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BioEd℠

Complex Traits

Categorizing Hair Types in Dogs

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Baylor College of Medicine

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OVERVIEW

Students explore phenotypic differences in hair types found in the coats of different dog breeds, as they begin to learn about complex traits. Based on information provided, students also predict the genotypes of different dog breeds.

Categorizing Hair Types in Dogs

Most characteristics, such as height, body shape and disease susceptibility, in living organisms are controlled by more than one gene. Coat type in dogs is an example. Variations in three genes determine the patterns of hair length, curl and presence of "furnishing" (beard and bushy eyebrows, combined with wiry hair) that are observable in about 95% of all dog breeds. In this activity, students will categorize the coat phenotypes of eight different dog breeds, and then will connect the phenotypes to possible genotypes.

The dog breeds that are included in this activity are the Bassett Hound, Bichon Frise, Border Terrier, English Cocker Spaniel, Golden Retriever, Havanese, Irish Water Spaniel, and Kerry Blue Terrier. These breeds display the complete range and combinations of coat types: long vs. short hair, curly vs. straight hair, and presence or absence of furnishings. The ancestors of modern dogs all had coats with short, straight hair without furnishings. The other characteristics have arisen because of mutations in genes related to hair growth and development. Mutations are changes in the DNA sequence, usually as a result of mistakes when DNA is copied. If the mutation is present in the egg or sperm cell of a parent, it is passed onto the offspring. In dogs, selective breeding has consolidated and increased the frequency of many mutations that affect appearance or behavior.

In 2016, 190 dog breeds were recognized by the American Kennel Club; 199 by the Westminnister Kennel Club.

Three different genes regulate hair type in dogs. Hair length (L), as described previously, can be long or short. The ancestral condition in dogs is short hair. Long-haired dogs have inherited a mutation involving the substitution of a single nucleotide in the gene responsible for terminating hair growth. Dogs with one or two copies of the mutation have long hair. Thus, dogs with the genotype "Ll" and "LL" have short hair. Dogs with the genotype "ll" have long hair.

Curl (C) is governed by a change in one of the genes responsible for a structural protein in hair (keratin). The mutation again involves the substitution of a single nucleotide—this time, a T (thymine) is substituted for a C (cytosine). The substitution is believed to affect folding of the completed protein, leading to curled or wavy hair. Dogs with straight hair have two copies of the straight form of the gene (cc); dogs with wavy hair have one copy of the straight form of the gene and one copy of the curly form (Cc); dogs with curly hair are homozygous for the curly mutation (CC).

Wiry hair is an interesting characteristic in dogs. Dogs that possess hair that is coarse and bristly like wire, always also have a beard (longer hair on the chin and muzzle and bushy eyebrows. Dog experts refer to the

additional facial hair features as "furnishings." All of these physical changes are due to the same mutation in a single gene. The gene is responsible for producing a signaling protein important for keratin development and initiation of hair growth. Importantly, in this case, one mutation in a single gene leads to multiple changes in the phenotype. The Irish terrier, shown at right, provides a good example of furnishing and wiry coat. The mutation leading to wiry hair and furnishings consists of the insertion of 167 base pairs within the signaling protein gene called RSPO2. This means that extra DNA was added into the existing sequence that comprised the gene. The extra section of DNA appears to change the levels and actions of the proteins produced by the gene.

TYPICAL IRISH SETTER

Only one copy of the "furnishings" (F) mutation is necessary for the characteristic to be present. A dog with the genotype "ff" will not have furnishings. However, a dog with Ff or FF will present the furnishings phenotype.

When only one copy of an allele is necessary for a trait to be present, inheritance of the trait is described as "dominant." Furnishings is an example of a dominant trait. Dogs with only one copy of the furnishings allele (genotype of Ff) will have wiry hair and a bearded face. Conversely, absence of furnishings is a recessive trait, because two copies of the allele (ff) are necessary for furnishings to be absent.

MATERIALS

- Complex Traits slide set (slides 27–41), available at http://www.bioedonline.org/slides/classroom-slides1/genetics-and-inheritance/complex-traits/
- Computer and projector, or interactive whiteboard
- Set of eight Dog Breed cards copied onto cardstock (see p. 25–26; one set per group)
- Copy of "Genetics of Dog Coats" (p. 27, one per student)
- Copy of "Confirmed Hair Genotypes" to be distributed after students have completed Part 2, item 6 (one per student, p. 28)

PROCEDURE

Part 1: Hair phenotypes

1. Remind students about the activity, "Genotypes and Phenotypes." Ask, *Is short or long hair the only distinguishing characteristic of dog's coats?* Students might mention curly vs. straight hair or coat color. Explain, *Coat color and patterns of color, for example, are governed by interactions among many different genes.* Show students Slide 27, with two different coat patterns. Mention, for example, that several different genes can be responsible for something that appears simple, such as a black coat.

GIANT SCHNAUZER

BASENJI

Basenji © Nikolai Tsvetkov. Giant Schnauzer © Aleksey Tugolukov. Irish Setter © Radomir Režný. Licensed for use.

2. Show Slide 28 and tell students that they will

be investigating hair length and texture in eight different dog breeds. Give each group of students one set of Dog Breed cards. Direct the members of each group to discuss the different kinds of fur or hair that can be observed on the dogs. Use the term "phenotype" when referring to the different observable features of hair.

3. Next, direct the groups to sort the eight cards into different categories of fur or hair. They should not use color as a criterion for sorting.

4. After the groups have sorted their cards, allow each group to present or describe the different coat categories they used.

