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FRUIT FLIES IN A SCIENTIST'S LAB

THE GENE-CHROMOSOME THEORY OF INHERITANCE

By the year 1900, many cell structures, including chromosomes, had been studied and described. Also by 1900, three separate European scientists had rediscovered Mendel's results, published over 30 years earlier, as they were preparing to publish their own similar results. Some scientists were taking Mendel seriously, and a few thought that perhaps chromosomes might be the carriers of Mendel's "factors."

Right around this time, scientists observed that similar chromosomes (those of the same type) paired with one another during meiosis. This led a young American graduate student named Walter Sutton to publish a paper outlining the gene-chromosome theory of inheritance, in which he proposed that chromosomes were the vehicle for Mendelian inheritance. Four points of current evidence suggested this

about chromosomes. First, fertilization involves the union of two gametes, egg and sperm, suggesting that, as Mendel's model predicted, each parent made equal genetic contribution to the zygote. Second, gametes contain only a haploid set of chromosomes, which was consistent with Mendel's model. Third, sperm contain almost no cytoplasm (the portion of a cell outside the nucleus) which means very few other organelles besides chromosomes are present in the sperm. Lastly, chromosomes had been demonstrated to segregate and assort independently in the same manner as Mendel's factors. However, many remained unconvinced. Their primary challenge to Sutton's theory was this: if chromosomes are the vehicle for "factors" (genes), why are there so many more traits than chromosomes?



Answer the following questions.

- 2.25 What were the four points that supported Walter Sutton's theory? _____

- 2.26 What objection did many scientists have to Sutton's hypothesis? _____

T. H. MORGAN'S WHITE-EYED FLY

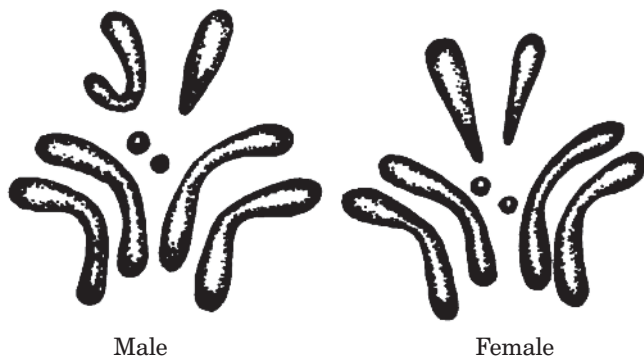
One of the men who doubted both Mendel's and Sutton's conclusions was biologist Thomas Hunt Morgan. In 1904, Morgan began research that would prove both Mendel and Sutton correct.

Morgan chose the common fruit fly, *Drosophila melanogaster*, for his studies. This tiny fly is very easy to handle and store, and completes its full life cycle in only two weeks, allowing numerous generations to be studied

in just a few months. Also, *Drosophila* has only four pairs of rather large chromosomes, which are easier to observe by microscope than those of most other organisms (see Figure 22).

Biologists had already observed that chromosomes exist as homologous pairs, and that both homologous pairs of each chromosome type were identical in size and shape in all pairs except one. This one pair was always identical in females, but not in males, who, instead of the two identical chromosomes, had

Figure 22: Drosophila Chromosomes



one regular-sized chromosome and one that was small and odd-shaped (see Figure 22). Scientists concluded that this pair of chromosomes was responsible for determining the sex of the organism and called them the **sex chromosomes**. The other chromosomes are called **autosomes**. They called the larger sex chromosome the X chromosome and the smaller one, present only in males, the Y chromosome. Females have the genotype XX, and males have the genotype XY. Because of this, females can contribute only X chromosomes to gametes, whereas males can contribute either X or Y. We will soon see the relevance of this to Morgan's work.

Figure 23: P-Generation Cross Between White-Eyed Male and Red-Eyed Female

	white-eyed male ($X^W Y$)		
	X^W	Y	
red-eyed female ($X^R X^R$)	X^R	$X^R X^W$	$X^R Y$
	X^R	$X^R X^W$	$X^R Y$

F₁ generation — all red eyes

X^R = X chromosome with normal red-eyed gene
 X^W = X chromosome with mutant white-eyed gene

One day in 1910 Morgan found a white-eyed *Drosophila*. Normally *Drosophila* have red eyes, so Morgan assumed this was a **mutant trait**; that is, one caused by a **mutation** (a defect or mistake in the DNA). He wanted to see if this trait would follow Mendelian principles, so he crossed the white-eyed fly to a normal red-eyed female (See Figure 23). The F₁ generation was all red-eyed, indicating that this was a recessive trait. Morgan then crossed flies from the F₁ with each other. He found, that as Mendelian principles predicted, the trait resurfaced in the F₂ generation (see Figure 24). Yet something was very unusual: all the white-eyed flies were males!

