



# Dog Genomics vs. Breed Stereotypes

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- Veterinarian
- Behavioral geneticist
- Founder of Functional Dog Collaborative
- Second author on the Mutt Paper

Second authors do a bunch of work  
...But don't have a lot of power!

Morrill, K., Hekman, J., Li, X., McClure, J., Logan, B., Goodman, L., ... & Karlsson, E. K. (2022). Ancestry-inclusive dog genomics challenges popular breed stereotypes. *Science*, 376(6592), eabk0639.



Question 1 / 11

Shapes and Colors

How old was Jenny when you adopted her?

☐ Young puppy (under 16 weeks)

☐ Older puppy (between 4 and 11 months)

☐ Young adult (between 1 and 2 years)

☐ Adult (Over 2 years)

We collected a very large sample size of behavioral information using owner surveys (16,000 dogs!).

Bias: owners who will fill out surveys online.

We also  
collected DNA  
on 2000+  
dogs.



# THE MUTTMIX PROJECT

"Appearances are a glimpse of the unseen." - Anaxagoras

[About this Project](#)

[Take Pup Quiz!](#)

[Take the Pup Quiz!](#)

[About this project](#)

We asked people how they identified the breeds in mutts.



**A**

### #1 Human sociability

less sociable to highly sociable

How comfortable dog is around people, especially if unfamiliar to them (17 questions)



### #2 Arousal level

aroused to composed

How easily stimulated dog is across contexts, i.e. activity level & impulse control (16 questions)



### #3 Toy-directed motor patterns

toy-directed to not toy-directed

How much dog displays motor patterns (e.g. grab-bite, chase), particularly towards toys (9 questions)



### #4 Biddability

biddable to independent

How readily dog responds to human direction, especially in the context of training (8 questions)



### #5 Agonistic threshold

assertive to diffident

How easily dog is provoked by a frightening, uncomfortable, or annoying stimulus (9 questions)



### #6 Dog sociability

less sociable to highly sociable

How comfortable dog is around other dogs, especially if unfamiliar to them (6 questions)



### #7 Environmental engagement

high engage. to low engage.

How interactive dog is with its familiar, daily environment (13 questions)



### #8 Proximity seeking

affectionate to aloof

How readily dog solicits human contact and closeness (7 questions)



**B**

### Does genetics matter?

Variation attributable to individual genetic differences

### Are breeds different?

Difference between dogs in a breed and randomly sampled dogs

### Gene mapping

Strength of top associated genomic locus? (minimum  $p=1 \times 10^{-6}$ )

### Functional relevance

Enrichment of brain-expressed genes at associated SNPs

### Does breed matter?

Variation attributable to breed

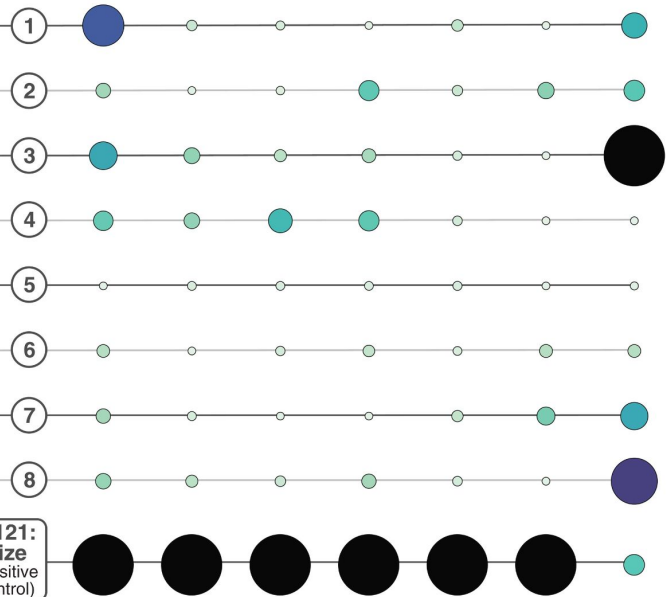
### Does breed matter (part 2)?

