FOCUS ON SCIENCE

# Genetics and Heredity

Advanced Level



Life Science
Reproduction, Heredity, and Evolution

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## Scientific Inquiry

**The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.**

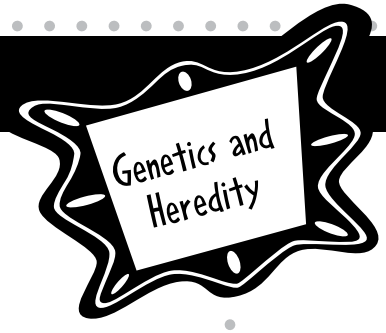
## Life Science

**Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.**

In all organisms, genetic traits are passed on from generation to generation.

Some genes are dominant and some are recessive. Some traits are inherited by mechanisms other than dominance and recessiveness.

The probability of traits being expressed can be determined using models of genetic inheritance. Some models of prediction are pedigree charts and Punnett squares.




# English Language Arts

The following is a selective listing of the competencies and indicators addressed in this book.

Word Recognition

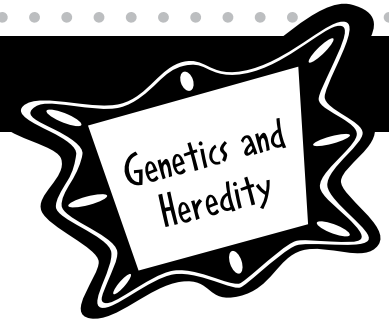
- Use word recognition skills and strategies quickly,accurately, and automatically when decoding unfamiliar words

Background Knowledge and Vocabulary Development

- Use self-monitoring strategies to identify specific vocabulary difficulties that disrupt comprehension,and employ an efficient course of action, such asusing a known word base or a resource such as aglossary to resolve the difficulty

Comprehension Strategies

- Use a variety of strategies (e.g., summarizing,forming questions, visualizing, and making connections) to support understanding of texts read

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## How to Help Your Students Make the Best Use of This Book

Encourage students to develop nonfiction literacy skills by completing the Active Reader activities. Also encourage them to . . .

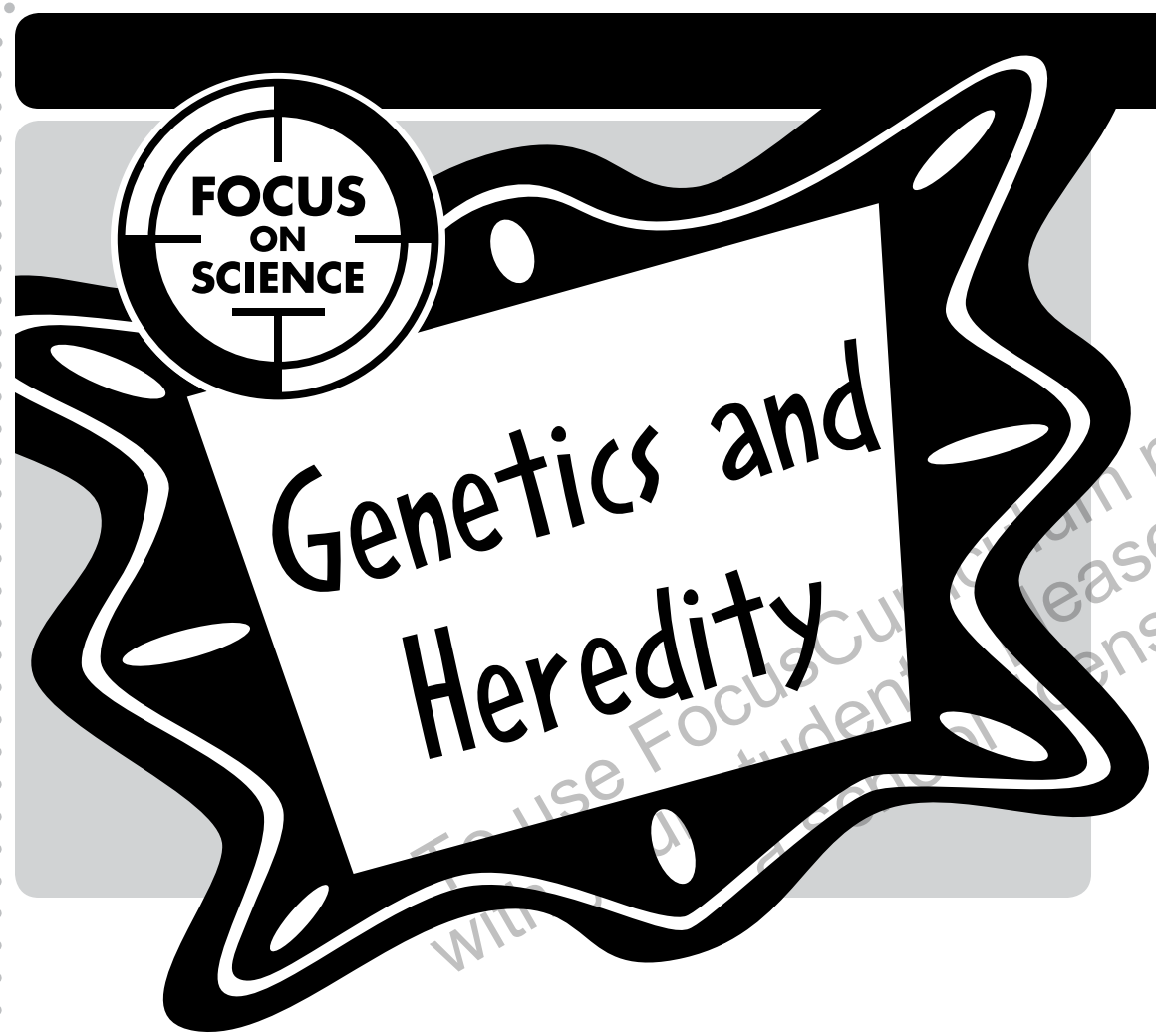
- Underline main ideas in paragraphs.
- Circle details that support the main ideas.
- Write down questions as they read.
- Circle key words as well as unfamiliar words.

