Exploring Genetic Diversity in the Olfactory Receptors of Dogs

From Wolf to Pug: What Sequence Variation Tells Us About the Evolution of Smell

Dogs are widely considered to have an excellent sense of smell, which is much more sensitive than that of humans. Since their domestication from grey wolves over 15,000 years ago, almost 400 breeds of dog have developed over time, with different abilities and traits, including sense of smell. Certain breeds have a strong reputation for their keen nose, whilst others are perceived to be less skilled in this area. Behavioural traits and anatomical features may account for some of these differences, but dog breeds also differ in their olfactory receptor genes. This article will summarise key findings from a recent article (Inoue *et al.* 2025[1]) that used whole-genome data sets from hundreds of dogs across many breeds, to investigate differences in the number of functional genes and variants for three chemosensory receptor gene families - olfactory receptors (ORs), vomeronasal receptors type 1 (V1Rs), and bitter taste receptors (T2Rs).

Olfactory Performance in Dogs

Scent hounds such as Beagles, Basset Hounds and Bloodhounds have been bred selectively for olfactory performance and, along with others such as Labrador Retrievers and German Shepherds, are used in the workplace as 'sniffer dogs,' in a range of critical tasks including detection of drugs or explosives and identification of people and even medical conditions. Such is their ability, that in many cases detection dogs are much more effective, reliable and versatile than instrumental detection methods.

Conversely, brachycephalic breeds such as Pugs and Bulldogs have short-nosed facial features and are considered to have impaired sense of smell compared with other breeds.[2] This is due to structural changes to the nose leading to reduced airflow to the nasal cavity and alterations in brain anatomy affecting the olfactory bulb.

Despite general assumptions based on their characteristics and the visual distinction between scent hounds and brachycephalic dogs, studies that have compared olfaction between different dog breeds have revealed some inconsistent results. In training-free olfactory tests, scent hounds and hand-reared grey wolves outperformed brachycephalic dogs and other breeds.[2] However, Pugs have been shown to outperform German Shepherds in odour discrimination tasks, especially when odorants were diluted.[3] It is possible that behavioural motivation may have contributed to those results. Thus, while olfactory capacity can be affected by physical features, behavioural factors or traits also play a role.

The Genetic Basis of Olfaction

In the main olfactory system, olfactory receptors (ORs) are expressed in the main olfactory epithelium of the nasal cavity, where they detect odours. Dogs have around 810 functional OR genes – twice as many as humans (~400), but fewer than half as many as African elephants (~2000).

