

The genomics of the American mutt: how genes affect appearance and behavior in mixed-breed dogs

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Dogs in animal shelters must be placed into their new homes based on limited information about their personalities. This information is often supplemented by guesswork based on whether the dog's appearance suggests particular breed ancestry. To better understand the influence of genetics and ancestry on canine behavior, we launched Darwin's Dogs, a citizen science project that collects behavioral information and DNA from pet dogs, regardless of their ancestry. To better understand difficulties in visual breed identification, we collected breed guesses about 21 extremely mixed-breed dogs on the website MuttMix.org.

The ongoing Darwin's Dogs project currently includes more than 1,300 sequenced purebred and mixed-breed dogs with complete behavioral profiles, and behavioral profiles only for about an additional 8,000+ dogs. We perform ancestry testing on every sequenced dog in the project. Our findings highlight the complexity of dog ancestry, specifically the deeply mixed-breed nature of many American mutts, and the limitations of existing genetic marker panels. Assessment of breed-specific traits through our behavioral data suggests that, while some breeds are more likely to display particular traits, these traits are not fixed for every dog in the breed. Moreover, some breed-characteristic behavioral traits do persist in mixed-breed dogs with ancestry from that breed, but not at high enough frequencies for breed to be used to predict behavior. We have successfully used this dataset to predict coat color, and coat length at high accuracy, and height at ~90% accuracy; it does not provide sufficient data to successfully predict behavior.

The MuttMix project, which closed its doors to new data on June 15, 2018 but continues to be open for guesses at muttmix.org, collected 432,743 breed ancestry guesses from 34,969 participants. Comparison of these guesses with our breed ancestry testing of the 21 mutts confirms that canine ancestry cannot be accurately ascertained by human perception alone in highly mixed-breed dogs.

Our work suggests that, with an extremely large data set, we can currently confidently predict "simple" or single-gene traits such as coat color; can predict intermediate traits such as height, controlled by a dozen or so genes, with somewhat less but still high confidence; and cannot yet predict complex traits such as behavioral traits, either using genetic testing or from knowledge of a dog's ancestry. Additionally, visual assessment of ancestry is extremely challenging in mixed-breed dogs, many of which may have very complex ancestry. Therefore, we recommend that shelters not rely on genetic testing or visual assessment of ancestry to make behavioral assessments of dogs in their care.