## Printing Instructions

Student Book: print pages 5–22

Assessments: print pages 23–26

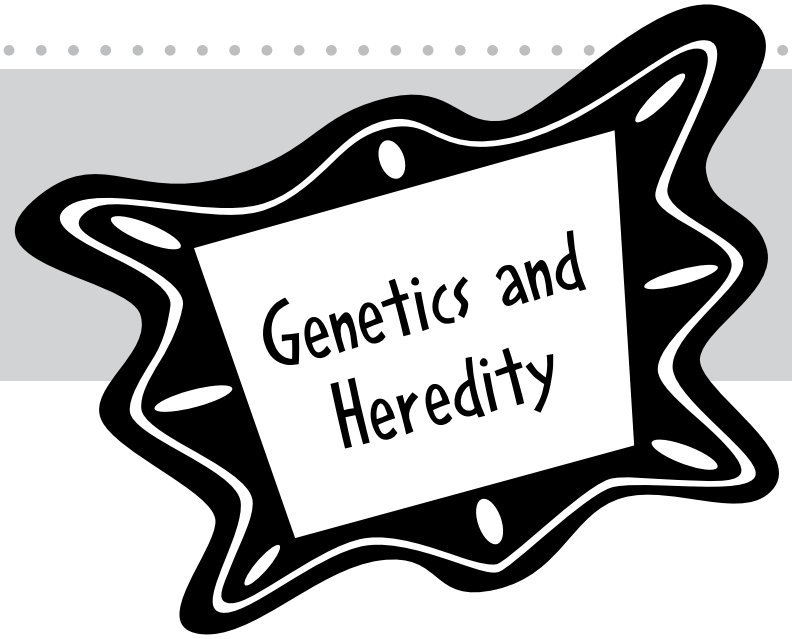
Answer Key: print pages 27–28




**How does life on Earth continue to adapt to environmental change?**

What traits have you inhertited from your ancestors? When you look in the mirror, can you see a resemblance to those who came before you? What other factors have influenced your traits and characteristics? For example, people born today tend to be bigger and taller than people born a hundred years ago because of such factors as nutrition, a cleaner environment, and better medicine.

How parents pass on traits to their offspring is a complicated process that scientists are still learning about. Genetics and heredity play a role in how organisms adapt to thrive in a changing environment.




# Table of Contents

Starting Points

# Build Background

## Compare and Contrast

**Read the passage below and anwer the questions that follow.**

### Asexual and Sexual Reproduction

Asexual reproduction is a strategy used by many different types of living things. Bacteria, yeasts, some plants, such as African violets, and some other invertebrate animals employ this strategy for reproduction.

In sexual reproduction, both the male and female of the species produce special cells that are responsible for reproduction. These cells are called gametes. A gamete is a cell that has the ability to fuse with another cell during fertilization. The female gamete is the egg. The female's eggs are fertilized by the male gamete, or sperm. Egg and sperm fuse to create a zygote, a cell that has a complete set of genetic information. Half comes from the male and half from the female. Now the cell can start to divide. It divides over and over until it develops, eventually, into a new individual capable of creating its own gametes.

### Genetic Information

Cells contain genetic information. Every cell in the body contains all the information the individual needs to grow and mature into a complete member of its species. This information is encoded in a molecule called DNA (deoxyribonucleic acid). A DNA molecule is long and twisty. A gene is a distinct portion of the DNA molecule, one that contains the instructions for a specific trait. Genes are packed in bundles called chromosomes. Humans have 23 pairs of chromosomes, for a total of 46.

Of all the cells in an individual's body, gametes are unusual. Instead of containing all of the chromosomes found in other cells, gametes contain only half the chromosomes.



**1. Asexual and sexual reproduction are both strategies organisms use to accomplish what purpose?**

_____

**2. What is the difference between a gamete and a zygote?**

_____

**3. How are genes and chromosomes alike and different?**

_____

Starting Points

# Key Vocabulary

## Rate Your Knowledge

**Each word in the list below is important, but some may be new to you. Rate your knowledge of each by putting a check or a few words in the appropriate column. After completing this book, come back to this page and write the definitions of words you did not know.**

| | I don't know it. | I've seen it, and I think it means . . . | I know it well. It means . . . |
|---|---|---|---|
| allele | | | |
| dominant gene | | | |
| recessive gene | | | |
| inherited trait | | | |
| genotype | | | |
| phenotype | | | |
| pedigree | | | |



## Word Relationships

**Think about the words in the list above as you answer these questions.**

1. **Which three words in the list are adjecctives?** _____
2. **Which six words in the list are nouns?** _____