Effect of breed ancestry in mutts

### Evidence for past selection

Overlap of behavior loci and selection signals in breeds

test:  $h^2_{SNP}$  ANOVA PPS LMER MLMMA MAGMA



Q121: size (positive control)

Normalized score:

0.0 0.25 0.50 0.75 1.0

**A****Biddability**

How readily dog responds to human direction, especially in the context of training eight questions; defined by factor analysis of complete surveys for 10,253 dogs

**Heritability**

(1910 sequenced dogs)  
 $30.5 \pm 8.5\%$  ( $\pm$ SE)

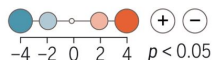
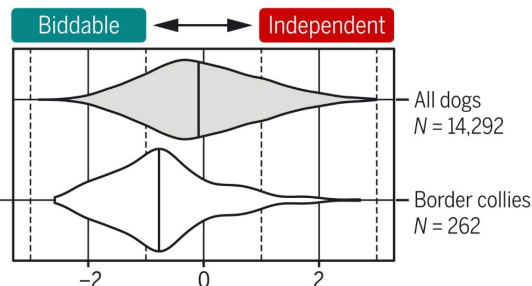
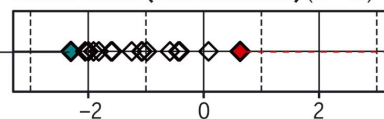
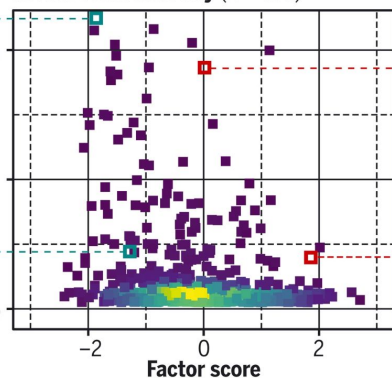
**B****Top 10 most differentiated breeds:****Independent**

- + Basset hound
- + Alaskan malamute
- + Shiba inu
- + Miniature pinscher
- + Great pyrenees
- + Siberian husky
- + Beagle
- + West highland white terrier
- + Dachshund
- + Yorkshire terrier

**Biddable**

- Belgian malinois
- Vizsla
- Border collie
- Australian cattle dog
- German shepherd dog
- Australian shepherd
- Golden retriever
- Bernese mountain dog
- Catahoula leopard dog
- Labrador retriever

Permutation z-score

**C****D****Sprocket****Border collies (DNA confirmed) ( $N = 16$ )****Caboose****E****Molly****Mixed-breed dogs with border collie ancestry ( $N = 638$ )****Hunter****Lily****TWoowie**



“Breed offers little predictive value for individuals, explaining just 9% of variation in behavior.”

- 0-25% with a median of 9% (some traits were more heritable)
- Statistical model: “how much of variation in behavior is explained by the ‘breed’ variable?”
- “Agonistic threshold” was the factor *least* explained by genetics *or* breed
- *We did not ask “given a dog is X breed, how likely is the dog to have Y trait.”*

darwinsark.org/muttomics

Personality  
traits




Breed-defining  
traits

# Every dog is an individual

How reliable are the behavioral traits we look for in dog breeds?

Select the features of a dog's personality below | Reset here 

 Human Sociability

Highly

Any


Less

 Arousal Level

Composed

Any

Aroused

 Toy-directed

Not

Any


Yes

 Biddability

Independent

Any


Biddable

 Agonistic Threshold

Diffident

Any


Assertive

 Dog Sociability

Highly

Any


Less

 Environmental Engagement

Low

Any

High

 Proximity Seeking

Aloof

Any

Affectionate

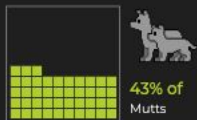
You selected a dog...

You selected a dog...

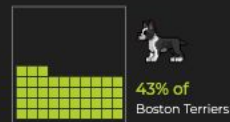
communicates  
displeasure

How common is a dog like this among...

