Baby Mice

Seif's pet mouse had babies. Five of the babies were black and two were white. The father mouse was black. The mother mouse was white. Seif and his friends wondered why the mice were different colors. These were their ideas:

Jerome: Baby mice inherit more traits from their fathers than their mothers.

Alexa: The baby mice got half their traits from their father and half from their mother.

June: Male traits are stronger than female traits.

Seif: Black mice have more traits than white mice.

Fiona: The black baby mice are probably male and the white baby mice are probably female.

Lydia: Parent's traits like fur color don't matter—nature decides what something will look like.

Billy: Blood type determines what traits babies will have.

Which friend do you most agree with and why? Explain your thinking.

Baby Mice

Teacher Notes

Purpose

The purpose of this assessment probe is to elicit students' basic ideas about inheritance of genetic traits. The probe is designed to reveal the variety of ideas students have about how traits, such as fur color, are passed on to offspring.

Related Concepts

chromosomes, genes, inherited traits

Explanation

The best response is Alexa's. The first step in the production of offspring from the two mice is fertilization of the female's egg by the male's sperm. Egg and sperm each contain half the number of mouse chromosomes. Genes are found on chromosomes. A gene is a segment of DNA on a chromosome that carries instructions for a particular trait, such as fur color. During fertilization, matched pairs of chromosomes, half from the mother and half from the father, come together and a single cell results, which will divide and eventually become the baby mouse. The baby mouse contains a full set of chromosomes—with half the genes coming from the mother and half from the father. The combination that results determines the offspring's characteristics.

One way in which genes are expressed was described by Gregor Mendel, who believed that traits could be either dominant or recessive. When two genes for the same trait are paired and one of the genes is dominant, the dominant gene will be expressed. In the example of the mice, black fur color is dominant. Even if the offspring only have one gene for black fur, the trait that will be expressed is black fur. White fur is a recessive trait that is expressed when a dominant gene is not present. The white offspring have two genes for white fur color. Mendelian genetics is a first step in understanding how genes are expressed, but understanding genetics is much more complex.

The key idea in this probe is that an organism's inherited traits are determined by the pairing of genes from the mother and father, with each parent contributing 50% of the genes; the combination of dominant and recessive genes determines which traits are expressed. It is not the result of one sex having more or stronger traits (or genes) as described in Jerome's and June's responses. Black and white mice have the same number of genes (contrary to Seif's response); they are just expressed differently. Coat color in mice is not determined by sex as described in Fiona's response. For example, some of the white mice could be male if they received a recessive gene from both the mother and father. Lydia's response targets the idea of acquired characteristics, which are not inherited from an organism's parents. For example, if a mouse lost its tail in an accident, that would be an acquired trait—it would not be passed on to the offspring. Lydia's response is a teleological argument that implies that some intentional force of nature directs the traits that offspring will exhibit, rather than that traits are the result of gene expression. Billy's response is similar to historical beliefs. Before Mendel, many people thought traits were passed on through the blood.

Curricular and Instructional Considerations

Elementary Students

In the elementary grades, students are just beginning to learn about inherited characteristics. They observe that offspring do not always look exactly like their parents or each other. In the later elementary grades they begin to develop an understanding that traits are passed on from parents to offspring, but it is too early to introduce the mechanism of inheritance and the role of genes. By eliminating some of the distracters, this probe can be used to examine students' early ideas about how traits are passed on to offspring.

Middle School Students

In middle school, students learn basic ideas about the mechanism of inheritance, combining ideas about reproduction, cell division, and basic genetics. They develop an understanding of the role of chromosomes and genes in passing on characteristics from one generation to the next. The expectation at this grade level is that students should understand that half of their genes come from their mother and half from their father. This combination results in the inherited traits they exhibit. Students should recognize the role of chance in determining which chromosomal pairs come together during fertilization and that probability can help predict the outcome of inherited characteristics. However, the detailed mechanism of genetics exceeds the middle school level. This probe is useful in identifying whether students have preconceived ideas about how genetic traits are passed on to offspring.