   _____
3. **Which two words are synonyms?** _____
4. **Which two words are antonyms?** _____

Starting Points

# Key Concepts

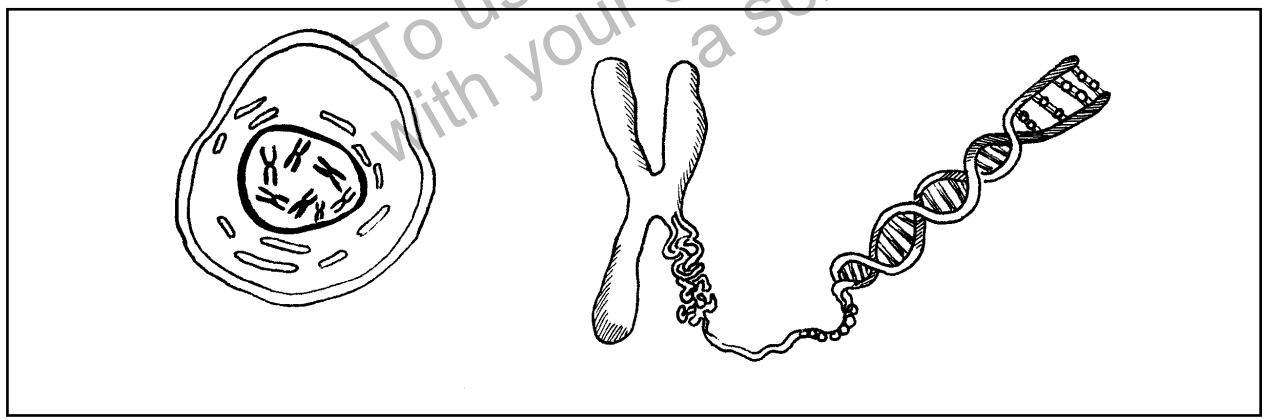
## How Parents Pass on Traits

Reproduction is the process by which living things give rise to the same type of living things. There are basically two reproductive strategies: asexual reproduction and sexual reproduction. All living things employ at least one of these strategies; some species employ both.

During reproduction, organisms pass on certain characteristics to their offspring. Another word for the characteristics of an organism is trait. These traits are encoded in genetic material within each cell. This material is a long molecule called deoxyribonucleic acid, or DNA. The DNA molecule is long and twisty. It is built from short segments, called genes, each of which contains a chemical code that governs a specific trait or characteristic. Genes are packed in bundles called chromosomes.

In asexual reproduction, offspring receive a duplicate set of genes from a single parent. In sexual reporduction, offspring recieve a combination of genes from two parents. In this case, the offspring may share some traits with one parent and some with another.





*Chromosomes contain the long, twisty DNA molecule that consists of genes linked together.*

### ACTIVE READER

***1 Differentiate*** *Some traits a person has are inherited. Some are learned. For the traits listed below, indicate I for inherited traits and L for learned traits.*

____ *hair color*

____ *good manners*

____ *ability to speak French*

____ *baldness*

____ *friendliness*

# Chapter 1 Genetic Traits and Inheritance

FOCUS

This section discusses traits and how they are passed on by parents to their offspring. Read on to learn about the relationship between traits and genes.

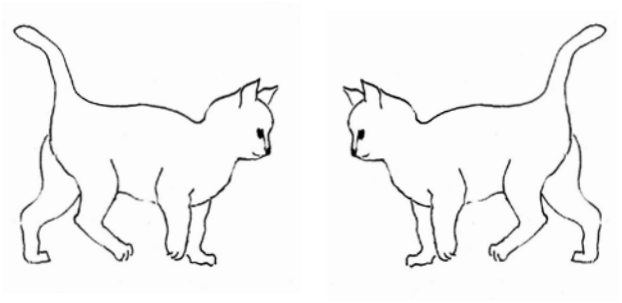
## Traits

Imagine a litter of kittens. Some of the kittens are completely black while others are covered in white fur. The mother of the kittens is completely covered in white fur. How could a mother cat with all white fur have a kitten with black fur? What process determines a kitten's fur color?

Since some of the kittens have white fur like their mother, a likely explanation is that the white-colored fur was somehow caused by a kitten's relationship to its mother. Perhaps the black fur coloring was caused by a similar relationship of a kitten to its father.

Human beings have been working to understand the processes that govern the transfer of traits from parents to offspring for thousands of years. In this case, when we use the word trait we mean a physical characteristic of an organism.

Traits can be things we can easily see in an organism, like the color of fur in the kittens. Sometimes traits are things we can't see in an organism's appearance, yet we know those traits are present. Let's return to this idea in a moment, but first let's talk about inheritance.



*Identical twins inherit an identical set of genes from their parents.*

### ACTIVE READER

***1 Define*** *What words or phrases mean the same, or almost the same, as the following words?*

*offspring* _____

*trait* _____

*govern* _____

*organism* _____

## Inherited Traits

**Inherited traits** are traits that are passed from parents to offspring genetically. The term genetic means that these traits are determined by genes. Genes are made of DNA, deoxyribonucleic acid, and are found inside the nucleus of each cell in a living thing. Every cell contains a duplicate set of genes. Genes work as instructions that tell an organism how to grow and develop. Genes also control the workings of all cells; they are part of every life process in a living thing. When organisms reproduce they pass copies of their genes to their offspring.

Some living things have only one parent. In this case the offspring receive a set of inherited traits that are identical to the parent's traits. In other cases, living things have two parents. Offspring with two parents receive genes from each parent. Sometimes a parent's traits are passed on but are not visible in the offspring. In the case of the black and white kittens, some have inherited their mother's fur coloring; their fur is white. However, some of the kittens have inherited black fur. These kittens received a black-fur gene from both their female and male parent.



*These kittens inherited a different set of genes from the same two parents. That is why they have different traits.*

### ACTIVE READER

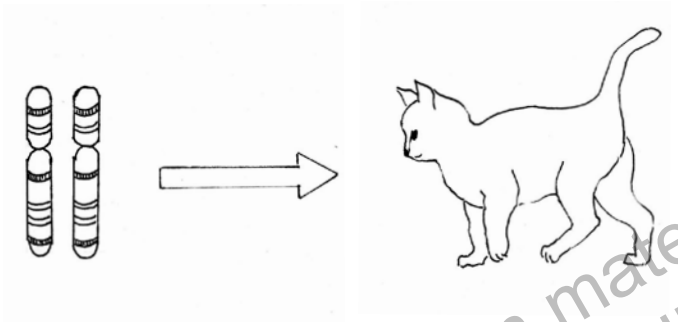
***1 Explain*** *In your own words, explain what is compared in the second paragraph on this page.*

## Genotype and Phenotype

In fact, a kitten with white fur may have inherited genes for both black and white fur. But, if so, the white-fur gene masks the black-fur gene, so the kitten has white fur instead of black.

An organism's **genotype** includes the full set of genes, all the instructions carried within each cell, whether or not they are visible in the organism. An organism's **phenotype** is that living thing's physical appearance as determined by genes which are expressed.

