Genetics and Reproduction

Reflect

Have you ever noticed how family members look alike? This is because certain characteristics are passed from the parents to their kids. These include physical **traits** such as eye color and body shape that are easy to observe.

What are some characteristics that parents can pass on to their kids?

Genes and Chromosomes

Inherited traits are determined by information stored in an organism's genes. **Genes** are sequences of **DNA** that are part of the structure of an organism's **chromosomes**. Chromosomes are located in the nucleus of every cell in that organism. An organism has two copies of each chromosome. During sexual reproduction, one copy comes from the organism's female parent. The other copy comes from the organism's male parent.

Do siblings inherit the exact characteristics of their parents?

Traits

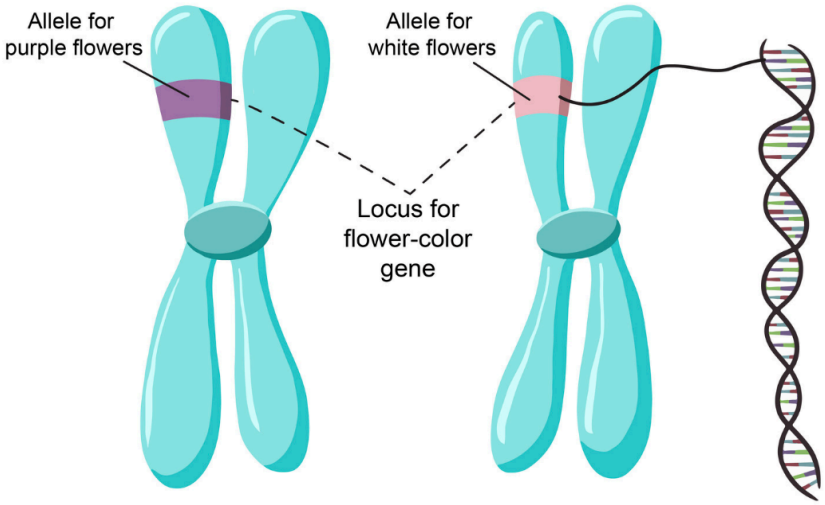
Heredity is the transmission of traits from one generation to the next. How are these traits passed on? Genetic instructions are a set of directions, and traits are like the results of following the directions. Cells follow genetic instructions provided by deoxyribonucleic acid (DNA) that determine their form and function. For example, one cell may be directed to be a red blood cell, another may be directed to be a brown eye pigment, and a third may be directed to form bone cells. DNA forms strands that are made up of smaller pieces, or segments, called genes. It is

these genes that govern the many traits of an organism. Traits are inherited qualities of an organism and can be divided into three types: physical traits such as height, eye color, or hair color; behavioral traits such as protective instincts; and predispositions to medical conditions such as cancer, heart disease, sickle cell anemia, and diabetes. The same trait can be shared by many organisms, yet it is the combination of traits that makes every individual unique.

When the process of heredity occurs asexually from a single parent, the offspring receives an exact duplicate of the parent's genetic material. When the process of heredity occurs from the sexual reproduction of two parents, the offspring receives half of the genetic material from the mother and half from the father.

Alleles

Because each chromosome is present in two copies, each gene is present in two copies. However, the DNA sequences of the two copies may not be the same. These variations of a gene are called **alleles**. As an example, suppose that a scientist inspected the chromosomes present in a flowering plant. The scientist might observe something similar to the situation diagrammed.