High School Students

In high school, students learn the details of Mendelian genetics and how various gene combinations occur and express themselves. They should be able to explain why some traits are expressed and some are not. They learn about genetics at a molecular level, including the role of DNA. This probe is useful at the high school level in determining students' precursor ideas before planning and teaching a unit on genetics.

Administering the Probe

This probe is best administered to middle and high school students. If using the probe with elementary students, substitute *characteristics* for *traits* if they are unfamiliar with the latter term. Depending on when genes are introduced in the curriculum, upper middle school or high school teachers can substitute the term *genes* for *traits* in Jerome's, Alexa's, June's, and Seif's responses.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 Life Cycles of Organisms

- Plants and animals closely resemble their parents.
- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal.

5–8 Reproduction and Heredity

★ In many species, including humans, females produce eggs and males produce sperm. Plants also produce sexually—the egg and sperm are produced in the flowers of flowering plants. An egg and a sperm unite to begin development of a new individual. That new individual receives genetic information from its mother (via the egg) and its father (via the sperm). Sexually produced offspring are never identical to either of their parents.

★ Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.

- Heredity information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information.

9–12 The Molecular Basis of Heredity

- In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA.

★ Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual.

Related Ideas In *Benchmarks for Science Literacy* (AAAS 1993)

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

K–2 Heredity

- There is variation among individuals of one kind within a population.

3–5 Heredity

- For offspring to resemble their parents, there must be a reliable way to transfer information from one generation to the next.

6–8 Heredity

★ In some kinds of organisms, all the genes come from a single parent, whereas in organisms that have sexes, typically half of the genes come from each parent.

9–12 Heredity

★ The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents.

Related Research

- "Early middle-school students explain inheritance only in observable features, but upper middle-school and high-school students have some understanding that characteristics are determined by a particular genetic entity which carries information translatable by the cell" (AAAS 1993, p. 341).
- When asked to describe how physical traits are passed from parents to offspring, elementary, middle, and high school students all exhibited misconceptions, including the idea that traits are inherited from only one of the parents and that certain traits only come from the mother or father (AAAS 1993).
- Studies have shown that it may not be until middle school that students can include in their explanations of inheritance the role of chance and probability (AAAS 1993).
- In a study by Hackling and Treagust (1982), 94% of 15-year-old students understood the concept that one's characteristics come from parents, 50% understood that reproduction and inheritance occur together, and 44% understood that one gets a mixture of features from both parents (Driver et al. 1994).
- In a sample of 52 students ages 11–14, Deadman and Kelly (1978) found that boys had a prevalent conception that characteristics from male parents were stronger in their expression (Driver et al. 1994).
- Engel Clough and Wood-Robinson (1985) found that some students had a tendency to favor the mother as the primary contributor of genetic material as well as a belief that daughters inherit from mothers and sons inherit from fathers (Driver et al. 1994).
- In a study of ideas about the mechanism of inheritance among children ages 7–13, Kargbo, Hobbs, and Erickson (1980) found that half the children gave a naturalistic explanation, such as nature makes offspring resemble parents. Some thought traits were decided by the brain or blood. Only a few children in the sample, who were among the older children in the group, mentioned any genetic principle. In analyzing the students' responses, the authors found that they were not giving flippant, unconsidered answers

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

but rather were drawing on established frameworks to make sense of inheritance (Driver et al. 1994).

- Several researchers have found that even before students receive formal instruction in genetics, they know the word *gene* and, less frequently, *chromosome*. However, students have little understanding of the nature or function of genes or chromosomes (Driver et al. 1994).
- Research shows that students have some idea of the randomness of inheritance, meaning that sometimes offspring are like their mother, sometimes they are like their father, and sometimes they are like both. However, students rarely show evidence of applying the concepts of chance and probability to common situations even after advanced courses (Driver et al. 1994).
- Use of the word *dominant* in regard to dominant and recessive traits may contribute to several misconceptions. For example, students may think that dominant traits are "stronger" and "overpower" the recessive trait, that dominant traits are more likely to be inherited, that dominant traits are more prevalent in the population, that dominant traits are "better," and that male or masculine traits are dominant (Donovan 1997).