**Genotype Codes For Phenotype**



How do these two ideas work in the litter of kittens? The white-furred kitten's phenotype is white fur. However, a white kitten may also carry the trait for black fur, but this trait is not visible. Genes responsible for visible traits are *expressed*. Genes which don't result in visible traits are *not expressed*. We would say that a kitten in this case has black and white fur within its genotype and white fur as its phenotype.

### ACTIVE READER

***1 Extend*** *What is a good way for you to remember the difference between genotype and phenotype? Develop your own mnemonic device and describe it in the space below.*



## FOCUS QUESTIONS

**1. If a kitten is born with both a white-fur gene and a black-fur gene, what color fur will the kitten have? Why?**


**Probability** When two parents have different traits, what determines which traits will be passed on to their children? Chance determines much of this process. Scientists call the study of chance probability.

**To get a better idea of how probability works try this exercise:**

1. **Start by gathering data. Find two coins of the same type.**
2. **Flip one coin in the air and record which side lands facing up. Record this on the chart below. Then flip the other coin. Record which side lands face-up on the chart below as well. You have completed one trail.**
3. **Repeat this process 31 more times, for a total of 32 trials.**
4. **Analyze your results on the next page.**



## Data Gathering

| Trial | Results | Trial | Results | Trial | Results |
|---|---|---|---|---|---|
| Example | H, T | 11 | | 22 | |
| 1 | | 12 | | 23 | |
| 2 | | 13 | | 24 | |
| 3 | | 14 | | 25 | |
| 4 | | 15 | | 26 | |
| 5 | | 16 | | 27 | |
| 6 | | 17 | | 28 | |
| 7 | | 18 | | 29 | |
| 8 | | 19 | | 30 | |
| 9 | | 20 | | 31 | |
| 10 | | 21 | | 32 | |


# Probability *continued*

## Analysis

**How many trials showed the following combinations?**

| | |
|---|---|
| **H, T** | |
| **T, H** | |
| **H, H** | |
| **T, T** | |

**You may start to notice a pattern similar to this:**

| | |
|---|---|
| **H, T** | **11** |
| **T, H** | **7** |
| **H, H** | **10** |
| **T, T** | **4** |



## Conclusion

In the example above the combinations HT, TH, and HH are all found more often than the pattern TT. This doesn't mean that the combination TT isn't possible, only that it is less likely to occur than the other combinations. Probability allows us to examine the likelihood of events repeating over time.

When organisms inherit traits some elements of chance can affect what traits offspring will receive from their parents. Some events may be impossible in certain situations: we could never get a result of TTT because we didn't use a third coin. However, depending on what type of coin you use and how carefully you flip and catch the coins, you may find some patterns that will repeat over time. Using these patterns you can predict that you will see similar outcomes in the future.

Keep the effects of probability in mind as you learn about heredity. Often, you may see some offspring that receive only combination of traits from their parents, even though other combinations of traits are possible. Probability influences which traits each offspring will receive.

# Chapter 2 Mendelian Genetics

FOCUS

The first paragraph an important event in the history of science and in the study of traits. Read to find out about Gregor Mendel, a monk who lived more than one hundred years ago.

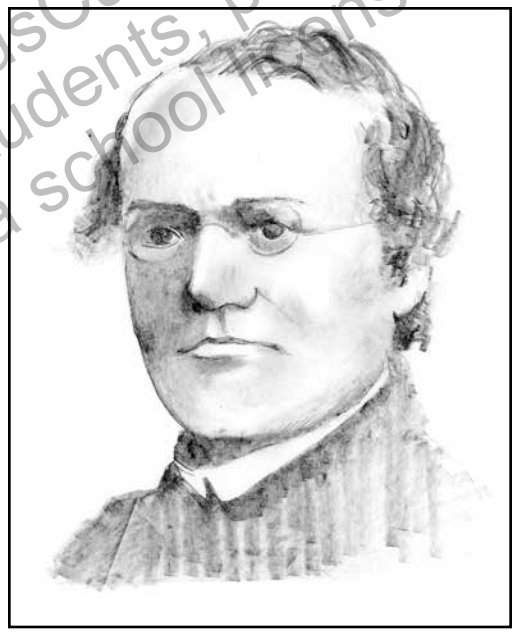
## Gregor Mendel

Gregor Mendel lived in the 19th century in the European country of Austria. Mendel was a Christian monk, who lived in a religious community called an abbey. Mendel was also a scientist and he became interested in the way that plants in the abbey garden passed traits from parents to their offspring. In Mendel's time very little was known about the way that cells work, so Mendel didn't know about structures like genes, or terms like phenotype and genotype. Mendel could observe that when two parent plants with different colored flowers (purple and white) were bred, their offspring had just one of the two colors (white). Later, if the offspring were allowed to self-pollinate, or to breed with themselves, they would produce offspring with the purple flowers. However, sometimes the offspring in that next, self-pollinating generation would have white flowers like the original parents.



### Hidden Traits

Mendel observed these processes thousands of time. Eventually he noticed a pattern where one trait could hide or mask another. This is what happened in the first generation when the purple flowers appeared in all the offspring of the white and purple flowered plants. Mendel called a trait that could hide, or mask another trait a **dominant** trait. Mendel called a trait that could be hidden, and then reappear in later generations, a **recessive** trait.