Homologous pair of chromosomes

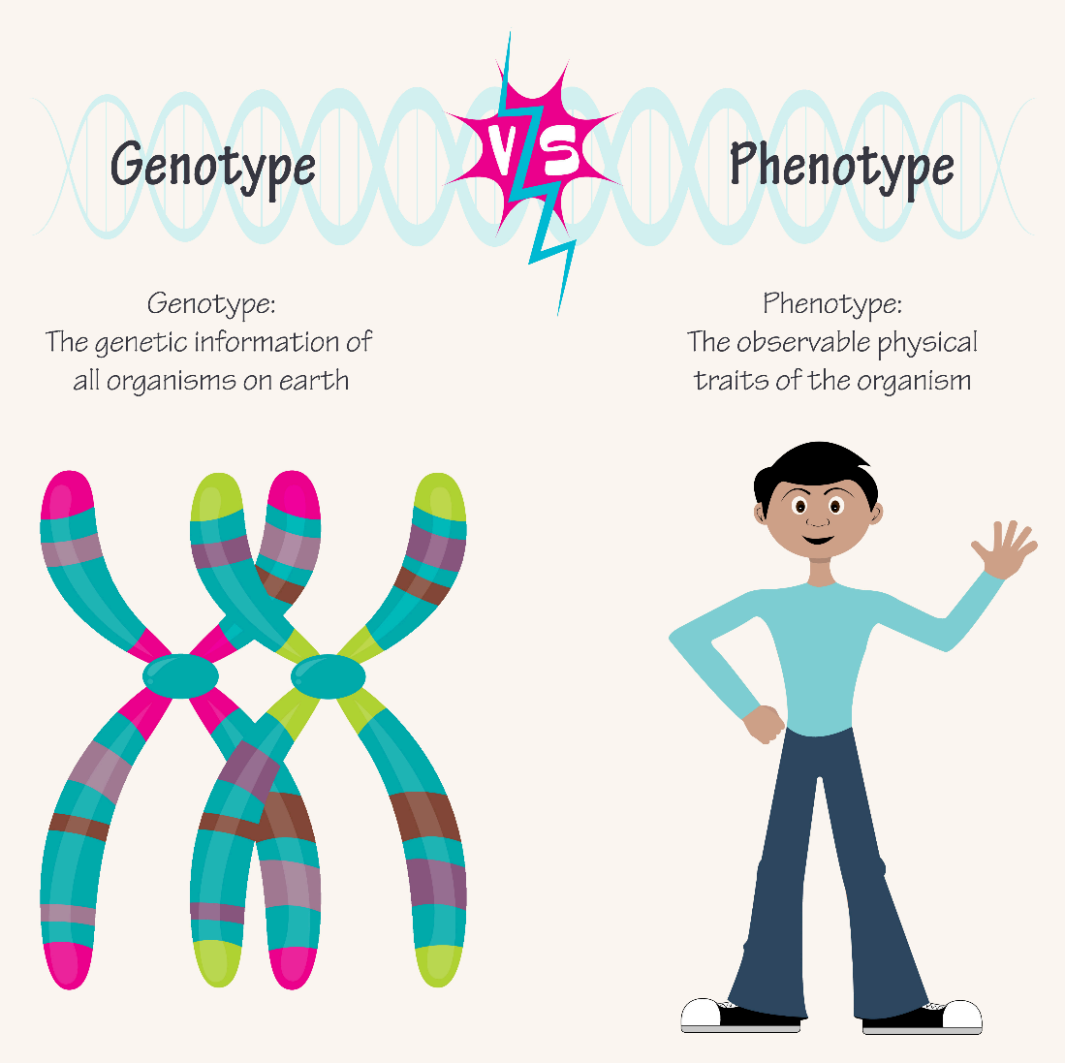
Alleles for the same gene have been identified on two chromosomes. One allele is coded for a purple flower color. The other allele is coded for a white flower color. One allele came from the plant's female parent. The other allele came from the plant's male parent.

The pair of alleles an organism inherits for each gene determines the **genotype** of that individual. Suppose the purple color allele is given the abbreviation P and the white color allele is given the abbreviation p. This plant's genotype for flower color is Pp.

An individual's **phenotype** refers to the traits that are expressed and observed. Suppose that the plant with a genotype of Pp has purple flowers. We say the plant's phenotype for flower color is purple. The table summarizes the possible genotypes and phenotypes resulting from the allele combinations for flower color (purple or white). Remember, in sexual reproduction, an offspring inherits one allele from each parent.