Mixed breed dogs



Breed dogs



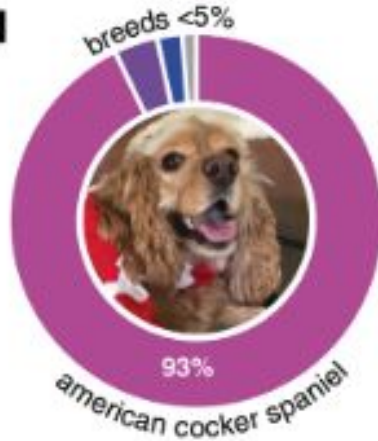
*“For more heritable, more breed-differentiated traits, like biddability (responsiveness to direction and commands), knowing breed ancestry can make behavioral predictions somewhat more accurate (see the figure). For less heritable, less breed-differentiated traits, like agonistic threshold (how easily a dog is provoked by frightening or uncomfortable stimuli), breed is almost uninformative.”*

*Behavioral factors show high variability within breeds, suggesting that although breed may affect the likelihood of a particular behavior to occur, breed alone is not, contrary to popular belief, informative enough to predict an individual's disposition.*

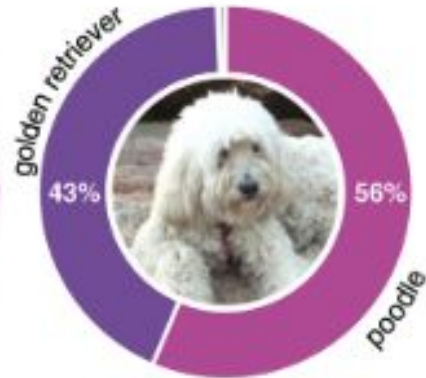


Many mutts have a *lot* of breeds in them!

