex-linked inheritance rather than Mendelian inheritance, and will result in a 1:1:1:1 phenotypic ratio in the F2 generation.

METHODS

Drosophila melanogaster or fruit flies are good organisms to use in the research of genetics. Fruit flies are used in genetics and biological research because fruit flies are inexpensive and easily cultured. Fruit flies also have high fecundity rates; a female fruit fly can lay up to 500 eggs in 10 days.

In order to test the hypothesis, the students had to observe the F2 generation. Because the fruit flies take two weeks to hatch and the group only had six weeks to finish the experiment, the instructor did the initial parent cross two weeks prior to the students arriving. The instructor crossed a homozygous recessive female (tt) with either a homozygous dominant male (TT) or dominant male with only one allele (X^TY). This cross produced the F1 generation which crossed and produced the F2 generation. The students analyzed the F2 generation to determine what kind of male was crossed with the females.

On June 26th the culture vessels were prepared by following the instructions in the Carolina Drosophila Manual. One part Drosophila medium was deposited into the bottom of the culture vessels with one part water. Then the medium was left to firm. Once the medium was firm, the yeast was added. Medium and yeast are used as a food source; medium is for the larva to eat, and yeast is for adult flies to eat. A piece of plastic mesh was added to the culture vessel to give the fruit flies more surface area, which was needed so that they would not crush one another or get stuck in the medium.

To sex the fruit flies, the flies were first transferred to an empty culture vessel to be anesthetized with FlyNap®. Then the flies were moved to a wide field stereomicroscope and separated by gender. Male fruit flies have heavy dark bristles around the base of the genitalia, and females do not.

After the F1 flies were sexed, six males and six females were put into a culture vessel to breed the F2 generation. Since there was not enough time to wait for F2 generation to hatch naturally, the culture vessels were put in an incubator at 28.5 °C to speed up the process of development. After the F1 flies reproduced, they were released so they would not be counted with the F2 generation. As the F2 flies hatched over a seven day period they were counted and categorized. The flies were then categorized by traits and gender. The wings groups categorized by male with wings, males without wings, females with wings, and females without wings. The eyes group categorized by males with red eyes, males with white eyes, females with red eyes, and females with white eyes.

A table was created to show the totals of each category: wings, no wings, red eyes and white eyes. The group performed a Chi square test to compare the observed results to the expected Mendelian ratio of 3:1 and the expected sex-linked ratio of 1:1:1:1 in the F2 generation. A Chi square test tells whether there is a significant difference between the expected and observed results or if the difference is due to chance.

RESULTS

Table 1 shows the number of observed flies compared to expected flies with and without wings. The expected ratio was 3 (flies with wing): 1 (fly without wings) as predicted by the Mendelian inheritance cross. The observed ratio was 5 (flies with wings): 1 (fly without wings). The Chi square test compared the ratios, the result of which was a p-value of much less than 0.01. This meant that there was very close to 0% probability that the difference was due to chance, and that there was a significant difference between the observed and expected ratios. Based on the data, the gene for wings is not passed through Mendelian inheritance (Table 1).

Table 1. – This table shows the winged and non winged observed 5:1 and expected 3:1 ratios for the Mendelian inheritance.

	Observed 5:1	Expected 3:1
Wings	343	309
No wings	69	103
Total	412	412

Table 2 shows the comparison of observed to expected female to male flies with and without wings. The expected ratio was 1 (male with wings): 1 (male without wings): 1 (female with wings): 1 (female without wings), as predicted by the sex-linked inheritance cross. The expected ratio was also based on a 1:1 ratio of females to males. The observed ratio was 11 (males with wings): 3 (males without wings): 9 (females with wings): 1 (female without wings).

The Chi square test resulted in a p-value of much less than 0.01, showing that there was a significant difference between the observed and expected ratios. Based on the data, the gene for wings is not passed through sex-linked inheritance (Table 2).

Table 2. – This table shows the winged and non winged observed 11:3:9:1and expected 1:1:1:1 ratios for the sex-linked inheritance.

	Observed 11:3:9:1	Expected 1:1:1:1
Males Wings	189	103
Males No Wings	51	103
Females Wings	154	103
Females No Wings	18	103

Table 3 compares the observed and expected male to female ratios. The expected ratio was 1 (female): 1 (male) as predicted any time a male and female reproduce. The observed ratio, however, was not 1 (female): 1 (male). The Chi square test resulted in a p-value of much less than 0.01, showing that there was a significant difference between the observed and expected ratios (Table 3). Because of the results of the Chi square test, the decision was made to use the observed ratio when comparing for sex-linked inheritance.

Table 3. - This table shows the observed and expected female to male ratios.