Allele Combinations for Purple and White Flowers

Genotype	Phenotype
PP	Purple
Pp	Purple
pp	White



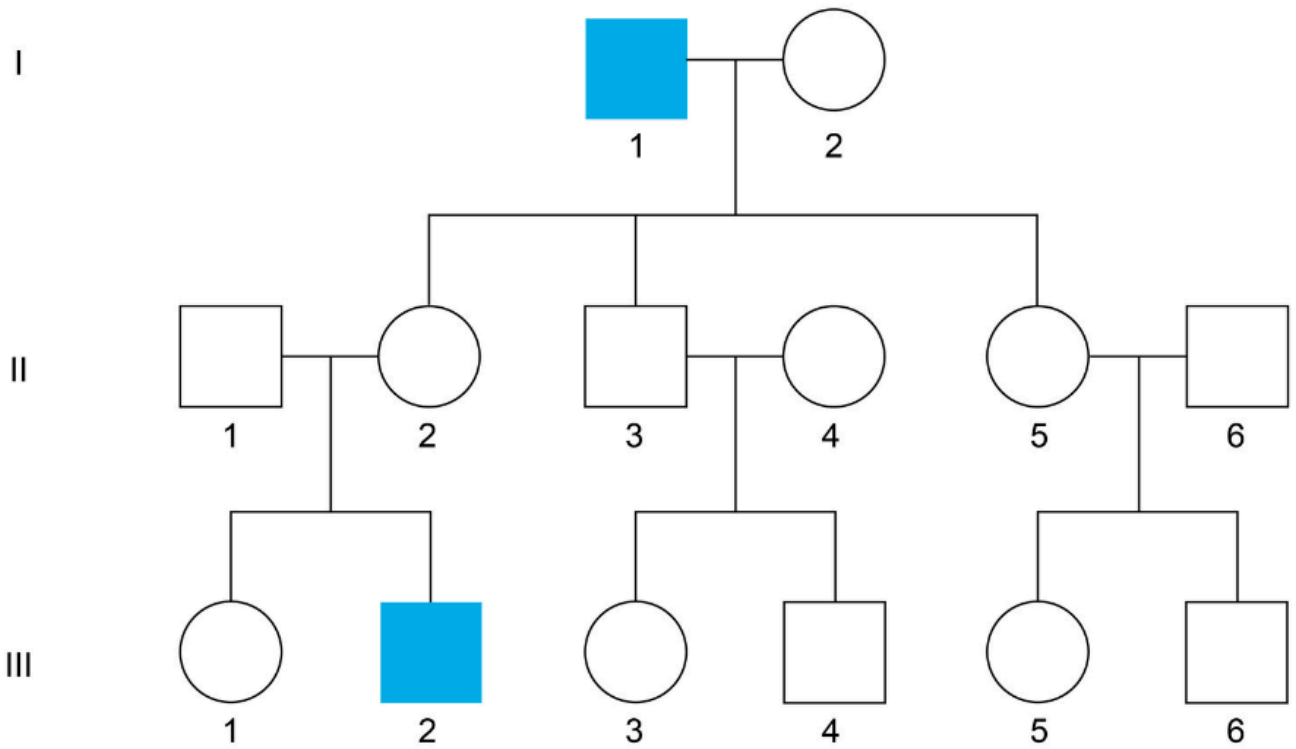
What Do You Think?

Suppose a plant has two alleles for purple flowers. What is the plant's genotype for flower color? What is the genotype and phenotype for flower color if a plant has two alleles for white flowers?

Reflect

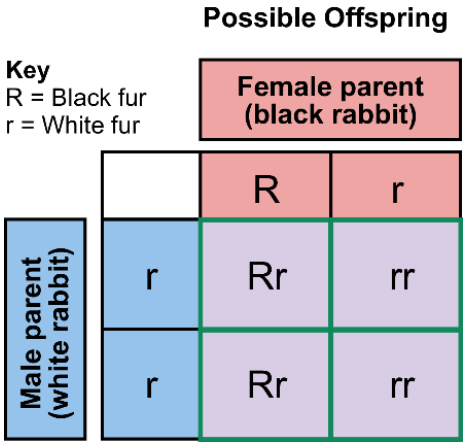
You may have noticed an interesting phenomenon in the table about the flower alleles. Three different genotypes (PP, Pp, and pp) produced only two phenotypes (purple color or white color). This is because the allele for purple color, P, is **dominant**, and the allele for white color, p, is **recessive**. Dominant alleles are expressed if they are present. Recessive alleles are expressed only when the dominant allele is absent. Therefore, PP and Pp genotypes have the same purple phenotype. Only the pp genotype has the white phenotype.

