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11.1 The Work of Gregor Mendel

Lesson Objectives

- Describe Mendel's studies and conclusions about inheritance.
- Describe what happens during segregation.

Lesson Summary

The Experiments of Gregor Mendel The delivery of characteristics from parents to offspring is heredity. The scientific study of heredity is **genetics**. Gregor Mendel founded modern genetics with his experiments on a convenient model system, pea plants:

- **Fertilization** is the process in which reproductive cells (egg from the female and sperm from the male) join to produce a new cell.
- A **trait** is a specific characteristic, such as (in peas) seed color or plant height.
- Mendel prevented self-pollination in the peas. He controlled fertilization so he could study how traits passed from one generation to the next.
- He created **hybrids**, which are crosses between true-breeding parents (the P generation) with different traits.
  - These hybrids were the F_1 (first filial) generation.
  - They each showed the characteristic of only one parent.
- Mendel found that traits are controlled by factors that pass from parent to offspring. Those factors are **genes**. The different forms of a gene are **alleles.**
- Mendel's **principle of dominance** states that some alleles are dominant and others are recessive. The recessive allele is exhibited only when the dominant allele is not present.

Segregation Mendel allowed members of the F_1 generation to self-pollinate. The trait controlled by the recessive allele appeared in the next generation (F_2) in about one-fourth of the offspring—even when it did not appear in the F_1 generation.

- Separation of alleles is **segregation.**
- When **gametes** (sex cells) form, alleles segregate so that each gamete carries only one allele for each gene.
- The F_2 generation gets a new combination of alleles: one from each parent.

The Experiments of Gregor Mendel

Match the term with its definition.

Term		Definition
_____ **1.**	genes	**A.** Specific characteristics that vary among individuals
_____ **2.**	hybrids	**B.** The offspring of true-breeding parents with different traits
_____ **3.**	traits	**C.** Factors that determine traits
_____ **4.**	alleles	**D.** Sex cells, egg or sperm
_____ **5.**	gametes	**E.** The different forms of a gene

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6. Why are peas a good model system for studying heredity?

_____

_____

7. How did Mendel cross-pollinate flowers?

_____

_____

8. What is the difference between a gene and an allele?

_____

_____

9. State the principle of dominance.

_____

_____

The table shows some crosses between true-breeding parents that carry pairs of dominant alleles (such as SS) or pairs of recessive alleles (such as ss). Complete the table to show the combination of alleles in the offspring. Then use it to answer Questions 10–11.

Dominant and Recessive Forms of Pea Plant Traits

Trait	Parent Plants (P Generation)			Offspring (F_1 Generation)
Seed Color	Yellow *YY* 	X	Green *yy* 	Yellow *Yy* 
Seed Coat Color	White *gg* 	X	Gray *GG* 	Gray _____ 
Pod Shape	Constricted *ss* 	X	Smooth *SS* 	Smooth _____ 
Pod Color	Green *CC* 	X	Yellow *cc* 	Green _____ 