Figure 24: Cross Between Red-Eyed Male and Red-Eyed Female From F₁ Generation

	red-eyed male ($X^R Y$)		
	X^R	Y	
red-eyed female ($X^R X^W$)	X^R	$X^R X^R$	$X^R Y$
	X^W	$X^R X^W$	$X^W Y$

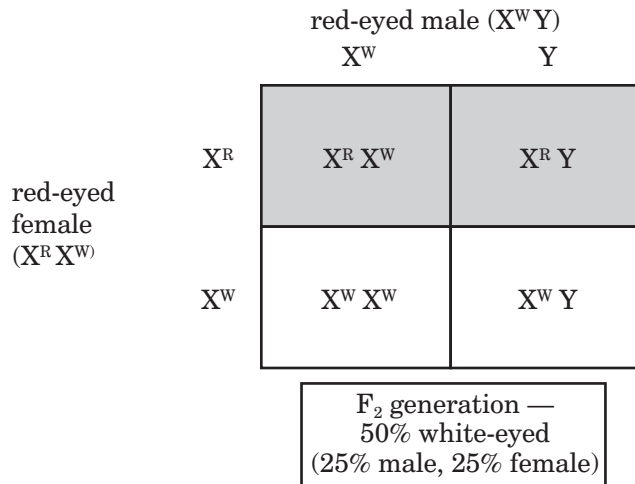
F₂ generation — 25% white-eyed males

X^R = X chromosome with normal red-eyed gene
 X^W = X chromosome with mutant white-eyed gene

Morgan then decided to testcross a white-eyed male with one of the red-eyed females (genotype $X^R X^W$) from the F₁ to determine whether the white-eyed trait could be produced in females (see Figure 25). He found that it was indeed possible to produce a white-eyed female, and in so doing, Morgan established some highly significant facts.

First of all, Morgan proved that chromosomes were indeed the vehicle for Mendelian inheritance. The white-eyed trait followed exactly with the segregation of the X chromosome. In other words, the transmission of the

Figure 25: Cross Between White-Eyed Male and Red-Eyed Female From F₁ Generation



white-eyed trait through the generations of flies studied exactly followed the transmission of the mutant X chromosome.

Second, Morgan's work proved that some traits are sex-linked, that is, the genes for the trait are found only on the X chromosome. The recessive gene for white eyes is found on the X chromosome. This is why Morgan originally found the trait only in male flies, who have only one copy of the X chromosome. Why is this? Females have two X chromosomes, and only rarely under normal circumstances will both of these carry the recessive gene. A female will usually have a normal copy of the gene on at least one chromosome. The normal copy, being dominant, will cause the expression of red eyes. However, any male who inherits the mutant gene on its X chromosome will have white eyes because it lacks a second X chromosome to dominate and express the normal trait, red eyes. Therefore, sex-linked traits are seen most often in males, who do not have a second X chromosome to carry a normal copy of the gene.



Complete the following exercises.

- 2.27 What are the two types of chromosomes? _____
- 2.28 What is the allele combination for females? _____ males? _____
- 2.29 What allele combination produces a white-eyed female? _____
- 2.30 If you have a female red-eyed fly, how can you determine if it is a carrier (heterozygous for the recessive gene) of the white-eyed gene? _____

- 2.31 Name three reasons that *Drosophila* is commonly used in genetic studies. _____

- 2.32 What is a mutant trait? _____

- 2.33 In your own words, explain why sex-linked gene defects are most often expressed in males. _____

THE SCIENTIFIC METHOD

We have talked about scientists and their experiments. In our day, the term “scientist” brings many thoughts to people’s minds. Most of us imagine people in white coats working with complicated technology, higher mathematics, and complex ideas. But have you ever wondered just exactly what science is, or just what kind of method scientists use to design and perform their experiments?