*Gregor Mendel, Father of Genetics*

### ACTIVE READER

***1 Describe*** *What is the difference between a dominant and a recessive trait?*

### Good to Know

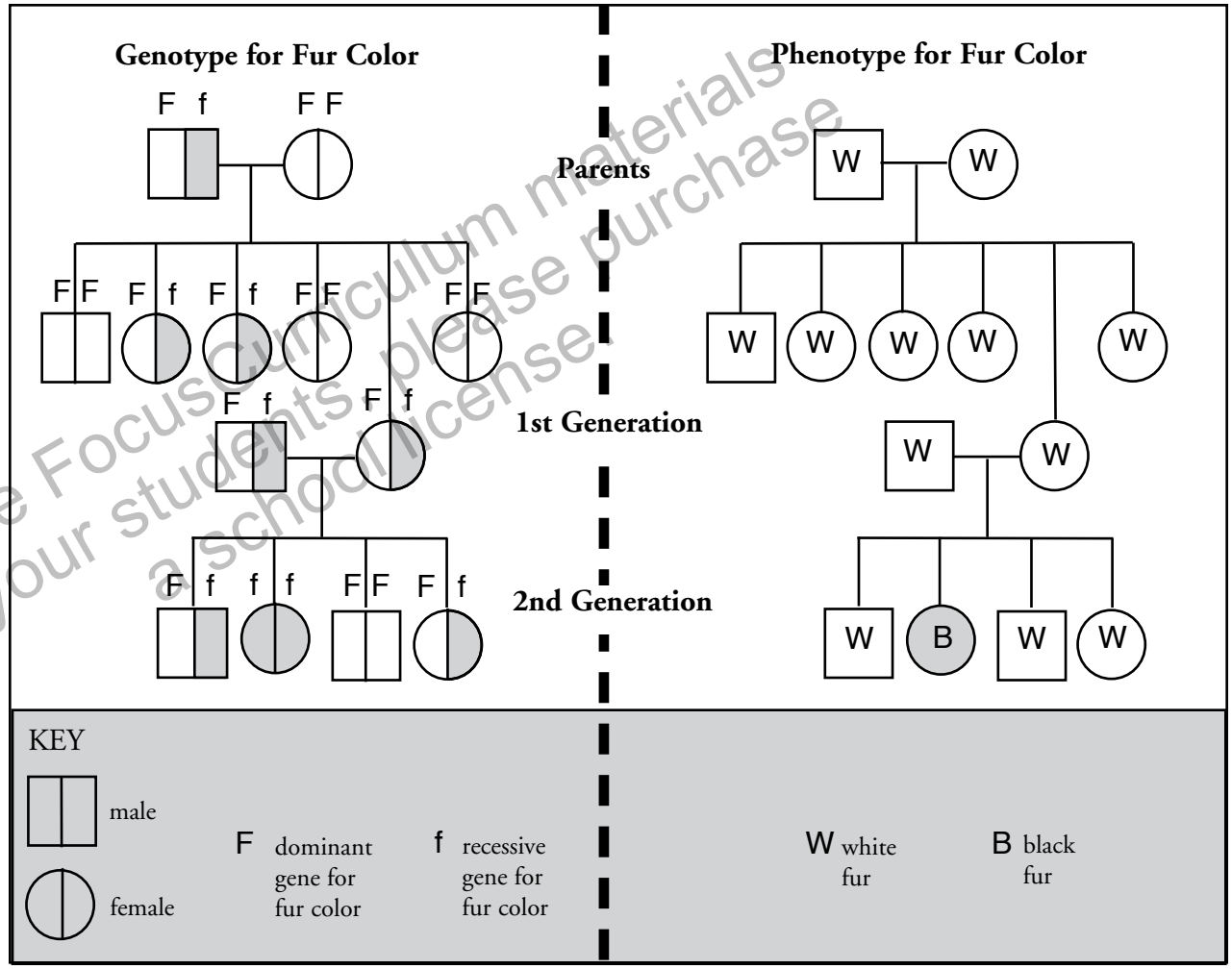
Mendel showed that offspring receive half of their genetic make-up from each parent. Different offspring receive a different set of hereditary factors. Traits are passed on intact; they are not combined. In other words, a white-flowered plant and a purple-flowered plant will not have a light purple-flowered offspring.

## Predicting Genetic Inheritance

A chart that shows how organisms are related through their genes is called a **Pedigree** Chart. These charts look a lot like a family tree. Pedigree Charts can be used to show genotype for a specific trait or the related phenotype that results from the genotype.

### Pedigree Charts

Comparing the charts for genotype and phenotype for fur color in cats explains what Mendel discovered about dominant and recessive traits. In the chart, the female cat has two genes for white fur, and the male has one for white fur and one for black. Since the gene for white fur is dominant, both cats are white. The recessive gene for black fur is inherited by some of the offspring in the 1st generation. However, all inherit at least one gene for white fur, and so all are born with white fur. In the second generation, a white female cat with a recessive gene has mated with a white male cat with a recessive gene. Of the four kittens in their 2nd generation litter, one inherits both recessive genes and therefore is born with black fur.



## Punnett Squares

When scientists want to predict the possible traits the offspring of two parents might possess they use a Punnett square. A Punnett square is a chart that allows scientists to track possible combinations of traits.

For example, in the Punnett square at the right, each parent has two **alleles** for a given gene. Alleles are different types of a gene. In the example above, the alleles the female parent cat possesses are shown on the top row. The male parent cat's alleles are shown down the left side. A parent can carry two dominant alleles, two recessive alleles, or a combination of dominant and recessive alleles.

| | F | F |
|---|---|---|
| F | FF | FF |
| f | fF | FF |

Here, the female has two dominant alleles and the male has a dominant and a recessive allele. Organisms can carry recessive and dominant traits, but they will only express, or show, the dominant trait. In this case, we are examining the gene for fur color. The Punnett Square shows us that three out of four offspring of these two cats will probably inherit two dominant alleles. One in four will probably inherit one dominant and one recessive allele. However, all offspring of these two cats will be white because all will inherit at least one dominant allele.