10. What is the dominant shape of a pea pod? How do you know?

_____

_____

11. What symbol represents the recessive allele for pod color?

_____

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Segregation

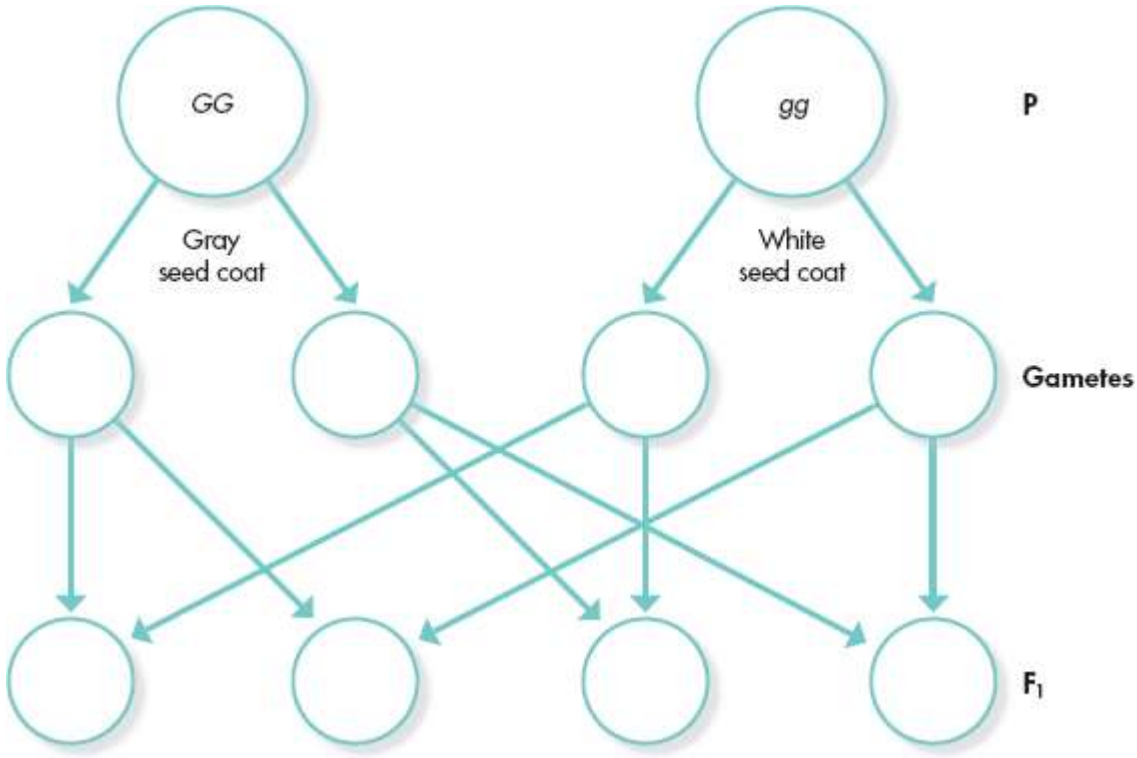
12. What is segregation? What is the result of segregation?

_____

_____

13. **THINK VISUALLY** The capital letter *G* represents the allele in peas that causes the dominant trait, gray seed coat. The lower-case letter *g* represents the recessive allele that causes the recessive trait, white seed coat.

In the circles, show the alleles in the gametes of the parent generation. Show how the alleles recombine in the F_1 plants.



Apply the Big idea

14. A black cat and a white cat have four black kittens in the F_1 generation. In the F_2 generation, there are three black kittens and one white kitten. Explain how the F_2 generation proves that genetic information passes unchanged from one generation to the next, even when a specific trait is not exhibited.

_____

_____

_____

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11.2 Applying Mendel's Principles

Lesson Objectives

- Explain how geneticists use the principles of probability to make Punnett squares.
- Explain the principle of independent assortment.
- Explain how Mendel's principles apply to all organisms.

Lesson Summary

Probability and Punnett Squares

Probability is the likelihood that a particular event will occur. Probability predicts the recombination of alleles:

- Of an allele pair, the probability of each allele in a gamete is ½, or 50 percent.
- When F_1 hybrid individuals are crossed, the probability of
  - two recessive alleles is ¼.
  - two dominant alleles is ¼.
  - one dominant allele and one recessive allele is ½ (¼ + ¼).
- Organisms that have two identical alleles for a gene are **homozygous** for that trait. If they have different alleles for the same gene, they are **heterozygous** for that trait.
- Physical traits are an organism's **phenotype**. Its **genotype** is its genetic makeup.
- A **Punnett square** is a mathematical tool that helps predict combinations in genetic crosses.

Independent Assortment

The principle of **independent assortment** states that genes for different traits segregate independently during the formation of gametes. In two-factor crosses, the phenotypes of the F_2 offspring occur in a 9:3:3:1 ratio: 9 with with both traits dominant, 3 with the first trait dominant and the second trait recessive, 3 with the first trait recessive and the second trait dominant, and 1 with both traits recessive.

A Summary of Mendel's Principles

- Genes are passed on from parents and determine traits.
- Where two or more alleles for a gene exist, some may be dominant and others recessive.
- In sexually reproducing organisms, offspring receive a copy of each gene from each parent. The alleles segregate when forming gametes.
- Alleles for different genes usually segregate independently.