There are different ways to describe and predict the genetic makeup and appearance of offspring. One common method of describing how a trait is inherited across generations is a **pedigree**. In a pedigree, different generations are shown on separate lines (rows labeled I, II, and III), with males typically represented by squares and females by circles. Pedigrees show not only the gender of offspring throughout multiple generations but also the way a particular trait is inherited. Individuals who exhibit a particular trait are shaded, while those who do not exhibit that trait are left unfilled. In the example, the father in the first generation and his grandson in the third generation both exhibited a particular trait, while none of their other family members did. By examining the shaded and unshaded shapes in the pedigree, it is easy to trace from where a certain trait was inherited.



Another way to predict the probabilities of genetic outcomes is through a **Punnett square**. In a Punnett square, the genotypes of both parents are listed around the diagram. One parent's genotype is listed in the top row with one allele per column, while the other parent's genotype is listed in the far-left column with one allele per row. The remainder of the diagram is filled out by combining the parent alleles that are closest to that square.

For example, imagine you wanted to predict the fur color of the offspring of a black rabbit and a white rabbit. The alleles for fur color are R for black, which is dominant, and r for white, which is recessive. Suppose the female parent is a black rabbit with the genotype Rr and the male parent is a white rabbit with the genotype rr. In creating the Punnett square for this scenario, the female parent's alleles would go along the top row, and the male parent's alleles would go down the left column.



Because there are two alleles for these genotypes, the Punnett square has four possible outcomes. In the top-left square, the dominant black allele R from the female parent would combine with the recessive white allele r from the male parent for an Rr genotype. Similarly, in the top-right square, the recessive white allele r from the female parent would combine with the recessive white allele r from the male parent for an rr genotype. This same pattern leads to the bottom two squares showing Rr and rr genotypes.

The Punnett square for this rabbit fur-color scenario reveals that, of the four possible genotype outcomes, two have Rr genotypes and two have rr genotypes. This means there is a 50% (two out of four) chance that the offspring will have black fur (Rr genotype) and a 50% (two out of four) chance that the offspring will have white fur (rr genotype). Punnett square diagrams are very useful tools in predicting the probability of an offspring inheriting a certain trait.

It is important to note that just because the probability of an outcome is 50%, it does not mean that 50% of the actual offspring of a population will have that trait. The size of the population affects the proportions. For instance, in a large population of humans, about half of all babies born will be boys and half will be girls. However, in a small population, such as one particular family, a generation of offspring could be all boys or all girls.

What Do You Think?

Could the shaded squares on the pedigree be dominant, or are they recessive? How do you know?

Look Out!

Reproduction is the process that allows a parent organism or organisms to produce new organisms known as offspring. Plants, animals, humans, microorganisms, and even individual cells can be considered parents in the reproductive process. Reproduction is a characteristic that helps define what is living and what is not. The process of reproduction ensures that the genetic information from a parent or parents is passed on. Reproduction is responsible for the continuation of the tremendous variety found on Earth.

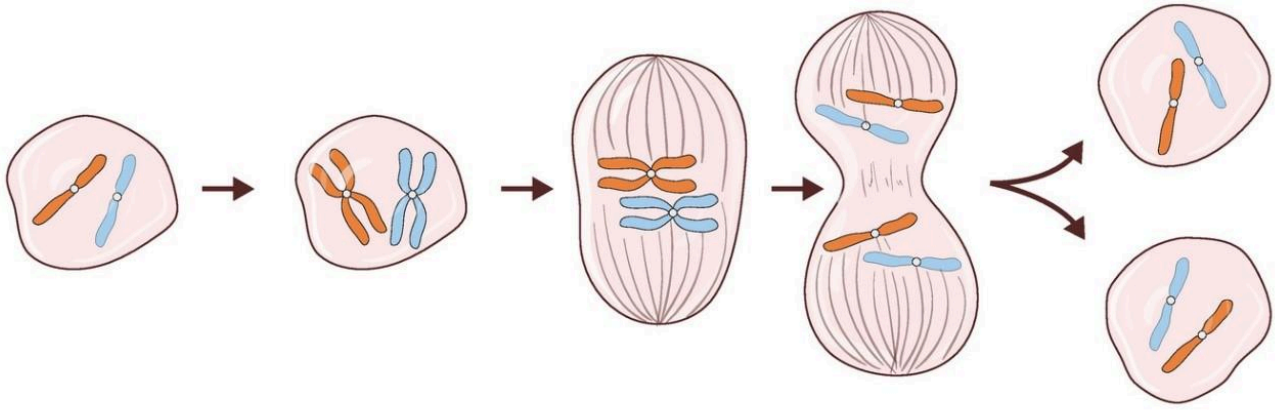
There are two basic types of reproduction: **asexual reproduction** and **sexual reproduction**. One type of reproduction isn't considered better than the other. They both have advantages and disadvantages to the individual and species.

