Common Student Ideas about Variation and Inheritance of Traits

Common Student Idea(s)	Scientific Explanation
1. Nature makes offspring look like their parents.	This naive idea doesn't take into account that genetic entities (genes found on chromosomes in the nucleus of each cell) control the expression of traits in an individual.
2. Genes control only an individual's visible traits (like hair color, skin color, and fur color), not the traits that aren't visible (like blood type, personality traits, and whether an individual will get cancer or other diseases).	Genes control protein production in all living things. It's easy to understand how different proteins might control variations in eye color or skin color, but it can be difficult to realize that they control nonphysical attributes as well. An ongoing nature-versus-nurture debate exists within the scientific community about the extent to which genes control various abilities and aspects of personality. Studies of identical twins separated at birth and raised in vastly different environments have found that genes may control many aspects of personality, such as likes and dislikes; the way a person laughs; the aptitude for art, music, or mathematics; and much more. But science hasn't yet determined the mechanism by which genes control these nonphysical traits. It's clear, however, that environment also has an impact on most traits. The relative amounts of variation accounted for by genes and by the environment varies depending on the trait, so in most cases it is unknown.
3. Individuals inherit traits from only one parent. Some traits come from the mother, and other traits come from the father.	Each parent contributes genetic material equally to offspring for every inherited trait. Each individual has two genes in every body cell (autosomal cell), one from each parent. Genes, however, have different forms called *alleles*. One allele may be dominant in relation to another allele, which means that the trait it confers will appear in individuals that have this allele regardless of having the other allele. Exhibiting the trait of one parent and not the other is the result of a particular combination of dominant or recessive alleles an individual received from both parents.
4. Girls get most of their genes from their mothers, while boys get most of their genes from their fathers.	Each parent contributes genetic material equally to offspring for every inherited trait, regardless of the offspring's gender.

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5. Dominant traits are stronger than recessive traits. Sometimes dominant traits come from the stronger or healthier parent. *[Boys, in particular, tend to think that genes inherited from a male parent are stronger than those inherited from a female parent.]*	Everyday use of the words *dominant* and *recessive* contributes to misconceptions about trait inheritance. With respect to genes, the word *dominant* doesn't mean stronger and is in no way related to the strength or health of a parent. Each parent contributes genetic material equally to offspring for every inherited trait. These genes are segments of DNA that provide instructions for protein construction in a cell. When a different set of instructions (alleles) is received from each parent, a cell will follow the instructions from the dominant allele regardless of which parent contributed the allele. Instructions from a recessive allele are followed only when an individual has two of these alleles, one from each parent.
6. Dominant traits are better because they give you a greater chance of survival or other evolutionary advantages.	Everyday use of the words *dominant* and *recessive* contributes to misconceptions about trait inheritance. Some traits are dominant strictly because the alleles (the different forms of a gene) that control these traits are expressed. There are various reasons why dominant rather than recessive alleles are expressed, but in each case, the dominant allele codes for a specific protein. For example, the dominant allele may code for a specific protein that triggers a chemical reaction that produces purple pigment and yields a purple flower. The recessive allele, on the other hand, codes for a protein that doesn't work because the dominant allele masks it. If the plant has two recessive alleles, the chemical reaction that produces purple pigment is blocked, and the resulting flower color is white. Dominant traits aren't necessarily advantageous, however. A dominant allele, for example, is associated with Marfan syndrome, an incurable genetic disorder characterized by unusual growth, exceptionally long limbs, and other serious health problems. There's also a significant risk that offspring will inherit the disorder.
7. Individuals are more likely to inherit dominant traits than recessive traits, so these traits must occur more often in a population.	Everyday use of the words *dominant* and *recessive* contributes to misconceptions about trait inheritance. Dominant traits don't necessarily confer any evolutionary advantage for survival or reproduction simply because they're dominant. In fact, many dominant traits are quite rare in a population, which means the proportion of alleles associated with these traits doesn't increase. New forms (alleles) of a gene can develop through random mutations of chromosomes in a sperm or egg. If the resulting alleles have a survival advantage—regardless of whether they are dominant or