Probability and Punnett Squares

1. What is probability? _____

_____

2. In a parent pea plant with the allele pair *Gg*, what is the probability that one gamete will contain the *G* allele? _____

_____

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3. Complete the graphic organizer to define the characteristics of homozygous and heterozygous genotypes and phenotypes.

	Homozygous	**Heterozygous**
Genotype		
Phenotype		

4. The dominant allele for smooth pod shape in peas is *S*. The recessive allele for constricted pod shape is *s*. In the Punnett square, show the result of crossing two heterozygous parents (*Ss*). Write the genotype and the phenotype of each type of offspring in the space provided.

	S	**s**
S	Genotype:_____ Phenotype:_____	Genotype:_____ Phenotype:_____
s	Genotype:_____ Phenotype:_____	Genotype:_____ Phenotype:_____

For Questions 5–9, refer to the Punnett square above.

5. What is the probability of a heterozygous offspring? Explain your answer.

_____

_____

6. What is the probability of a homozygous offspring? Explain.

_____

7. What is the probability of a homozygous recessive offspring?

_____

8. What is the probability of a smooth phenotype?

_____

9. What is the probability of a homozygous recessive individual (*ss*) producing a gamete with a dominant allele (*S*)? Explain.

_____

_____

Name _____ Class _____ Date _____

Independent Assortment

10. State the principle of independent assortment below.

_____

11. Using the principle of independent assortment, complete the Punnett square to show the results of an F_1 cross between two individuals heterozygous for both pod color (*C* = green and *c* = yellow) and pod shape (*S* = smooth and *s* + constricted). The gametes and some of the genotypes of the F_2 offspring are given.

	CS	**cS**	**Cs**	**cs**
CS	CCSS			
cS				ccSs
Cs			CCss	
cs		ccSs		

For Questions 12–15, refer to the Punnett square above.

12. Which genotype belongs to an offspring that is homozygous recessive for both traits? What is the probability of that genotype?

_____

13. What is the phenotype of an individual heterozygous for both traits?

_____

14. What is the probability of an F_2 offspring having the green pod color and smooth pod shape? Explain. (Note: Remember that more than one genotype can produce this phenotype.)

_____

_____

15. The Punnett square predicts a 9:3:3:1 ratio for phenotypes. Explain what that ratio means.

_____

_____

_____

_____

_____

_____

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Summary of Mendel's Principles

For Questions 16–20, complete each statement by writing the correct word or words

16. The units that determine the inheritance of biological characteristics are _____.

17. A form of a gene is a(n)_____.

18. If two or more forms of a gene exist, some may be dominant and others may be_____.

19. The offspring of most sexually reproducing organisms have two copies of each gene. One came from each_____.

20. Alleles from different genes usually_____independently from each other when gametes form.

For Questions 21–25, match the term with its description.

_____ **21.** Determine traits

_____ **22.** Can be two of these in one gene

_____ **23.** Allele that is expressed

_____ **24.** Where genes come from

_____ **25.** What genes do during gamete formation

A. parents

B. alleles

C. dominant

D. segregate

E. genes

26. Explain the importance of Thomas Hunt Morgan's experiments with fruit flies. Why was his work an important addition to Mendel's research?

_____

_____

Apply the Big idea

27. Four sisters begin attending your school. One has brown hair and brown eyes. Another has brown hair and blue eyes. The third also has blue eyes, but blond hair. The fourth has blond hair, too, but she has brown eyes. Explain how the principle of independent segregation accounts for these sisters having four different phenotypes for two traits.

_____

_____

_____

_____

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11.3 Other Patterns of Inheritance

Lesson Objectives

- Describe the other patterns of inheritance.
- Explain the relationship between genes and the environment.