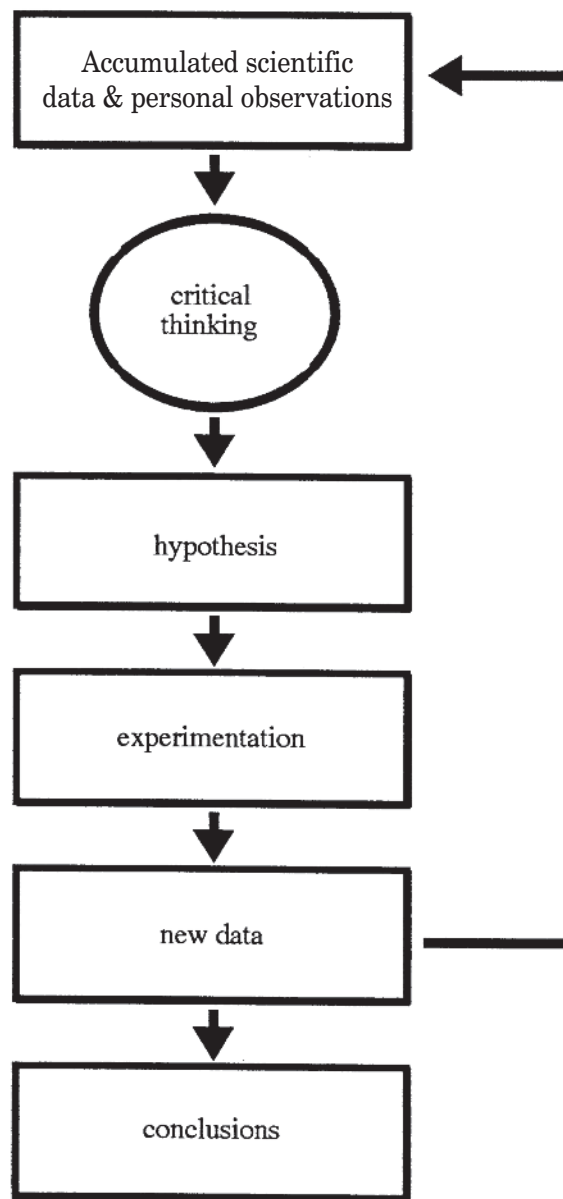
Science is simply the endeavor to obtain and logically organize facts about the natural world. Facts are obtained by observation, and often these observations serve to raise questions about what has been observed. For example, a gardener might observe that her summer crops produce best in a portion of the garden where compost (rotted kitchen and lawn scraps) had been applied the fall before. Based on her knowledge of raising plants, she might predict that the compost was the reason. Thus, an observed fact (superior plant growth in one section) led to critical thinking about the issue (wondering what might have produced the growth), and then to an educated prediction (that the compost was responsible for the superior growth).

Let’s say that in order to either support or disprove her prediction, our gardener performs an experiment. She marks off two plots in the garden, then makes sure these two plots receive equal sunlight, fertilizer, cultivation, etc., except that only one plot receives compost in the fall. Next summer, she will note whether or not the compost-treated spot has produced more fruit. To lend further validity to these results, she would need to do as Mendel did — take careful notes and counts, so that others can repeat her experiments and analyze her data.

That does not sound very complicated, does it? Professional scientists may perform much more sophisticated experiments than our gardener, but the principles of science remain the same no matter how simple or complicated the experiment may be. Science is no more than the process whereby facts are observed, predictions are made, and experiments are performed to produce more facts to confirm or reject the predictions.

In science, a prediction is called a **hypothe-**

Figure 26: The Scientific Method



sis. The goal of developing a hypothesis is to plan experiments whose results will shed new light on one’s observations. A hypothesis must therefore be testable to be useful. This process of observing, forming a hypothesis, experimenting, and then reaching a conclusion based on the new facts, is called the **scientific method** (see Figure 26).

A hypothesis that has survived many experiments is called a **theory**, like the cell theory or the atomic theory. A theory that has never been disproved despite many years of testing

may eventually be called a law, like the law of gravity or the laws of thermodynamics. Man does not make these laws — he only discovers them! God is the Author of the laws of the universe.

The work of Mendel, Sutton, Morgan and many others brought about the gene-chromosome theory — that chromosomes are the vehicle for genes, the determiners of traits. This theory — now universally accepted as accurate — began as ideas in the minds of individuals. Mendel, Morgan, and others observed the inheritance of traits in living things and became curious about the hidden mechanisms behind what they saw. They acquainted them-

selves with the work of previous researchers and then, using their knowledge of science and mathematics, proposed ideas that might explain what they saw. Then came years of experimenting, seemingly endless hours of counting, and finally new data with which to form conclusions and new hypotheses for further experimentation. Through their efforts and insight, God chose to reveal a few more aspects of the function of His creation. Only a Scriptural perspective will enable mankind to more fully glorify God as He allows us to see deeper into the marvelously ordered complexities of His creation.



Complete the following exercise.

2.34

In your own words, describe how either Mendel or Morgan used the scientific method in his work. _____