	Observed	Expected
Females	172	206
Males	240	206
Total	412	412

Table 4 shows the comparison of observed to expected female to male flies with and without wings. The expected ratio was modified to reflect the female to male ratio actually obtained. The observed ratio was 11 (males with wings): 3 (males without wings): 9 (females with wings): 1 (female without wings). The Chi square test resulted in a p-value of much less than 0.01, showing that there was a significant difference between the observed and expected ratios. Based on the data, the gene for wings is not passed through sex-linked inheritance.

Table 4. – This table shows the winged and non winged observed 11:3:9:1 and expected 1:1:1:1 for the second sex-linked.

	Observed	Expected
Males Wings	189	119
Males No Wings	51	119
Females Wings	154	87
Females No Wings	18	87
Total	412	412

Table 5 shows the number of observed flies compared to the expected flies with red or white eyes. The expected ratio was 3 (flies with red eyes): 1 (fly with white eyes) as predicted by the Mendelian inheritance cross. The observed ratio was 1 (fly with red eyes): 1 (fly with white eyes). The Chi square test resulted in a p-value of much less than 0.01, showing that there was a significant difference between the observed and expected ratios. Based on the data, the gene for eye color is not passed through Mendelian inheritance (Table 5).

Table 5. – This table shows the red eyed and white eyed observed 1:1 and expected 3:1 ratios for the Mendelian inheritance.

	Observed 1:1	Expected 3:1
Red Eyes	426	635
White Eyes	421	212
Total Flies	847	847

Table 6 shows the comparison of observed to expected female to male flies with red or white eyes. The expected ratio was 1 (male with red eyes): 1 (female with red eyes): 1 (male with white eyes): 1 (female with white eyes), as predicted by the sex-linked inheritance cross. The expected ratio was also based on a 1:1 ratio of females to males. The observed ratio was 1 (male with red eyes): 2 (females with red eyes): 1 (male with white eyes): 1 (female with white eyes). The Chi square test resulted in a p-value of much less than 0.01, showing that there was a significant difference between the observed and expected ratios. Based on the data, the gene for eye color is not passed through sex-linked inheritance.

Table 6. – This table shows the red eyed and white eyed observed 1:2:1:1 and expected 1:1:1:1 ratios for the sex-linked inheritance.

	Observed 1:2:1:1	Expected 1:1:1:1
Red Eyes Male	167	212
Red Eyes Female	259	212
White Eyes Males	177	212
White eye Females	244	212

Table 7 compares the observed and expected male to female ratios. The expected ratio was 1 (female): 1 (male), as predicted by any time a male and female reproduce. The observed ratio was 2 (females): 1 (male). The Chi square test resulted in a p-value of much less than 0.01, showing that there was a significant difference between the observed and expected ratios (Table 3). Because of the results of the Chi square test, the decision was made to use the observed ratio when comparing for sex-linked inheritance.

Table 7. - This table shows the observed 2:1 and expected 1:1 female to male ratios.

	Observed 2:1	Expected 1:1
Females	503	424
Males	344	424

Table 8 shows the comparison of observed to expected female to male flies with red or white eyes. The expected ratio was modified to reflect the female to male ratio actually observed. The observed ratio was 1 (male with red eyes): 2 (females with red eyes): 1 (male with white eyes): 1 (female with white eyes). The Chi square test resulted in a p-value of 0.86422836, showing that there was an 86% probability that the difference was due to chance, and that there was not a significant difference between the observed and expected ratios. Based on this data, the gene for eye color is passed through sex-linked inheritance.

Table 8. – This table shows the red eyed and white eyed observed 1:2:1:1 and expected 1:1:1:1 for the second sex-linked.

	Observed 1:2:1:1	Expected 1:1:1:1
Red Eyes Male	167	172
Red Eyes Female	259	252
White Eyes Males	177	172
White eye Females	244	252
Total Flies	847	847

Discussion and Conclusion

The purpose of the study was to use the ratios in the F2 generation to determine whether the genes in *Drosophila melanogaster* for eye color and wings are found on the autosomes, resulting in Mendelian inheritance, or the sex chromosomes, resulting in sex-linked inheritance. The null hypothesis stated that the genes for eye color and wings were Mendelian inherited and would result in a phenotypic 3:1 ratio in the F2 generation. The alternative hypothesis stated that the gene for eye color and wings was not Mendelian but sex-linked, and would result in a phenotypic 1:1:1:1 ratio in the F2 generation.

The wings group rejected both the null hypothesis and alternative hypothesis. Based on the p-values that were acquired from the Chi-squared tests, the data showed that the observed ratios were all significantly different from the expected Mendelian ratio and the expected sex-linked ratio.