Asexual Reproduction

Asexual reproduction is the process that involves just one parent. In this process, a large number of offspring can be produced in a very short amount of time. It also produces offspring that are genetically identical to the parent. In other words, asexual reproduction produces clones of the original parent. Asexual reproduction is the main form of reproduction for single-celled organisms like bacteria and archaea. Other asexually reproducing organisms that might be more familiar to you are sea stars and stick insects. Although many organisms reproduce asexually, most organisms reproduce sexually.

Let's think about asexual reproduction as an analogy. Paige has several hobbies, but baking is by far her favorite thing to do in her free time. She is such a great baker that people have started asking her to make her special cupcakes for their parties. A few times, people have placed large orders, and Paige has had to double the recipe. To do this, she multiplies the measurement of each ingredient by two and puts that amount in the mixing bowl. The end result is twice as many cupcakes, all exactly the same as those that are made when she uses the original recipe.

Inside your body, your cells are undergoing the same kind of “recipe.” They are doubling all the time. Most of your cells use the process of **mitosis** to create more cells. Mitosis results in two identical daughter cells that have the same genetic material as the parent cell. This process allows for growth as well as repair of damaged tissues. Mitosis begins when a cell doubles its genetic material, or DNA, in the nucleus. The doubled chromosomes line up in the center of the cell; then, they separate and move to opposite sides of the cell. The cell splits in half, forming two new daughter cells. The daughter cells are identical to the parent cell. In this way, mitosis is similar to Paige’s cupcakes from the doubled recipe.



Since asexual reproduction produces a clone of the parent, very little **genetic variation** occurs in offspring. Offspring look like the parent because the gene pool (all the genes in a population) contains more copies of the same genes. For example, in skin cells undergoing mitosis, this is a good thing because each “offspring” cell is just a clone of the “parent” cell.