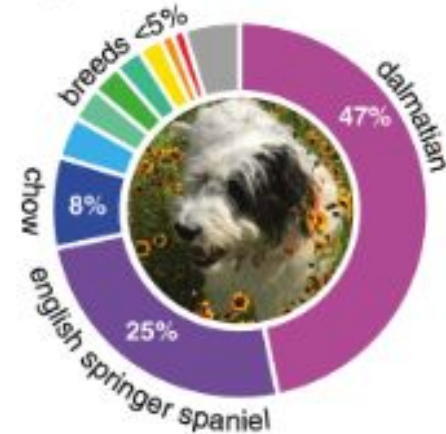
H



**Caramel: Purebred**



**Hubble: F1 hybrid**



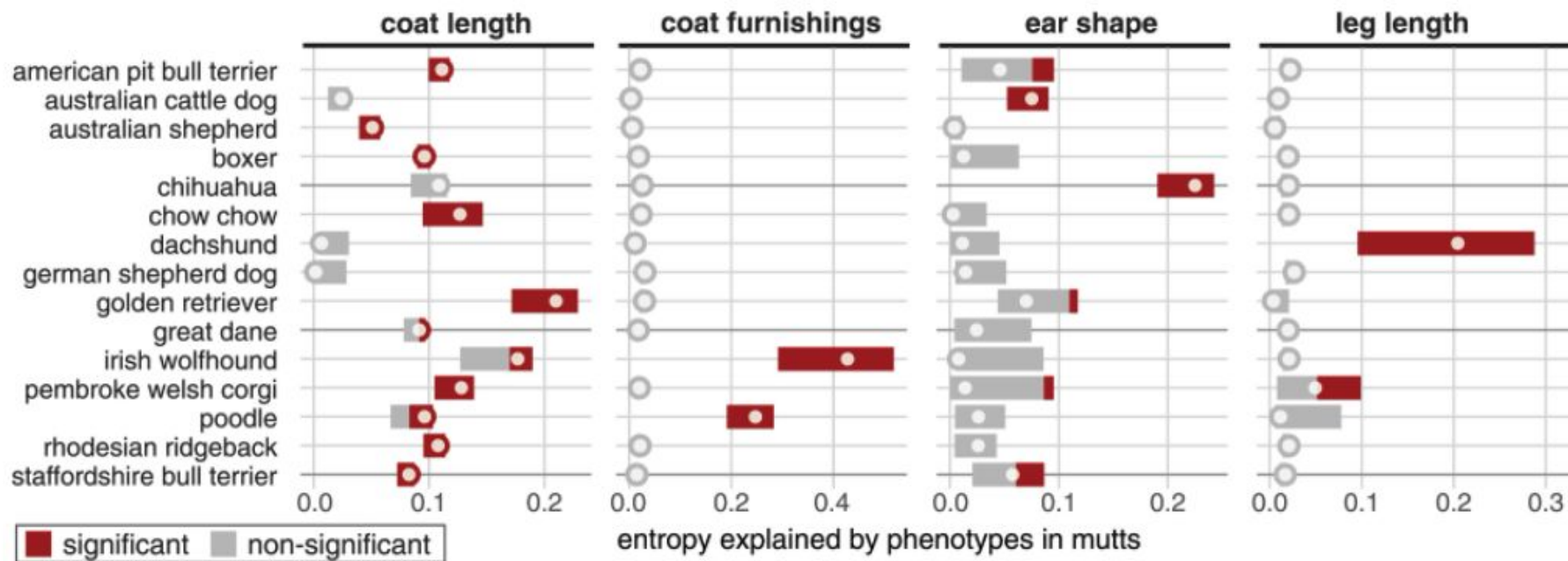
**Coconut: Recently admixed**



**Clarence: Highly admixed**

# How do we identify mutt ancestry?

F



The same amount of pittie ancestry can lead to very different phenotypes.

**D**

**American  
pit bull  
terrier**



**Jack #2**

% guessed

**1%**

% detected

**24%**



**Rosie**

**16%**

**30%**



**Reilly**

**17%**

**25%**



**Rudy**

**27%**

**28%**



**Clarence**

**39%**

**25%**



**Esme**

**60%**

**26%**

People use a limited set of traits to guess breed ancestry.

E

Maxine

Jack #1

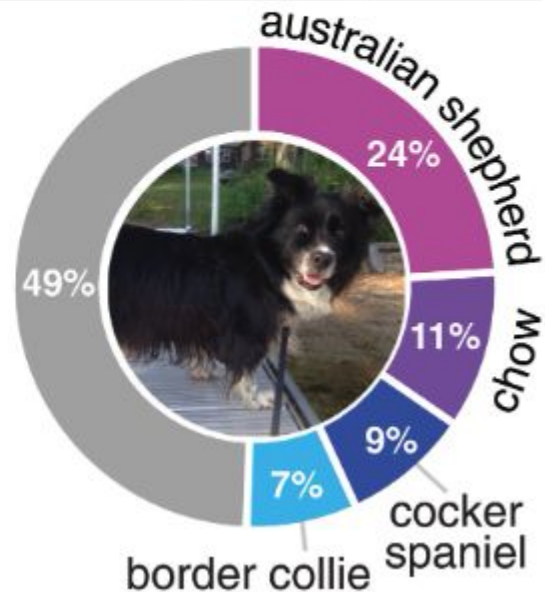
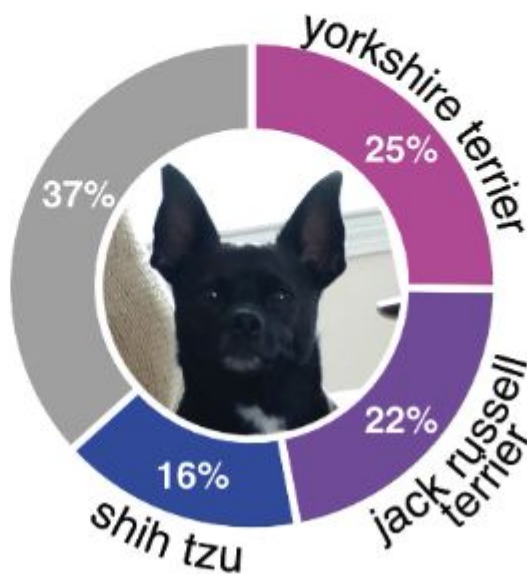
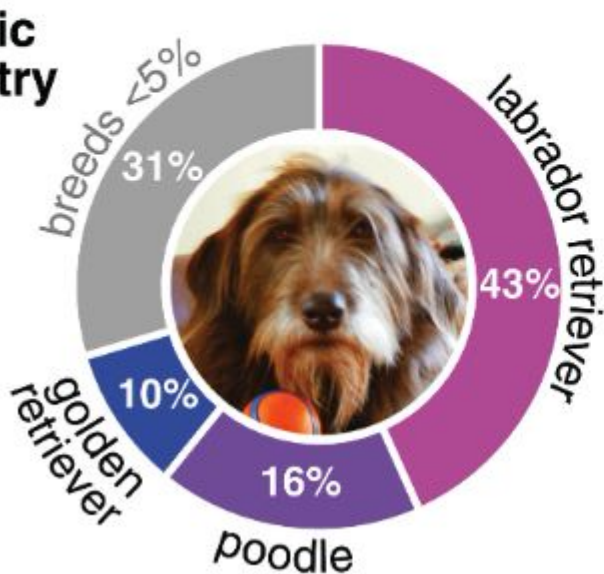
Bella