Lesson Summary

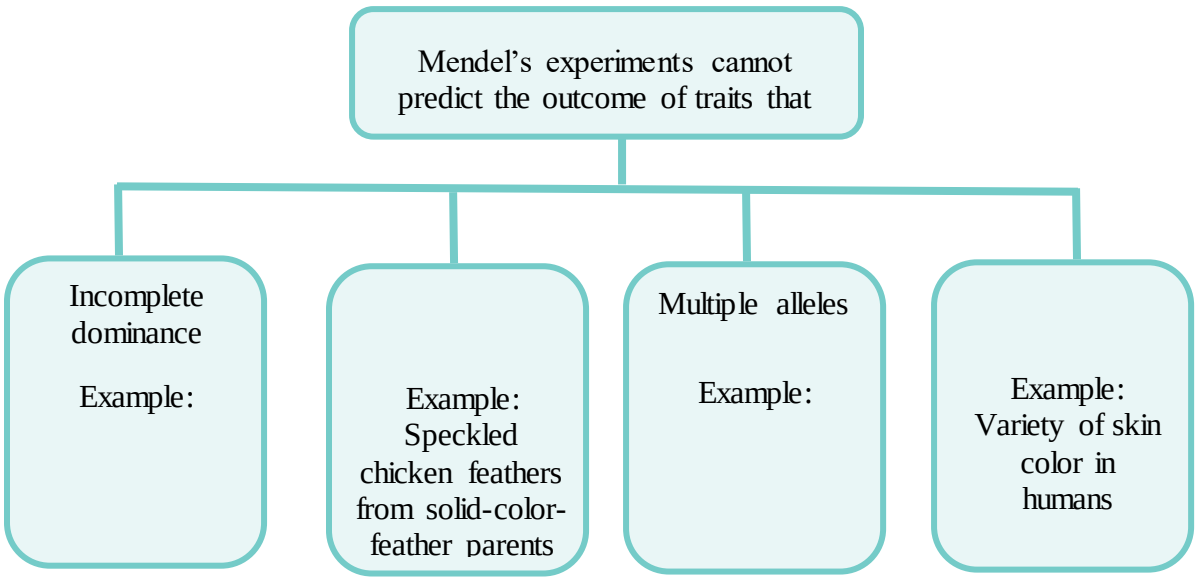
Beyond Dominant and Recessive Alleles Some alleles are neither dominant nor recessive:

- In cases of **incomplete dominance**, neither allele is completely dominant over the other. The phenotype is a blend of the two homozygous phenotypes.
- In cases of **codominance**, both alleles in the heterozygous genotype are expressed in the phenotypes.
- Genes with **multiple alleles** have more than two forms of the same gene. There may be more than one dominant form and several different phenotypes.
- **Polygenic traits** are controlled by the interaction of two or more genes and exhibit a wide range of phenotypes.

Genes and the Environment The phenotype of an organism results only partly from its genotype. Environmental conditions can affect how genes are expressed.

Beyond Dominant and Recessive Alleles

1. Complete the graphic organizer to summarize exceptions to Mendel's principle.



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For Questions 2–8, write True if the statement is true. If the statement is false, change the underlined word to make the statement true.

_____ **2.** When offspring show a blend of the parents' traits, <u>one</u> allele is dominant over the other.

_____ **3.** In <u>complete</u> dominance, the heterozygous phenotype lies somewhere between the two homozygous phenotypes.

_____ **4.** A heterozygous individual that exhibits the traits of both parents is an example of <u>codominance</u>.

_____ **5.** Many genes exist in several forms and are said to have <u>codominant</u> alleles.

_____ **6.** While multiple alleles may exist in a population, an individual usually carries only two alleles for each <u>gene</u>.

_____ **7.** Traits produced by two or more genes are <u>codominant</u>.

_____ **8.** Polygenic traits often show a wide range of <u>phenotypes</u>.

9. A plant breeder produced a purple flower by crossing a red parent with a blue parent. Use *RR* as the genotype for the red parent and *BB* for the blue parent. Complete the Punnett square to show the resulting genotypes and phenotypes of the offspring.

	Gamete allele: _____	**Gamete allele:** _____
Gamete allele: _____	Genotype:_____ Phenotype:_____	Genotype:_____ Phenotype:_____
Gamete allele: _____	Genotype:_____ Phenotype:_____	Genotype:_____ Phenotype:_____

For Questions 10–11, refer to the Punnett square above.

10. What type of inheritance is the example in Question 9?

_____

11. If the offspring had been red and blue spotted flowers, what kind of inheritance would be most likely?

_____

12. Explain the difference between multiple alleles and polygenic traits.

_____

_____

_____

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Genes and the Environment

For Questions 13–16, complete each statement by writing in the correct word or words.