## Another Example

Let's look at another example from the pedigree chart on page 17 and analyze it with a Punnett square. In the first generation, a female with alleles for both white fur (F) and black fur (f) mates with a male that possesses those same alleles. As you can see in the Punnet square, some of the offspring may have two dominant alleles (FF), some may have both dominant and recessive alleles (fF, Ff), and some may have only recessive alleles (ff).

| | F | f |
|---|---|---|
| F | FF | Ff |
| f | fF | ff |

### ACTIVE READER

***1 Analyze*** *In the example on this page, which combination of alleles will result in the expression of the recessive trait in an offspring?*

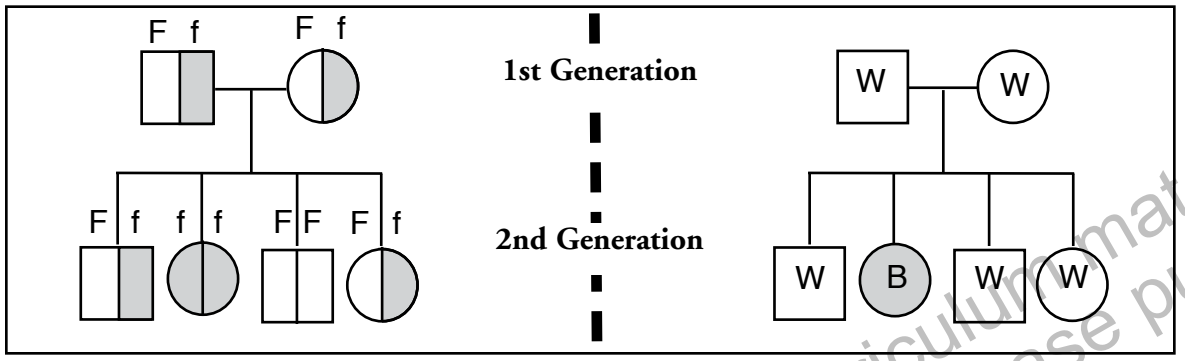
_____ FF

_____ Ff

_____ fF

_____ ff

So, according to the chart, the offspring of these two cats can possess dominant alleles, recessive alleles, or a mixture of the two. This is what we see reflected in the pedigree chart for the second generation:




## Good to Know

When a male and female both carry a dominant and a recessive allele for a trait, their offspring have a 25%, or 1 in 4, chance of receiving two recessive alleles. This does not mean that the recessive trait will always show up in 1 out of every 4 offspring. It just means that there's a 25% chance of it happening in any offspring.



## FOCUS QUESTIONS

**1. Complete the Punnett square for fur color in cats. If white fur is dominant (F) and black fur is recessive (f), explain the likelihood of an offspring being born with black fur.**

| | f | f |
|---|---|---|
| F | | |
| f | | |

## Stop and Think

This page will help summarize what you have read so far.

1. **A trait that can be carried by an organism, but is not always visible in the organism's phenotype is called**

   (1) dominant
   (2) expressed
   (3) recessive
   (4) allele

Base your answer to question 2 on the Punnet square below and your knowledge of science. The Punnett square shows possible genetic combinations of two parents who possess genes for a widow's peak. A widow's peak is a point of hair lower than the rest of the hairline on a person's forehead. Widow's peak is a dominant trait; straight hairline is reecessive.

| | W | w |
|---|---|---|
| W | WW | Ww |
| w | wW | ww |

2. **According to the Punnett square, which combinations of alleles will result in an individual who expresses, or shows, a widow's peak?**

_____

_____

**Dear Ms. Understanding,**

My cat has a father that is black and a mother that is white. But my cat has patches and stripes. What's going on here?

*Color Me Confused*

**Dear Confused,**

While many traits can follow the rules of dominant and recessive traits, scientists have found that this isn't always the case. The alleles of some genes may be expressed in a way that is linked to genes for a completely different trait. In some cases in cats, the gender of an offspring may affect the appearance of that offspring. Perhaps the gender of the kittens combined with the colors determined by their genes is affecting their coloring. Environmental factors like temperature or nutrition can also change the way genes are expressed. Understanding heredity is an adventure and we are only at the very first step in that adventure when we look at dominant and recessive alleles!

*Ms. Understanding*

# Glossary

**allele –** An allele is one of two or more versions of a gene. An individual inherits two alleles for each gene, one from each parent. If the two alleles are the same, the individual is homozygous for that gene. If the alleles are different, the individual is heterozygous. Though the term "allele" was originally used to describe variation among genes, it now also refers to variation among non-coding DNA sequences.

**DNA –** DNA is the chemical name for the molecule that carries genetic instructions in all living things. The DNA molecule consists of two strands that wind around one another to form a double helix. Each strand has a backbone made of alternating sugar (deoxyribose) and phosphate groups. Attached to each sugar is one of four bases--adenine (A), cytosine (C), guanine (G), and thymine (T). The two strands are held together by bonds between the bases; adenine bonds with thymine, and cytosine bonds with guanine. The sequence of the bases along the backbones serves as instructions for assembling protein and RNA molecules.

**dominant –** Dominant refers to the relationship between two versions of a gene. Individuals receive two versions of each gene, known as alleles, from each parent. If the alleles of a gene are different, one allele will be expressed; it is the dominant gene. The effect of the other allele, called recessive, is masked.

**gene –** The gene is the basic physical unit of inheritance. Genes are passed from parents to offspring and contain the information needed to specify traits. Genes are arranged, one after another, on structures called chromosomes. A chromosome contains a single, long DNA molecule, only a portion of which corresponds to a single gene. Humans have approximately 23,000 genes arranged on their chromosomes.

**inherited trait –** An inherited trait is one that is genetically determined. Inherited traits are passed from parent to offspring according to the rules of Mendelian genetics. Most traits are not strictly determined by genes, but rather are influenced by both genes and the environment.

**Mendelian inheritance –** Mendelian inheritance refers to patterns of inheritance that are characteristic of organisms that reproduce sexually. The Austrian monk Gregor Mendel performed thousands of crosses with garden peas at his monastery during the middle of the 19th century. Mendel explained his results by describing two laws of inheritance that introduced the idea of dominant and recessive genes.