**Guessed (top two)** irish wolfhound (67%)  
airedale terrier (25%)

chihuahua (91%)  
boston terrier (33%)

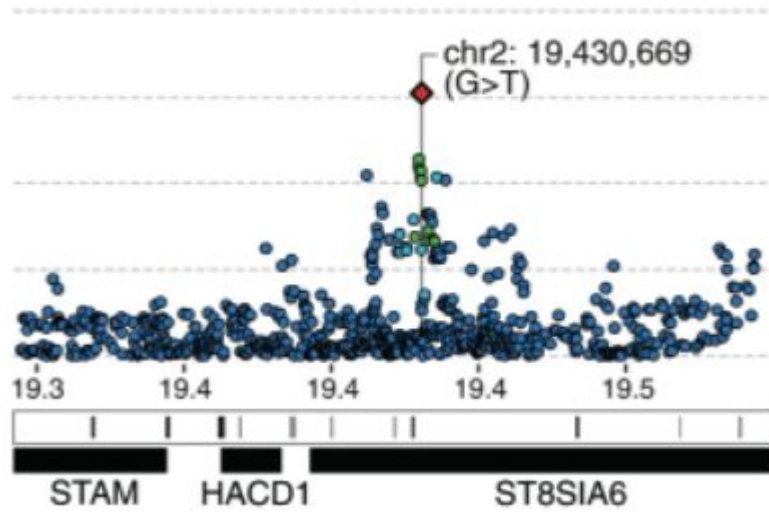
border collie (76%)  
corgi (70%)

**Genetic ancestry**

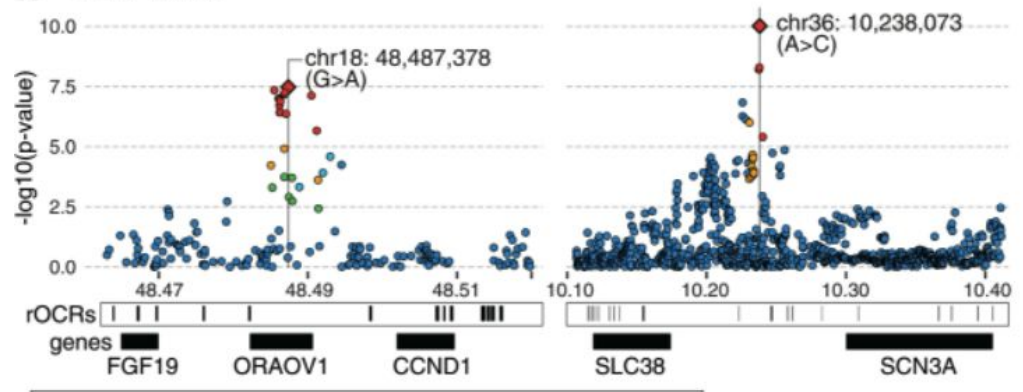


# New DNA regions associated with behavior!

**G** Factor 1: Human sociability.



**H** Q17: "Howls"





# Frequently asked questions

*Q: Were well-bred dogs used?*

*A: Dogs of all sorts were used! Which helps explain our findings: do you expect a field lab to behave the same as a guide dog lab or show lab?*

# Frequently asked questions

*Q: Does this paper say genetics don't matter?*

*A: Genetics are not the same as breed. This paper shows genetic influence on many traits.*

# Frequently asked questions

*Q: Does this paper say breed doesn't matter?*

*A: "Matter" or "doesn't matter" aren't scientific statements. This paper has a lot of analyses. What they mean in terms of "does breed matter" is up to the individual. The paper does show that using breed to predict an individual's behavior is a flawed approach.*

In my humble opinion...

