# Ancestry-inclusive dog genomics challenges popular breed stereotypes

## INTRODUCTION

Before the 1800s, dogs were probably primarily selected for functional roles such as hunting, guarding, and herding. Modern dog breeds are a recent invention defined by conformation to a physical ideal and purity of lineage. Breeds are commonly ascribed temperaments and behavioral proclivities based on the purported function of the ancestral source population. By extension, the breed ancestry of individual dogs is assumed to be predictive of temperament and behavior. Through our community science project Darwin’s Ark ([darwinsark.org](https://darwinsark.org/)), we enrolled a diverse cohort of pet dogs to explore how genetics shapes complex behavioral traits in this exceptional natural model.

## RATIONALE

Dogs are a natural system for investigating the genetics of complex traits. Millions of pet dogs live in human homes, sharing our environment, and receive sophisticated medical care. Behavioral disorders are treated with human psychiatric drugs, achieving similar response rates, and genetic studies suggest shared etiology with some human psychiatric conditions.

We developed Darwin’s Ark as an open data resource for collecting owner-reported phenotypes and genetic data and invited any dog owner to enroll their dog. We paired this with low-pass sequencing to capture nearly all common variation in this outbred population. Our inclusive approach achieved the large samples needed to investigate complex traits.

## RESULTS

We surveyed owners of 18,385 dogs (49% purebred) and sequenced the DNA of 2155 dogs. Most behavioral traits are heritable [heritability (h2) > 25%], but behavior only subtly differentiates breeds. Breed offers little predictive value for individuals, explaining just 9% of variation in behavior. For more heritable, more breed-differentiated traits, like biddability (responsiveness to direction and commands), knowing breed ancestry can make behavioral predictions somewhat more accurate (see the figure). For less heritable, less breed-differentiated traits, like agonistic threshold (how easily a dog is provoked by frightening or uncomfortable stimuli), breed is almost uninformative.

We used dogs of mixed breed ancestry to test the genetic effect of breed ancestry on behavior and compared that to survey responses from purebred dog owners. For some traits, like biddability and border collie ancestry, we confirm a genetic effect of breed that aligns with survey responses. For others, like human sociability and Labrador retriever ancestry, we found no significant effect.

Through genome-wide association, we found 11 regions that are significantly associated with behavior, including howling frequency and human sociability, and 136 suggestive regions. Regions associated with aesthetic traits are unusually differentiated in breeds, consistent with a history of selection, but those associated with behavior are not.

## CONCLUSION

In our ancestrally diverse cohort, we show that behavioral characteristics ascribed to modern breeds are polygenic, environmentally influenced, and found, at varying prevalence, in all breeds. We propose that behaviors perceived as characteristic of modern breeds derive from thousands of years of polygenic adaptation that predates breed formation, with modern breeds distinguished primarily by aesthetic traits. By embracing the full diversity of dogs—including purebred dogs, mixed-breed dogs, purpose-bred working dogs, and village dogs—we can fully realize dogs’ long-recognized potential as a natural model for genetic discovery.