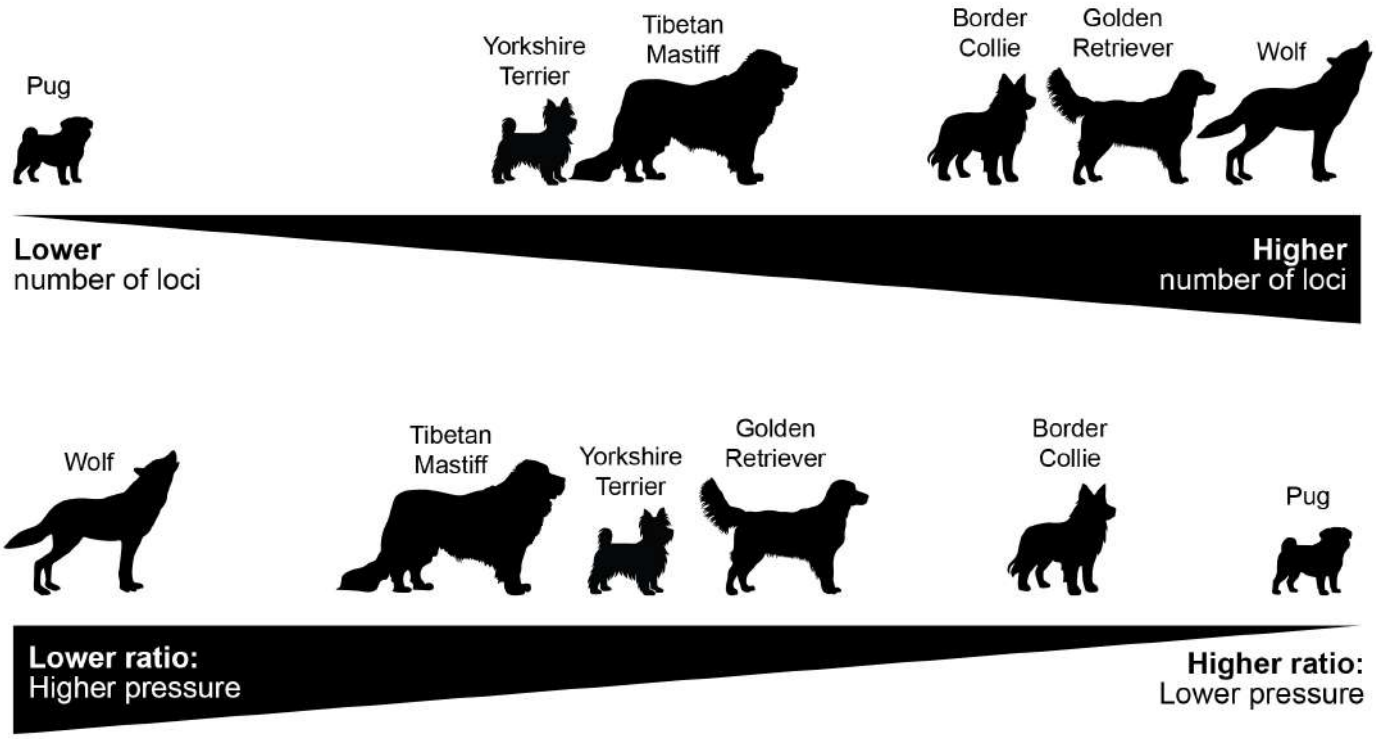
In the accessory olfactory system, or vomeronasal system, there are two types of receptors – vomeronasal receptors type 1 and type 2 (V1Rs and V2Rs) – for which the numbers of genes also vary greatly across mammalian species. V1Rs generally detect small molecules whereas V2Rs detect peptides and proteins. Around 8 to 9 functional V1R genes have been reported in dogs, but all V2R genes are pseudogenised and no longer produce functional receptors.

Sweet, umami and bitter tastes are mediated by taste receptors type 1 and type 2 (T1Rs and T2Rs), which are expressed on the tongue. There are three T1R genes in most mammals, including dogs, whereas T2R gene numbers vary across species.

A study published in early 2025 showed that, at the level of gene copy number, dogs have lost some functional OR gene copies over evolutionary time, with wolves and coyotes retaining larger OR gene repertoires compared with domestic dogs.[4] However, no differences in OR gene copy numbers were detected between dog breeds. This suggests that loss of OR gene copies in dogs occurred as part of the domestication process, but prior to breed formation.

Analysing Types of Genetic Variation in OR Genes Across Breeds

An analysis of single nucleotide variations (SNVs) published at the end of 2025 has built upon previous genetic studies and revealed genetic differences within chemosensory receptor genes across 121 breeds of dog and 8 grey wolves.[1] This study used data from the Dog Biomedical Variant Database Consortium – an international scientific collaboration established to support canine genomics and medical genetics research, for which Mars Petcare UK is a contributor of dog genomes. Whole-genome sequencing data across 635 individual dogs and 8 wolves were analysed to characterise SNVs in OR, V1R and T2R genes. Variants were classified according to predicted functional impact, with particular attention to nonsense mutations and frameshift mutations likely to disrupt receptor function. Overall, this revealed that numbers of V1R and T2R genes were similar across all animals studied, but the number of functioning OR genes varied.



Number of functional OR gene loci: Repertoire of OR genes (upper image)
Olfactory receptor gene N/S ratios: Genetic evolutionary pressure to remain unchanged (lower image)
Placement of breeds is illustrative and not all comparisons were made directly or significant; see Inoue et al. for full analyses and results.