13. An organism's _____ results from its genotype and its environment.

14. Some _____ produce variable traits depending on environmental conditions.

15. Western white butterflies vary in their wing color because their _____ varies depending on when they hatch.

16. _____ is an environmental variable that affects wing color in western white butterflies.

For each of the following examples, write G if the trait is determined by genotype, and E if it is determined by environment.

17. _____ Turtles whose eggs hatch at higher temperatures tend to be female.

18. _____ A blue-eyed girl is born to two blue-eyed parents.

19. _____ Bees in a colony are assigned different jobs. As they develop, workers begin to look dramatically different.

20. _____ A pair of twins is separated at birth. They grow up in different countries and speak different languages.

21. _____ A litter of puppies is born. They are all gray except one, which is brown.

22. _____ Tall pea plant seeds are planted in different locations around a yard. They produce plants of different heights.

23. _____ A kitten is born with six toes.

24. _____ A rabbit is born weak with hunger.

Apply the Big idea

25. A dog gave birth to four puppies. The father has brown eyes, and the mother has green eyes. Two puppies have brown eyes. One has green eyes. One puppy has blue eyes. What does this tell you about how the cellular information for eye color is passed on? Explain.

_____

_____

_____

_____

_____

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11.4 Meiosis

Lesson Objectives

- Contrast the number of chromosomes in body cells and in gametes.
- Summarize the events of meiosis.
- Contrast meiosis and mitosis.
- Describe how alleles from different genes can be inherited together.

Lesson Summary

Chromosome Number

Homologous chromosomes are pairs of chromosomes that correspond in body cells. One chromosome from each pair comes from each parent.

- A cell that contains both sets of homologous chromosomes has a **diploid** number of chromosomes (meaning "two sets").
- **Haploid** cells contain only one set of chromosomes. Gametes are haploid.

Phases of Meiosis

Meiosis is the process that separates homologous pairs of chromosomes in a diploid cell, forming a haploid gamete. The phases are as follows:

- Meiosis I, which is preceded by a replication of chromosomes. Its stages are

- Prophase I: Each replicated chromosome pairs with its corresponding homologous chromosome forming a **tetrad.** During tetrad formation, alleles can be exchanged between chromatids, a process called **crossing-over.**
- Metaphase I: Paired homologous chromosomes line up across the center of the cell.
- Anaphase I: Spindle fibers pull each homologous pair toward opposite ends of the cell.
- Telophase I: A nuclear membrane forms around each cluster of chromosomes. Cytokinesis then occurs, resulting in two new cells. The resulting daughter cells contain chromosome sets that are different from each other and the parent cell.

- Meiosis II: Chromosomes do not replicate.

- Prophase II: Chromosomes, each consisting of two chromatids, become visible.
- Metaphase II, Anaphase II, Telophase II, and Cytokinesis: These phases are similar to meiosis I. Four haploid cells form. They are the gametes. During fertilization, two gametes unite forming a **zygote.**

Comparing Meiosis and Mitosis

- Mitosis is one cell division that results in two genetically identical diploid cells.
- Meiosis is two cell divisions that result in four genetically different haploid cells.

Gene Linkage and Gene Maps

- Alleles tend to be inherited together if they are located on the same chromosome.
- Chromosomes, not genes, segregate independently.
- The farther apart genes are on a chromosome, the more likely is cross over.
- Information on linkage and the frequency of crossing-over lets geneticists construct maps of the locations of genes on chromosomes.

Name _____ Class _____ Date _____

Chromosome Number

For Questions 1–8, write True if the statement is true. If the statement is false, change the underlined word to make the statement true.

_____ **1.** The offspring of two parents obtains a single copy of every gene from each parent.

_____ **2.** A gamete must contain one complete set of genes.

_____ **3.** Genes are located at specific positions on spindles.

_____ **4.** A pair of corresponding chromosomes is homozygous.

_____ **5.** One member of each homologous chromosome pair comes from each gene.

_____ **6.** A cell that contains both sets of homologous chromosomes is haploid.

_____ **7.** The gametes of sexually reproducing organisms are haploid.

_____ **8.** If an organism's haploid number is 6, its diploid number is 3.

Phases of Meiosis

On the lines provided, identify the stage of meiosis I or meiosis II in which the event described occurs.