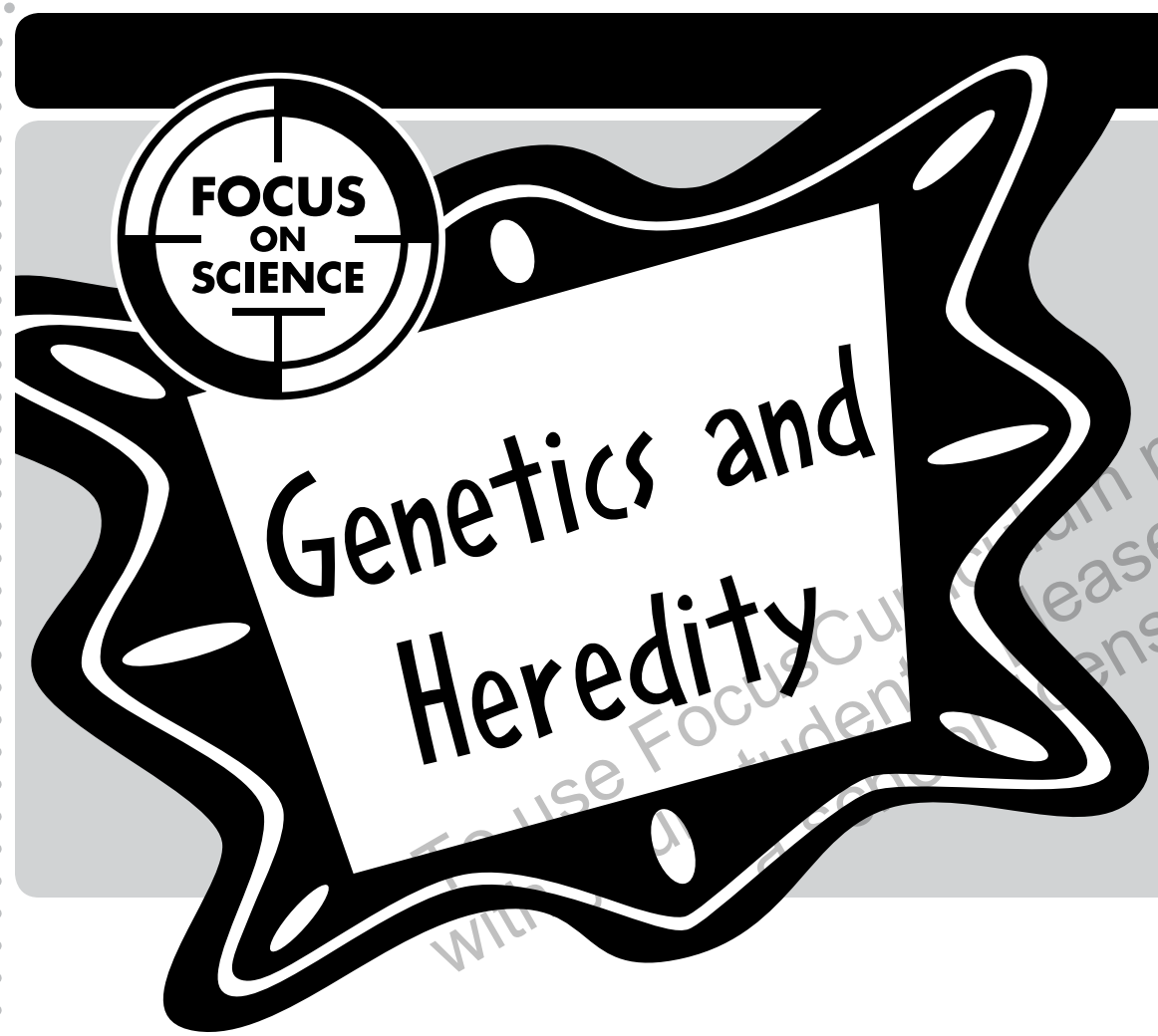
**Mendel, Johann (Gregor) –** Gregor Mendel was an Austrian monk who in the 19th century worked out the basic laws of inheritance, even before the term "gene" had been coined. In his monastery garden, Mendel performed thousands of crosses with garden peas. Mendel explained his results by describing two laws of inheritance that introduced the idea of dominant and recessive traits.

# Glossary

**pedigree –** A pedigree is a genetic representation of a family tree that diagrams the inheritance of a trait or disease though several generations. The pedigree shows the relationships between family members and indicates which individuals express or silently carry the trait in question.

**phenotype –** A phenotype is an individual's observable traits, such as height, eye color, and blood type. The genetic contribution to the phenotype is called the genotype. Some traits are largely determined by the genotype, while other traits are largely determined by environmental factors.

**recessive –** Recessive is a quality found in the relationship between two versions of a gene. Individuals receive one version of a gene, called an allele, from each parent. If the alleles are different, the dominant allele will be expressed, while the effect of the other allele, called recessive, is masked. In the case of a recessive genetic disorder, an individual must inherit two copies of the mutated allele in order for the disease to be present.






# Assessments

# Check Understanding



In the Answer Document on this page, mark your answer in the row of circles for each question by filling in the circle that has the same number as the answer you have chosen.

1. What is a phenotype?

   (1) a bundle of genetic material

   (2) a physical appearance

   (3) a zygote

   (4) an allele for a dominant trait

2. In organisms who inherit both a dominant and a recessive gene for a particular trait, how often will the recessive gene be expressed?