The eyes group rejected the null hypothesis because there was not a 3:1 ratio based on the p-value, which was much less than 0.01 in the Chi square test for Mendelian inheritance. The alternative hypothesis was accepted because of the sex-linked ratio was found when using the observed male to female ratio. The resulting p-value was much greater than 0.01 in the Chi square test for sex-linked inheritance, indicating that the gene for eye color was sex-linked.

The wing group did not obtain a 3:1 Mendelian ratio or a 1:1:1:1 sex-linked ratio because the wing group obtained significantly (five times) more winged flies than non-winged flies. When the flies with no wings hatched some of the flies got stuck in the medium because they could not fly. The group did not count the flies stuck in the medium and this led to incomplete results and a small sample size. The other reason why the wing group obtained a small sample size is that the students were inexperienced at handling and transferring the flies. The wing group collected 412 flies whereas the eye color group collected 847 flies; the wing group collected less than half of what the eye color group collected.

The students in the wing group and the eye color group did not obtain a 1(male): 1 (female) ratio. The wing group counted more male than female flies, and the eye color group counted more female than male flies. A reason that the wing group counted more male than female flies, and specifically more non-winged males than non-winged females, is that since the females emerged before the male flies, more non-winged females probably got stuck in the medium than the non-winged males. The non-winged flies were more likely than the winged flies to get stuck in the medium they could not fly into the empty culture vessel used to collect live flies for data collection during transfer.

The reason that the eye color group counted more female than male flies could be that the females hatch first. If more time was allotted, then all of the flies would have been able to hatch, and the group would have been able to count all of the flies. In all likelihood, most of the male flies were still not hatched. Other reasons that the two groups did not obtain a 1 (male): 1 (female) ratio could be that inexperienced students incorrectly identified the male and the female flies, or that the flies escaped while handling them. The students only had one day to learn how to handle the flies.

The main limitation to the study was time. Not all the F2 generation flies hatched during the experiment. There was still some pupa incased in the culture vessel when the group stopped collecting the data. This could have altered the male to female ratio because the females hatch first; the remaining flies were mostly likely males. Incubation became a factor because the group did not have enough time. If the group had more time, then the flies could have hatched naturally, which is better than incubation. When the group incubated the flies, the lifecycle sped up. This may have caused an unhealthy development, and premature deaths and dead flies were stuck in the medium. The flies stuck in the medium were difficult to remove, so they were not counted. The group was inexperienced because there was only one day to practice handling the flies. This was also the students first time transferring flies, making culture vessels and sexing the fruit flies. Inexperienced students may have allowed a fly to escape from the culture vessel when transferring the flies. If the group practiced transferring the flies more, the flies may not have escaped and the group would have a bigger sample size. In addition, a male fly could have been sexed incorrectly if the fly had a lighter spot than usual on its genitalia. Some of the culture vessels might not have been prepared correctly, and the medium could have been too dry. Therefore in some culture vessels flies died and the sample size reduced because the females could not lay their eggs in dry medium to make more flies; and some culture vessels were useless.

An improvement to the study could be that the group could have extracted all the flies. This would include the dead flies stuck in the medium and the flies that escaped, both of which were not counted. The dead flies stuck in the medium were not counted, but could have been counted by extracting the medium after all the flies were released. Another improvement could allow them to hatch naturally instead of through incubation. Making more usable culture vessels also could have yielded a bigger sample size.

Some questions arose when the group was performing the study. Did the incubator help a specific gender hatch faster? Does incubation lower or raise the fecundity rate? How would different culture vessels with different amounts of medium effect the growth of the fruit flies? Did the specific species of fruit fly make a difference to the outcome of the experiment?

The study of genetics is important to helping people understand how traits are passed down through generations, and to predict genetic diseases and disabilities. This study of Mendelian and sex-linked inheritance is only a very small part of what is actually being done in this increasingly important field. The more people can learn about genetics, the more knowledge they can gain about the prevention and elimination of negatively inherited traits.

BIBLIOGRAPHY

Flagg, R. O., Ph. D (1988). Carolina drosophila manual. Burlington, North Carolina: Carolina Biological Supply Company.

Joseph, S, Miller, L, & Kenneth, R (1998). *Prentice Hall: Biology*. Lebanon: Prentice Hall.

Klug, W., Cummings, M., & Spencer, C., 2006. *Concepts of genetics eight edition*. Upper Saddle: Pearson Education

Mittwoch, U. (1967). *Sex Chromosomes*. New York, London: Academic Press

Schraer, W. D., & Stoltze, H. J. (Eds.). (1999). Biology, The study of life. Upper Saddle River, New Jersey: Prentice Hall.

Solomon, E. P., Berg, L. R., & Martin, D. W. (2002). *Biology*. Thomas Learning Inc..