Part 2: Hair genotypes

1. Remind students about what they already have learned about the gene mutation that determines whether a dog has long or short hair. (If necessary, revisit Slide 24.) Discuss the other characteristics that contribute to hair type in dogs. Show Slide 29 and explain that three genes govern the hair type in most breeds of dogs. The gene for hair length is one of the three genes. Curl is affected by a gene that codes for one of the structural proteins in hair. Like the gene for hair length, a single point mutation is responsible for the curly allele. In this case, however, one inherited copy of the mutation (Cc) causes soft, wavy hair and two copies (CC) cause soft, *curly* hair. A dog must have two copies of the original ("ancestral") version of the allele (cc) to have straight hair.

2. Display Slide 30 showing a photo of an Irish terrier with furnishing and wiry hair. Ask if any of the students have a dog with similar facial and coat hair. Mention that the eyebrows and beard are called "furnishings." Tell students that the coat hair is stiff like wire. In the case of the gene for furnishing, extra DNA (167 base pairs) has been inserted into the original gene. The protein produced by the gene is involved in switching on other genes, and the additional DNA changes how that protein regulates hair growth. Mention that this is an example of how a single gene can have effects in many different parts of the body.

3. Give each group of students the sheet entitled "Genetics of Dog Coats" (Slide 31). Tell students that they will decide on the phenotype and genotype of each dog, based on what they have learned about the genetics of hair type.

4. Display Slide 32. Point out that photos of a dog's coat may be misleading because of breed standards in dog competitions.

The Bichon frise on the left has curly hair that looks short. On the right is a Bichon Frise with its hair combed out, which reveals the coat's length.

5. Project Slide 33 showing the Bichon Frise by itself. Tell students, *Let's figure out what the genotype of the dog must be, based on the traits that we have observed and recorded.*
   - *Since the Bichon has long hair, which combination of alleles is possible?* ["ll" is the only possible genotype.]
   - *We determined that the hair is curly. What genotypes are possible?* [Since the Bichon is clearly "curly," and not wavy or straight, the genotype is CC].
   - *Since the dog has furnishing, what are the*

possible genotypes? [It is not possible to know if the individual pictured is homozygous, FF, or heterozygous, Ff. However, since the trait appears consistently within members of the breed, it is reasonable to assume that most individuals of this breed are homozygous for the furnishings allele, FF].

6. Let each group work through the remaining dog breeds. (Slides 33–40 contain enlarged images all eight dogs for use as needed.) Tell students to determine the phenotypes of all the dogs, before proceeding to the genotypes. If you have Internet access in your classroom, students may want to access additional photographs of the different breeds to look for characteristics, such as furnishings.

7. Have the groups report on their conclusions regarding the genotype and phenotypes of each breed, by asking each group to present the findings for a different breed. Or, have each group submit a written explanation of the decisions they made regarding each breed.

8. Distribute the student sheet, "Confirmed Hair Genotypes," which summarizes typical genotypes for each breed (Slide 41) for a discussion with the class. Students may notice that in most cases, the breeds are homozygous for dominant traits. Based on phenotype, it is not possible to know if an individual has a single or both alleles for a trait that shows a dominant pattern of inheritance. However, because dog breeds have been selected over generations to "breed true," most of the variant alleles have been eliminated over time. In other words, dogs with undesirable characteristics themselves (or whose offspring had undesirable characteristics) were not bred to produce additional offspring.

EXTENSIONS

- If students have questions about dog coat color, access one of the commercial dog testing websites to find a summary of the many different genes (and genetic tests) that are involved in determining color and patterns. Simply search, "dog coat color genetic testing."
- Much of the research on the Dog Genome has been led by Dr. Elaine Ostrander of the National Human Genome Research Institute of the National Institutes of Health. The following video summarizes much of the work to date on the dog genome, including examples used in this set of activities. In addition, she describes the relevance of studying dog genetics to understanding human diseases.

  https://www.youtube.com/watch?v=sxtX1pfSUec

- More information about the Dog Genome project can be found at the URL below.

  http://research.nhgri.nih.gov/dog_genome/

Dog Breed Cards

1. Bichon Frise

2. Border Terrier

3. Havanese

4. Basset Hound

Dog Breed Cards *(cont.)*

5. English Springer Spaniel

6. Irish Water Spaniel

7. Golden Retriever

8. Kerry Blue Terrier

English Cocker Spaniel © Zdenek Maly. Golden Retriever © Eric Isselee. Kerry Blue Terrier © Bonzami Emmanuelle. Licensed for use. Irish Water Spaniel © The Kennel Club. CC-BY-SA 2.0 (www.flickr.com)

Genetics of Dog Coats

	PHENOTYPE Describe the hair type using the phenotype traits listed below.			GENOTYPE Fill in the genotype that corresponds to each phenotype you identified.		
DOG BREED	Short or Long	Curly, Wavy, or Straight	With or Without Furnishings	LL = short Ll = short ll = long	CC = curly Cc = wavy cc = straight	FF = furnishings Ff = furnishings ff = no furnishings
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

Confirmed Hair Genotypes

1.

Bichon Frise
II, CC, FF

2.

Border Terrier
LL, cc, FF

3.

Havanese
II, cc, FF

4.

Basset Hound
LL, cc, ff

5.

English Cocker Spaniel
II, cc, ff

6.

Irish Water Spaniel
II, CC, ff

7.

Golden Retriever
II, cc, ff

8.

Kerry Blue Terrier
LI or II, CC or Cc, FF