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	recessive—these alleles will likely increase proportionally in a population, since individuals with these alleles will have more success reproducing and passing them on to their offspring. If a mutation results in a disadvantageous allele, individuals with this allele will have less reproductive success and fewer offspring to inherit the allele. Consequently, this allele will be unlikely to increase proportionally in future generations. If an allele confers a neutral trait—neither advantageous nor disadvantageous—random events make it impossible to predict any proportional increases or decreases of this allele in a population (typically a small population).
8. A baby's developing brain decides which traits the organism will have.	The genes we inherit from our parents determine our traits. We can't choose which traits we'll have. Not even our developing brains can decide or control this in the womb! The implication of this common misconception is that all organisms have brains. The laws of inheritance apply to *all* sexually reproducing organisms, including simple animals without brains (like sponges), plants, fungi, and even some single-celled organisms. Some traits are *acquired*, not inherited, such as the ability to ride a bicycle or curly hair from a perm at the beauty parlor. Our experiences and choices control many of the traits we acquire. So even though our brains can't choose *inherited* traits, they can play a role in developing *acquired* traits.
9. Genetic information is in an organism's blood or heart. *[Alternatively, some young people believe that genetic information is in an organism's stomach.]*	Historically, before Mendel's ideas about inheritance were accepted, many scientists believed that traits were passed to offspring through the mother's blood. However, this early idea—and other ideas asserting that traits are passed to offspring in nongenetic ways—failed to recognize that *all* of the genetic information that controls trait expression in an individual is found in the nucleus of every body cell.
10. Genes and chromosomes are either unrelated to each other or are the same thing.	Many students use the terms *genes* and *chromosomes* without understanding how they're related. One common misconception is that genes and chromosomes are distinct entities in a body cell. Alternatively, students may think that genes and chromosomes are the same thing. Correctly understood, each organism has a specific number of chromosomes. Each chromosome, which is found in the nucleus of every body cell, is one long DNA molecule made up of sequences of nucleotide bases that are formed from the amino acids guanine,

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	cytosine, adenine and thymine. These sequences of nucleotide bases appear at specific locations on strands of DNA in chromosomes and provide the chemical code that can be translated into a protein in an organism. Each of these sequences is called a *gene*.
11. Alleles are different from genes, but like genes, they have something to do with inheritance.	Alleles are variations of the same gene. Genes provide the instructions for a particular trait, and alleles provide instructions for variations of that trait. For example, each flower has a gene that determines its color, and different forms of the gene—alleles—provide instructions for different flower colors. In terms of DNA, alleles of a particular gene have slight variations in the sequence of nucleotide bases.
12. Traits are found on chromosomes.	*Traits* aren't found on chromosomes. Genes (specific sequences of nucleotide bases) are located at specific positions along the strands of DNA in chromosomes. Genes code for specific proteins in the nucleus of body cells. These proteins form the structures or trigger the chemical reactions in a cell that determine the traits of an individual.
13. The complexity of an organism determines how many chromosomes it has. More complex organisms—like humans— have more chromosomes, and less complex organisms—like plants— have fewer chromosomes.	Different organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, or 46 chromosomes altogether. Dogs have 39 pairs of chromosomes, and peas have seven pairs. Scientists aren't sure why some organisms have more or fewer chromosomes than others, but it's clear that the number of chromosomes is *not* related to the complexity of an organism. Some relatively simple organisms have many chromosomes (one type of fern has 92 pairs!), while some very complex organisms have fewer chromosomes (kangaroos have just eight pairs).
14. One gene is always responsible for one trait, and each gene has two variations, one dominant and one recessive.	Many students think that all traits follow a simple Mendelian pattern in which two alleles of a gene exist for a particular trait, one dominant and one recessive. However, more complex traits may exhibit different patterns. For example: • Many genes have more than two possible alleles, although an individual can have at most two different alleles for a gene. • One allele may not be completely dominant in relation to another allele. In this case, three variations of the trait will appear: two extremes with an intermediate trait between them. • Two alleles may be equally dominant. In this case, three variations of the trait may appear: two

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	individual variations, and a third variation in which both of the other variations are expressed codominantly. This pattern is seen in human blood types, which include blood type A, blood type B, and blood type AB. Type AB is an example of two alleles that are equally dominant. • Many different genes, with all their allele variations, control a number of traits, such as height, skin color, and intelligence. This results in continuous variations across a large range of traits.
15. A Punnett square is an easy way to solve most genetics problems.	Many students rely on Punnett squares as an algorithm for getting the "right" answer to a genetics problem, but often at the expense of a meaningful conceptual understanding of the biological processes involved. A Punnett square represents two biological processes. The first process is *gamete formation*, in which paired chromosomes, and their corresponding genes, separate from each parent and form different gametes in the process of making sperm or eggs. The second process is *fertilization*, the random combination of chromosomes that occurs in the union of sperm and egg. While most students find it easy completing a Punnett square to model fertilization, many don't realize that this tool also models the process of gamete formation.
16. The rules for inheriting traits works in animals, since there are clearly two parents that contribute an egg and a sperm, but these rules don't make sense in plants.	Reproduction in plants is a difficult concept for many students to grasp. Consequently, they don't have a clear understanding of how plants inherit traits. The rules for trait inheritance are similar for all sexually reproducing organisms, including plants, animals, and many fungi and single-celled organisms. However, not all organisms capable of reproducing sexually do so in every instance. Some plants can reproduce simply by growing from a cutting or sprouting new plants from the same root. And some animals can grow into two identical organisms from a segmented portion of the original organism. These *asexual* forms of reproduction result in new organisms whose genes are identical to the original organism.