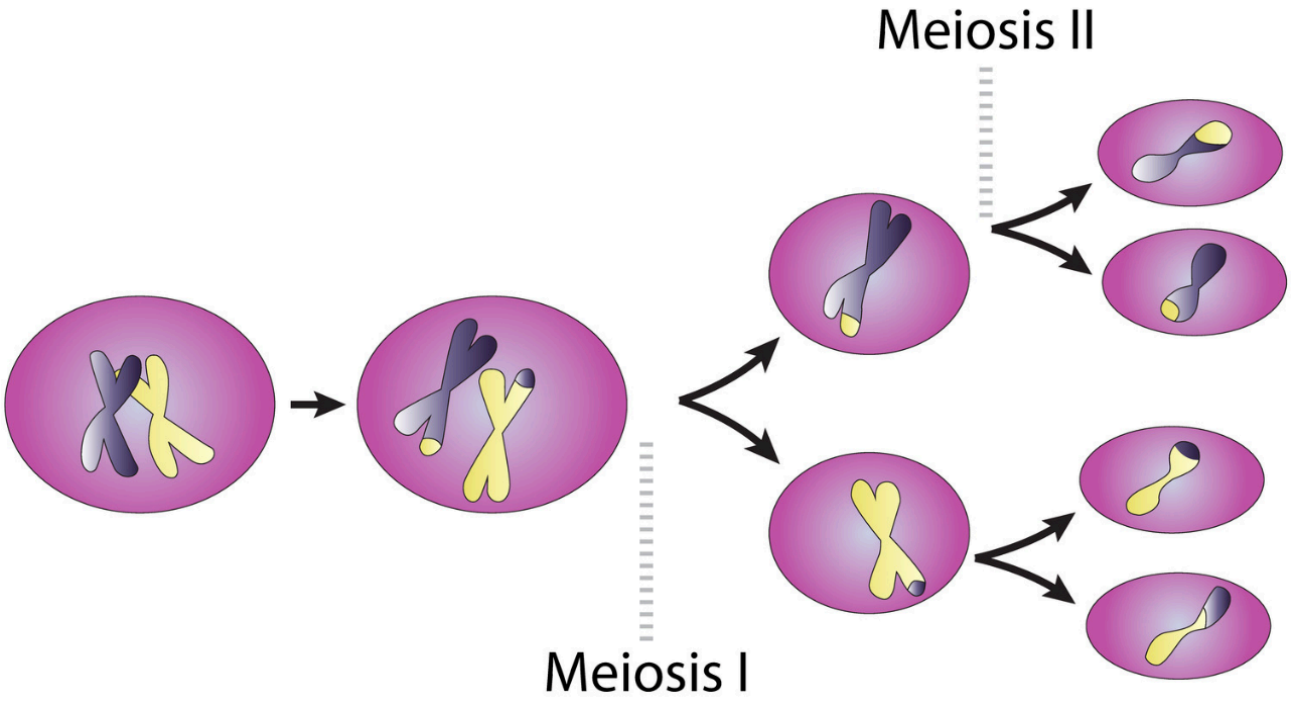
There are other forms of asexual reproduction. Some of these include budding used by hydra and a few other organisms. In this process, the growth of an offspring occurs on the surface of the parent. Bacteria and some single-celled organisms use binary fission to reproduce. They double their genetic material and then simply divide in half. Fungi are among the organisms that reproduce by producing spores. Some plants reproduce asexually by the process of vegetative propagation. In this process, a new plant emerges from a part of the parent plant. It is important to remember that any parent organism or cell that reproduces asexually produces a copy of itself. This does not result in genetic variation.

Sexual Reproduction

Sexual reproduction is the process involving two parents whose genetic material is combined to produce a new organism that is different from either parent. Sexual reproduction leads to a tremendous amount of genetic variation in offspring because the two parents are genetically diverse. This has the advantage of better survival of a species. The offspring is born with a mix of traits from both parents. However, it takes a longer amount of time for the offspring to be produced and usually results in a smaller number of offspring in comparison to asexual reproduction.

Genetics and Reproduction

In organisms that use sexual reproduction to produce offspring, the process of **meiosis** occurs to allow for genetic variation in offspring. Meiosis occurs in cells that are destined to become gametes (eggs or sperm). During meiosis, each parent cell makes a copy of its chromosomes but donates only half to the offspring. This method is commonly seen in multicellular eukaryotes such as flowering plants, humans, and birds. The offspring resulting from sexual reproduction will not look exactly like either parent but will resemble both in different ways. We say that offspring created by sexual reproduction are genetically diverse.



When the process of meiosis occurs in a cell, four daughter cells are produced. The number of chromosomes in the four daughter cells is equal to half the number of chromosomes in the parent cell. Meiosis consists of two divisions known as meiosis I and meiosis II. Meiosis I results in the creation of two daughter cells with the same number of chromosomes as the parent cell. Meiosis II occurs when the daughter cells divide to create four cells with half the chromosomes (genetic material) as the parent cell.

Because each parent donates half of the offspring's genetic material in sexual reproduction, the result is a wide variation in the genes of the offspring. Although sexual reproduction provides this wide genetic variation, it is costly to the organism reproducing. Energy and time must be spent finding mates and nurturing the offspring during pregnancy and often after birth. Sexually reproducing plants must use energy to produce flowers, attract pollinators, and find ways to disperse seeds, among other things.

Using Models for Asexual and Sexual Reproduction

Pedigrees and Punnett squares are tools primarily used to study and predict the inheritance of traits in sexually reproducing organisms. In sexual reproduction, two parents contribute genetic material to their offspring, which results in a diverse combination of traits in the offspring.