Olfactory Receptor Gene Variation Among Dogs and Wolves

The number of functional gene loci was not significantly different between dogs and wolves for any of the three chemosensory receptors. However, SNV analysis showed that within those loci, dogs had higher ratios of nonsynonymous to synonymous substitutions in OR and T2R genes compared with wolves, suggesting less evolutionary pressure for these olfactory genes to stay unchanged and functional in dogs. This is in keeping with, and builds upon, findings from an earlier study, which concluded that dogs had fewer functional OR gene copies.[4] Thus, not only has the number of OR genes in dogs decreased since the domestication from grey wolves 15,000 years ago, but the remaining genes have also accumulated more mutations. The number of OR genes in a species' genome is closely related to size of the cribriform plate (CP) – a bony structure that forms part of the ethmoid bone found in the roof of the nasal cavity.[5] The CP supports the olfactory bulb, allowing olfactory nerves to pass from the mucosa to the bulb, and so is crucial for olfaction. CP size is reduced in domestic dogs compared with wolves and the main olfactory bulb is less developed.[4,6,7]

Number of Olfactory Receptor Genes in Scent Hounds

Across the 121 breeds included in the SNV study, seven were classified as scent hounds according to the Fédération Cynologique Internationale; these were Alpine Dachsbracke, Basset Hound, Bavarian Hound, Beagle, Dalmatian dog, Petit Basset Griffon Vendeen and Rhodesian Ridgeback. Surprisingly, the analysis revealed that these scent hounds did not have more functional OR genes compared with several other breed groups, including sight hounds. This is contrary to the common belief that scent hounds have been selectively bred for enhanced olfactory abilities. Other studies have also found that scent hounds and other breeds are comparable in terms of relative CP size and estimated numbers of OR genes.[4,6] However, in scent detection tests scent hounds can outperform other breeds and they are widely used for roles that require olfactory performance.[2] It may be that their aptitude for such roles is due to factors such as trainability, rather than substantial differences in olfactory genes and function.

Number of Olfactory Receptor Genes in Pugs

While scent hounds are commonly believed to have superior sense of smell, brachycephalic dogs are not generally associated with such skills.[2] Accordingly, in SNV analyses, Pugs had the fewest functional OR gene loci or unique functional OR genes compared with all other breeds with 10 or more samples. Pugs also showed a significantly higher nonsynonymous to synonymous substitution ratio than other breeds. This suggests that the functional OR gene repertoire has degenerated in the Pug lineage and that selective pressure to maintain functional OR genes is relaxed. Thus, not only are Pugs brachycephalic, which can affect olfaction, but their sensory genome has also been eroded. While this is consistent with the existing view that Pugs have reduced sense of smell, there are data showing that Pugs can do well in olfaction tests.[3] Again, this may be due to other characteristics such as behavioural motivation.

Another interesting finding was that one particular OR gene locus, Dog-OR7D4-1, was completely pseudogenised in Pugs, but remained mostly functional (>90%) in all other breeds. This gene evolved from the same ancestral gene as OR7D4 in humans, which encodes a receptor for androstenone. This steroidal pheromone in boar saliva acts as a sex pheromone in pigs but has measurable effects in dogs and humans. The functional implications for radical alteration and potential loss of this specific OR gene in Pugs are unknown, however it suggests that Pugs are missing one 'dimension,' of smell that other dogs retain.

Summary

- Generally, numbers of V1R and T2R genes were similar across all dogs studied, but the number of functioning OR genes varied.
- Dogs were found to have a higher ratio of nonsynonymous to synonymous substitutions in OR and T2R genes compared with wolves suggesting less evolutionary pressure for these chemosensory genes to stay unchanged.
- Scent hounds did not have more functional OR genes compared with other breeds, including sight hounds.
- Pugs had the fewest functional OR gene loci or unique functional OR genes compared with other breeds and had a higher nonsynonymous to synonymous ratio.
- Pugs appear to have lost the receptor for androstenone, whereas this remains functional in most other breeds.

Chemosensory Diversity Across Dog Breeds

The differences in OR gene repertoires across dog breeds demonstrated in this study provide insights into the genetic basis of chemosensory diversity. These findings, in turn, can help us understand some of the differences we see in olfactory function between dog breeds that exist today, such as reduced sense of smell in Pugs. The results also shed some light on the possible effects of domestication from wolves, namely, a relaxing of functional constraints on OR and T2R genes.

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