...breed increases the likelihood of seeing certain traits.

That does not mean it is a good way of predicting traits in an individual.

# Take away messages: shelters

- Visual breed identification of mixed-breed dogs is unreliable.
- A purebred may have specific breed traits but may not.
- Assess each dog as an individual!



# Take away messages: legislators/lawyers (and others working against BSL)

- Visual breed identification of mixed-breed dogs is unreliable.
- A purebred may have specific breed traits but may not.
- “Agonistic threshold” is not strongly associated with any breed.
- Mixed breeds are less likely than purebreds to have breed traits.

All dogs are individuals!

# Where to get The Data

*All survey and genetic data from dogs of the Darwin's Ark and Mendel's Mutts cohorts, data from the MuttMix survey, and scripts used in analyses are archived in Dryad (104) and Zenodo (105).*

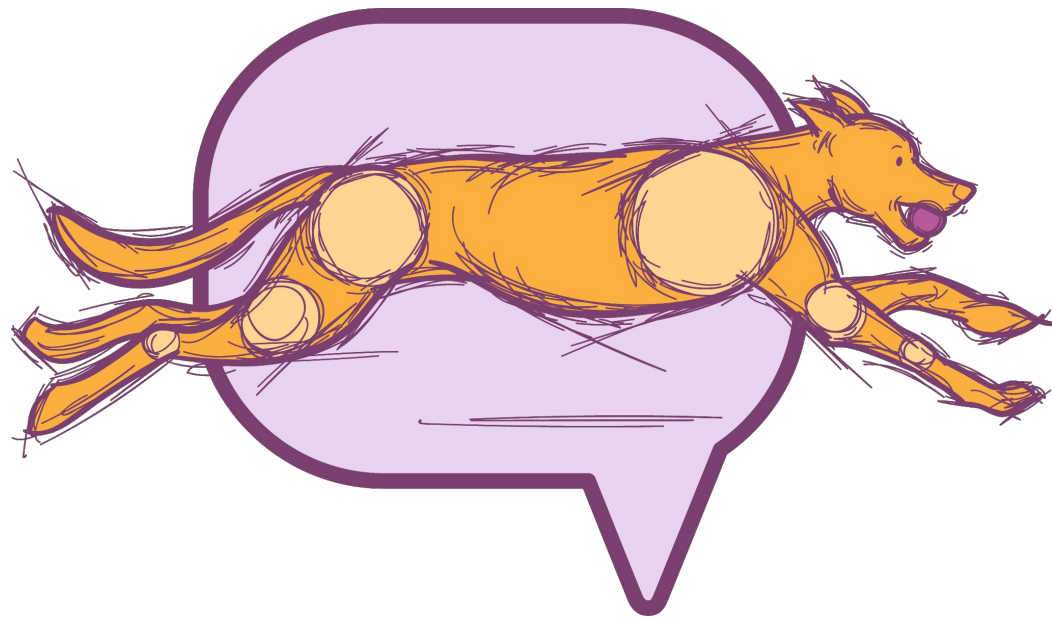
<https://datadryad.org/stash/dataset/doi:10.5061%2Fdryad.g4f4qrfr0>

## *Supplemental information*

[https://www.science.org/doi/suppl/10.1126/science.abk0639/suppl\\_file/science.abk0639\\_sm.pdf](https://www.science.org/doi/suppl/10.1126/science.abk0639/suppl_file/science.abk0639_sm.pdf)

## *Data S1 to S20*

[https://www.science.org/doi/suppl/10.1126/science.abk0639/suppl\\_file/science.abk0639\\_data\\_s1\\_to\\_s20.zip](https://www.science.org/doi/suppl/10.1126/science.abk0639/suppl_file/science.abk0639_data_s1_to_s20.zip)



# The Functional Dog Collaborative

Supporting the ethical breeding of healthy, behaviorally sound dogs.

Keep dogs out of shelters by intervening as early as possible: produce dogs who make great pets.

[functionalbreeding.org](https://functionalbreeding.org)

# Your questions?



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Mailing list: [dogzombie.com](http://dogzombie.com)

Functional Dog Collaborative:  
[functionalbreeding.org](http://functionalbreeding.org)