Asexual reproduction, on the other hand, involves the production of offspring without the fusion of genetic material from two parents. Instead, a single parent typically produces genetically identical or nearly identical offspring. Since asexual reproduction doesn't involve the mixing of genetic material from two individuals, pedigrees and Punnett squares are not usually used to analyze or predict inheritance in asexual organisms.

Instead, asexual reproduction is typically studied through other methods, such as observing the traits of the parent and the offspring directly and tracking the genetic changes that may occur over time due to mutation or other mechanisms. In asexual reproduction, the genetic makeup of the offspring is usually very similar or identical to the parent, and the patterns of inheritance are much simpler than in sexual reproduction.

Try Now

1. Genetic outcomes are the results of combining chromosomes from two different parents who reproduce sexually. The processes that take place during meiosis help contribute to genetic variation among offspring. Use what you have learned about genetic outcomes and Punnett squares to solve the following mystery.

   A newborn child was brought to the hospital nursery before he was marked with his parents' names. The hospital workers must use what they know about genetic outcomes to determine to whom the child belongs. They use his traits in this process. The baby has freckles (*F* dominant) and attached earlobes (*l* recessive). They believe that the baby most likely belongs to a couple in which the man has attached earlobes but no freckles. It is known that the woman is heterozygous for freckles and earlobe type.

   Complete the Punnett square to determine the probability that the child belongs to this couple. The possible combinations of the father's alleles are written across the top, and the possible combinations of the mother's alleles are written down the left side. Write your answer in the table, and include a brief statement that explains how you reached your answer.

   Write your answer in the chart below.

	fl	fl	fl	fl
FL				
Fl				
fL				
fl				

2. Take a look at the two graphic organizers below. Which graphic organizer best represents asexual reproduction? Which graphic organizer best represents sexual reproduction? Explain your answers.

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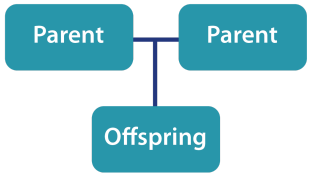

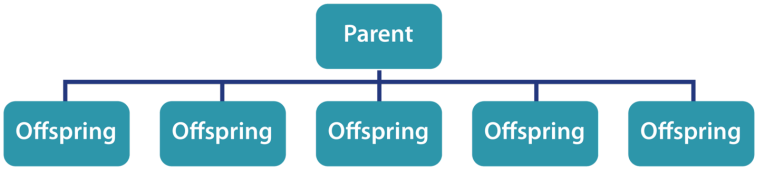

3. Use what you know about asexual and sexual reproduction to sort the terms below into the correct columns. If the term is related to asexual reproduction, write it in the column on the left. If the term is related to sexual reproduction, write it in the column on the right. If the term is related to both types of reproduction, write it in both columns.

   Sort the following terms:

   DNA, male and female, one parent, unique, budding, spores, uniform, traits, egg, sperm

Asexual Reproduction	Sexual Reproduction

Connecting With Your Child

Asexual Reproduction in Plants

To help your child learn more about asexual reproduction, test the vegetative propagation capabilities of a household plant. Choose a common household plant such as the spider plant (scientific name: *Chlorophytum comosum*). Try vegetative propagation using several different parts of the plant, such as a piece of stem, a piece of root, a leaf (with no stem), a leaf with some stem, and the tip of a leaf.

Place a toothpick on either side of your plant part (or in the case of the leaf, put the toothpick right through it). Then, place the plant part in a cup of water and position the toothpick so that a portion of the plant part is not totally submerged and that it has access to light and air. Change the water every few days to prevent it from getting stagnant. Observe how long it takes the plant to start growing, and note if the plant part does not grow at all. You and your child could also try planting the plant parts in some potting soil to see if that changes your results. In addition, you can try this with a potato that has sprouted or with an avocado pit.

Here are some questions to discuss with your child:

1. Which parts of the plant successfully formed new plants?
2. How does the DNA in the new plants compare to the DNA of the parent plant?
3. Why might this strategy be an advantage for plants in the wild?
4. How might gardeners use this method to populate their gardens?