_____ **9.** Each replicated chromosome pairs with its corresponding homologous chromosome.

_____ **10.** Crossing-over occurs between tetrads.

_____ **11.** Paired homologous chromosomes line up across the center of the cell.

_____ **12.** Spindle fibers pull each homologous chromosome pair toward an opposite end of the cell.

_____ **13.** A nuclear membrane forms around each cluster of chromosomes and cytokinesis follows, forming two new cells.

_____ **14.** Chromosomes consist of two chromatids, but they do not pair to form tetrads.

_____ **15.** A nuclear membrane forms around each cluster of chromosomes and cytokinesis follows, forming four new cells.

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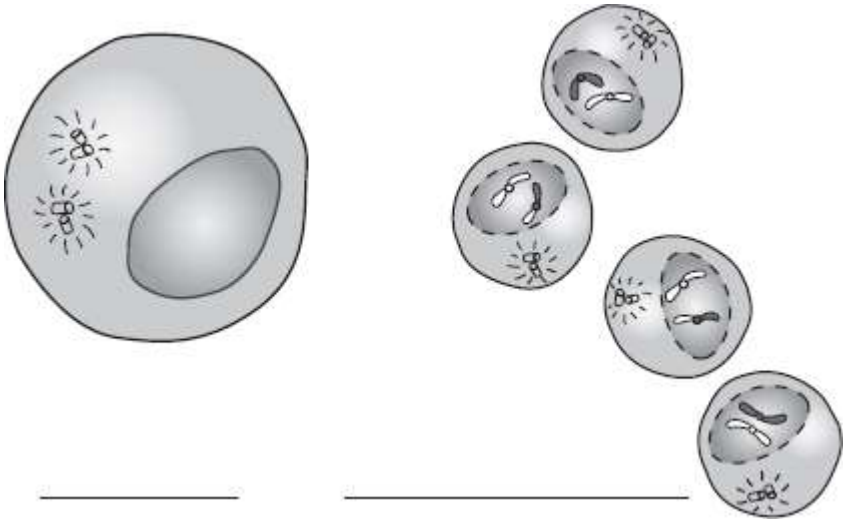
16. **THINK VISUALLY** Draw two homologous pairs of chromosomes (in different colors if you have them) in these diagrams to illustrate what happens during these three phases of meiosis.

Prophase I Metaphase I Anaphase II

17. Identify which phase of meiosis is shown in the diagrams below.



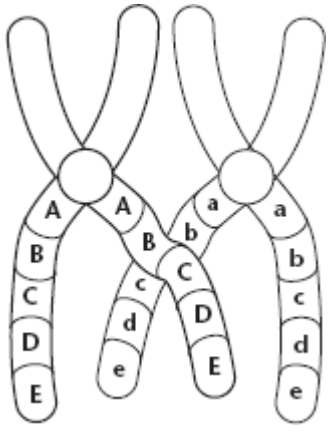
_____ _____

Use this diagram to answer Questions 18–20.

18. What does the diagram show?

_____

_____



19. During what phase of meiosis does this process occur?

_____

_____

20. What is the result of this process?

_____

_____

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Comparing Meiosis and Mitosis

21. Complete the table to compare meiosis and mitosis.

	Mitosis	Meiosis
Form of reproduction		
Number of daughter cells		
Change in chromosome number		
Number of cell divisions		
Difference in alleles between parent cell and daughter cells		

For Questions 22–27, complete each statement by writing the correct word or words.

22. A diploid cell that enters mitosis with 16 chromosomes will divide to produce _____ daughter cells. Each of these daughter cells will have _____ chromosomes.

23. If the diploid number of chromosomes for an organism is 16, each daughter cell after mitosis will contain _____ chromosomes.

24. A diploid cell that enters meiosis with 16 chromosomes will pass through _____ cell divisions, producing _____ daughter cells, each with _____ chromosomes.