   (1) in every offspring

   (2) in about one-quarter of the offspring

   (3) in about one-half of the offspring

   (4) in none of the offspring



**Answer Document**

1. ① ② ③ ④ 2. ① ② ③ ④

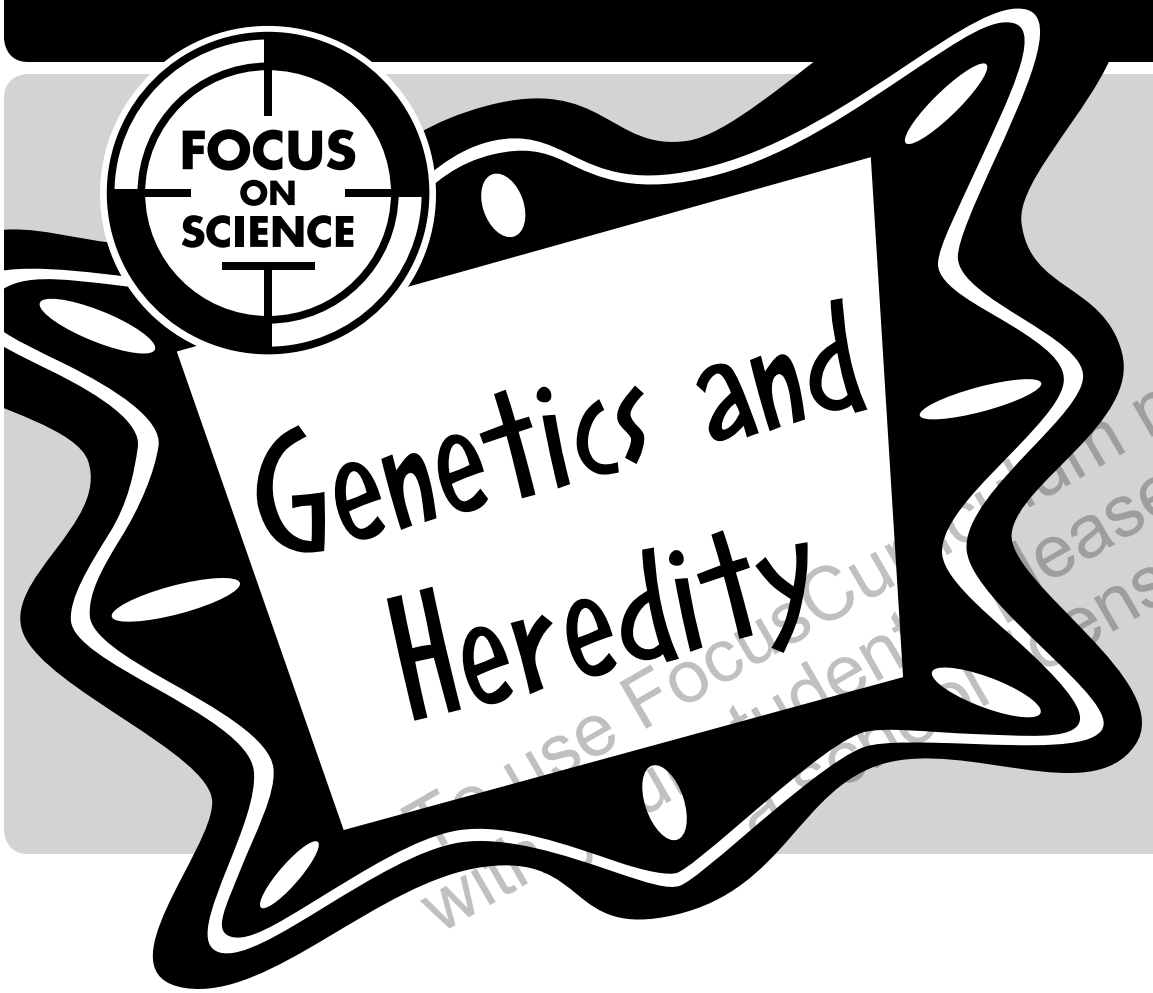
# Check Understanding



In pea plants, wrinkled seeds are dominant to smooth seeds. Base your answer to question 3 on the Punnet square below and on your knowledge of science.

| | S | S |
|---|---|---|
| s | | |
| s | | |

3. Complete the Punnet square above and explain whether the offspring of the two pea plants are likely to have wrinkled seeds, smooth seeds, or if both types of seeds are likely to show up in the offspring.






# Answer Key

# Answer Key

Page 8: Starting Points
Build Background
Compare and Contrast: 1. Reproduction strategies are employed by organisms to give rise to other organisms of the same kind.; 2. A gamete contains half the chromosomes needed to create a living organism. A zygote is a fertilized egg that has all the chromosomes needed to give rise to a living organism.; 3. Chromosomes are collections of genes.

Page 9: Starting Points
Key Vocabulary
Rate Your Knowledge: Answers will vary according to the student's prior knowledge.
Word Relatinships: 1. dominant, recessive, inherited; 2. allele, gene, trait, genotype, phenotype, pedigree; 3. allele, gene; 4. dominant, recessive

Page 10: Starting Points
Key Concepts
Active Reader: 1. I - hair color; L - good manners; L - ability to speak French; I - baldness; L - friendliness

Page 11: Chapter 1
Active Reader: 1. offspring - children; trait - characteristic; govern - control; organism - living thing

Page 12: Chapter 1
Active Reader: 1. Answers should explain that two strategies for reproduction, asexual and sexual, are compared.

Page 13: Chapter 1
Active Reader: Responses will vary.

Pages 14 and 15: Chapter 1
Think Like a Scientist: Probability: Student's answers will vary depending on the data they gather.

Page 16: Chapter 2
Active Reader: 1. A dominant trait is a trait that masks other possible variations of a gene, or alleles, that have been inherited.

Page 18: Chapter 2
Active Reader: 1. ff

Page 19: Chapter 2
Focus Questions: 1.

| | f | f |
|---|---|---|
| F | Ff | Ff |
| f | ff | ff |

Any offspring born to these parents has a 50% chance of having black fur.

Page 20: Chapter 2
Stop and Think: 1. (3); 2. WW, Ww, wW

Page 25: Chapter 2
Check Understanding: 1. (2); 2. (4)

Page 26: Chapter 2
Check Understanding: 3.

| | S | S |
|---|---|---|
| s | Ss | Ss |
| s | Ss | Ss |

All offspring of these parents have the dominant gene and will all have the dominant trait, wrinkled seeds.