Suggestions for Instruction and Assessment

- Children in early grades should have observational experiences to compare how offspring of familiar animals resemble each other and their parents, describing and drawing examples of similarities and differences.
- In upper elementary grades, rather than describing a characteristic (e.g., the mouse has black fur) students should begin to develop an inventory of traits that come from parents (e.g., fur color). They should discuss and have opportunities to resolve differences in opinion about traits that come from parents, traits that come from interaction with the environment, characteristics that are learned, and things they are unsure about.
- In middle school, combine the study of genetics with the study of reproduction.
- Use caution with terminology at the high school level when teaching genetics, particularly with the concept of dominance so as not to imply the idea that some genes are "stronger" than others.
- Genetics terminology may hinder conceptual learning when terms are used imprecisely. If students are told "Inherited traits are carried on chromosomes," they may then confuse the terms *trait* and *gene*. (Genes, not traits, are carried on chromosomes.) Clear and consistent use of terms such as *trait, gene,* and *allele* is essential for constructing an accurate conceptual foundation of genetics (Bryant 2003).
- Caution should be used when students are asked to develop or use models to represent the mechanism of inheritance. Some models oversimplify the process of random assortment, recombination, and pairing of genes and expression of traits.
- Be aware of problems in using Punnett

squares. As stated by Bryant (2003),

"The Punnett square works well for studying the inheritance of genetic traits controlled by a single gene, and can even be applied when two or more traits are considered simultaneously, as long as the genes are not located on the same chromosome (linked). Students often learn to use Punnett squares to obtain correct answers to genetics problems, but they fail to understand that a Punnett square represents two biological processes—gamete formation and fertilization. Students rely on Punnett squares as algorithms for getting the "right answer," often at the expense of meaningful conceptual understanding" (p. 11).

Related NSTA Science Store Publications and Journal Articles

American Association for the Advancement of Science (AAAS). 2001. *Atlas of science literacy.* (See "DNA and Inherited Characteristics," pp. 68–69.) New York: Oxford University Press.

Baker, W., and C. Thomas. 1998. Gummy bear genetics. *The Science Teacher* 65 (8): 25.

Bryant, R. J. 2003. Toothpick chromosomes: Simple manipulatives to help students understand genetics. *Science Scope* 26 (7): 10–15.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

Fetters, M. K., and M. Templin. 2002. Building traits. *The Science Teacher* 69 (4): 56–60.

Hazen, R., and J. Trefil. 1992. *Science matters.* (See "Code of Life," pp. 224–242.) New York: Anchor Books.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Rice, E., M. Krasney, and M. Smith. 2006. *Garden genetics: Teaching with edible plants.* Arlington, VA: NSTA Press.

Related Curriculum Topic Study Guides

(Keeley 2005)

"Mechanism of Inheritance (Genetics)"

"Reproduction, Growth, and Development (Life Cycles)"

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Bryant, R. J. 2003. Toothpick chromosomes: Simple manipulatives to help students understand genetics. *Science Scope* 26 (7): 10–15.

Deadman, J., and P. Kelly. 1978. What do secondary school boys understand about evolution and heredity before they are taught the topics? *Journal of Biological Education* 12 (1): 7–15.

Donovan, M. 1997. The vocabulary of biology and the problem of semantics. *Journal of College Science Teaching* 26: 381–382.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

Engel Clough, E., and C. Wood-Robinson. 1985. Children's understanding of inheritance. *Journal of Biological Education* 19 (4): 304–310.

Hackling, M., and D. Treagust. 1982. What lower secondary students should understand about the mechanisms of inheritance, and what they should do following instruction. *Research in Science Education* 12: 78–88.

Kargbo, D., E. Hobbs, and G. Erickson. 1980. Children's beliefs about inherited characteristics. *Journal of Biological Education* 14 (2): 137–146.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.