25. Gametes have a _____ number of chromosomes.

26. If an organism's haploid number is 5, its diploid number is _____.

27. While a haploid number of chromosomes may be even or odd, a diploid number is always _____.

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Gene Linkage and Gene Maps

28. What did Thomas Hunt Morgan discover that seemed to violate Mendel's principles?

_____

_____

29. How did Morgan explain his finding?

_____

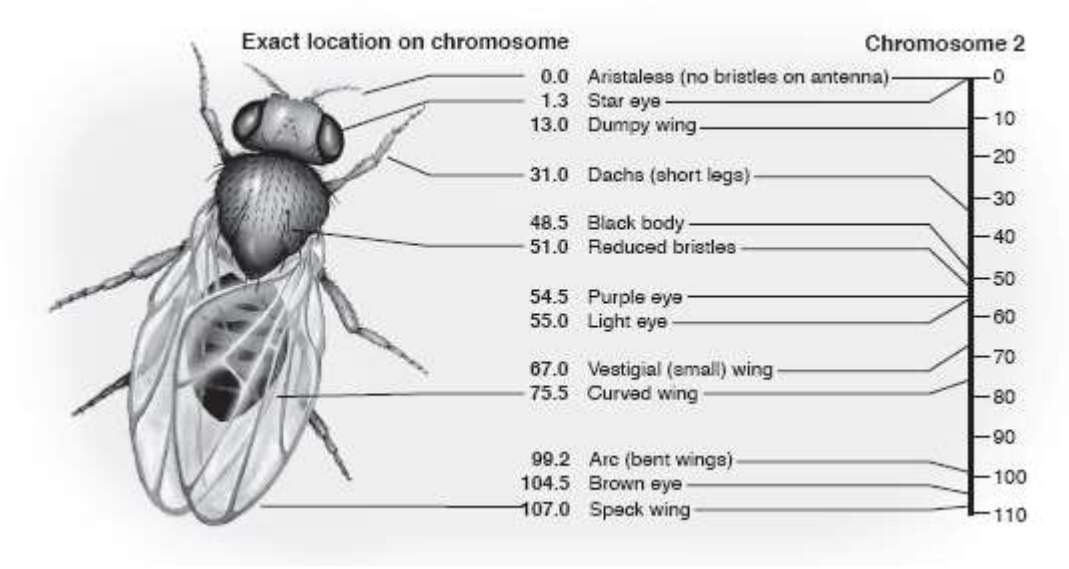
_____

30. How did Alfred Sturtevant use gene linkage to create gene maps?

_____

_____

Use this diagram to answer Questions 31–34.



31. What does the diagram show?

_____

32. How was the information in this diagram gathered?

_____

33. Which pairs of characteristics are more likely to cross over: curved wing and dumpy wing; or curved wing and vestigial (small) wing? Why?

_____

_____

34. Which pair of genes shown is least likely to cross over? How do you know?

_____

_____

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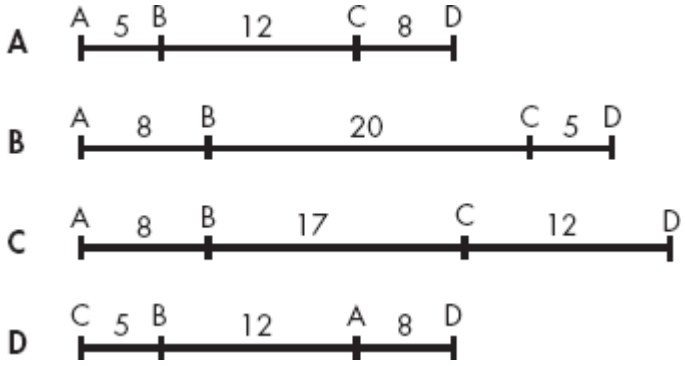
Use this diagram to answer Questions 35–38.



35. In which gene map is the probability of crossing-over between A and D greatest? _____

36. In which gene map is the probability of crossing-over between A and D the least? _____

37. In which map are genes C and D most closely linked? _____

38. In map D, which genes are least likely to cross over? _____

Apply the Big idea

39. Some housecats have orange fur with darker orange stripes. The traits of these *tabby* cats are usually seen in male cats. *Tortoiseshell* cats have patches of many different colors. "Torties," as they are called, are almost always female. What does this tell you about the way cellular information about color and sex are passed on in cats?

_____

_____

_____

_____