Published in final edited form as:
*Allergy*. 2016 January ; 71(1): 27–35. doi:10.1111/all.12726.

# Allergens in veterinary medicine

**R. S. Mueller**[1], **J. Janda**[2], **E. Jensen-Jarolim**[3], **C. Rhyner**[4], and **E. Marti**[5]

[1]Centre for Clinical Veterinary Medicine, Ludwig Maximilian University Munich, Munich, Germany [2]Institute of Animal Physiology and Genetics, Czech Academy of Sciences, Libechov, Czech Republic [3]Comparative Medicine, Messerli Research-Institute, University of Veterinary Medicine Vienna, Medical University Vienna and University Vienna, Vienna, Austria [4]Swiss Institute of Allergy and Asthma Research, Davos [5]Department of Clinical Research and Veterinary Public Health, University of Bern, Bern, Switzerland

## Abstract

Allergic diseases in animals are increasingly gaining importance in veterinary practice and as research models. For intradermal testing and allergen immunotherapy, a good knowledge of relevant allergens for the individual species is of great importance. Currently, the knowledge about relevant veterinary allergens is based on sensitization rates identified by intradermal testing or serum testing for allergen-specific IgE; crude extracts are the basis for most evaluations. Only a few studies provide evidence about the molecular structure of (particularly) dust mite, insect and mould allergens in dogs and horses, respectively. In those species, some major allergens differ from those in humans. This position paper summarizes the current knowledge about relevant allergens in dogs, cats and horses.

### Keywords

atopy; cat; dog; dust mites; horse

Allergic diseases are frequently observed in veterinary practice. With increasing standards in veterinary care, intradermal testing and allergen immunotherapy were introduced to small animal practice in the mid-nineteen hundreds; later, serum testing for allergen-specific IgE was developed for dogs, cats and horses. Although atopic asthma is rare in the dog and not much is known with regard to allergic rhinitis, atopic dermatitis is a frequently encountered disease in small animal practice and a focus of research in veterinary dermatology. It resembles human atopic dermatitis and has been proposed as a canine model for its human counterpart (1). Due to distinct breed predispositions (2), a genetic base in the dog was assumed for years and more recently has been confirmed with gene microarray studies (3). Atopic dermatitis is regularly observed in cats, but the clinical signs of atopic dermatitis are

**Correspondence** Ralf S. Mueller, Centre for Clinical Veterinary Medicine, Ludwig Maximilian University Munich, Munich, Germany. Tel.: +49 89 2180 2654 Fax: +49 89 2180 99 2654 R.Mueller@lmu.de.

Author contributions

All authors conceived the position paper, RM wrote the introduction and the sections on mite and flea allergens, EM those on insect allergens other than flea, EJJ those on pollen allergens, JJ those on mould allergens and CR the outlook and future trends. RM collated the parts and edited the manuscript, and all authors critically commented on drafts of the manuscript.


Europe PMC Funders Author Manuscripts

very different from the disease observed in humans (4). In contrast to dogs, feline asthma is not uncommon. Although intradermal testing, serum testing for allergen-specific IgE and allergen immunotherapy are used regularly in feline patients, studies elucidating the exact pathogenesis in this species are scarce. Horses develop skin and respiratory disorders that have been attributed to allergy. While recurrent airway obstruction, previously called 'heaves', has many similarities to human asthma, the best understood allergic disease in horses is insect-bite hypersensitivity (5). An effective treatment for this disease still remains elusive. In contrast to human medicine, where allergen immunotherapy is predominantly used for atopic rhinitis and asthma, allergen immunotherapy is an accepted and frequently conducted treatment for atopic dermatitis in the dog, cat and horse (6), although data on the major allergens relevant for dogs, cats and horses are limited (Table 1). In contrast to environmental allergens, studies evaluating food allergens in veterinary medicine are rare. Food rechallenges after elimination diets are notoriously difficult and not performed in a double-blinded fashion. Skin and serum testing for food allergens has been shown in many studies to be unreliable (7, 8). For this reason, this position paper focusses on information currently published regarding environmental allergens in canine, feline and equine medicine.

## Allergens in canine medicine

In canine allergology, dust mites are considered relevant and important allergens. This was initially based on the high number of positive reactions with intradermal testing against *Dermatophagoides (D.) farinae* and *D. pteronissynus*. The clinical relevance is further documented by a number of studies documenting the presence of mites and mite antigens in the dogs' environment as well as on the dogs' skin and coat (9), and clinical signs and T-cell responses after exposure to dust mite antigens in dogs sensitized to house dust mites (10). However, skin reactivity as well as dust mite-specific serum IgE has also been shown to be present in a high number of normal dogs (11), indicating that sensitization is not always associated with clinical signs. Sensitization without clinical disease is also reported in humans and varies between 13 and 36%, but in contrast to dogs, the rate of sensitization is generally lower than in atopic patients (12, 13). In some areas such as the UK, *D. pteronyssinus* is the predominant mite in the environment, and in other areas, *D. farinae* is more commonly found. Despite these differences in geographic prevalence, positive reactions to *D. farinae* are uniformly most frequently observed in intradermal tests (14, 15). Commercially available veterinary mite allergen preparations used in practice are extracts of *D. farinae* and *D. pteronyssinus* and are produced by a number of companies (15). Currently, to the authors' knowledge, recombinant mite allergens are not available for dogs and cats. The available human recombinant or purified mite antigens developed for humans are not considered suitable for dogs, as the currently identified major allergens in dogs differ from those in humans. On Western blot, binding of IgG4 to purified group 1 and 2 allergens was not observed in atopic dogs reacting to intradermal crude dust mite extract (16). The majority of atopic dogs in this study showed reactions to allergens of higher molecular weights (68 and 90 kDa, respectively). Similarly, only a minority of dust mite-allergic dogs with IgE antibodies against *D. farinae* and *D. pteronyssinus* had specific IgE against group 1 and group 2 allergens (17) or specifically against Der f 1, Der f 2, Der p 1 and Der p 2 (14). Homology of a protein with 98 kDa and 555 amino acids suggested a chitinase, which was

cloned, expressed and named Der f 15 (18). This molecule elicited positive reactions on intradermal testing in almost all atopic dogs reacting to a crude extract of *D. farinae*; similarly, all sera from dogs with antibodies against *D. farinae* extracts also had antibodies against Der f 15. A 60 kDa protein, Der f 18, was purified and showed sequence homology with other chitinases. Approximately 80% of atopic dogs with *D. farinae*-specific IgE antibodies also had antibodies against Der f 18 (19). Both Der f 15 and Der f 18 are localized to the digestive system of the mites. Der f 15 and Der f 18 can be considered major dust mite allergens in the dog. A range of minor allergens from 15-150 kDa were identified in dogs, but not characterized in more detail (17).

Sensitivity to storage mites such as *Tyrophagus putrescentiae, Lepidoglyphus destructor* and *Acarus siro* in dogs was based on skin test reactivity against mite extracts and storage mite-specific IgE (20, 21). Storage mites have been identified in the dogs' environment (22) as well as in dog food (23). However, the amount of contamination in the dog food seems to be dependent on optimal environmental conditions including warm temperature and high humidity (23) and is also influenced by the packaging material, and the duration the package has been open. In most studies evaluating storage mite sensitization, reactions against crude extracts were measured. In one study, the major allergens confirmed were >80 kD (20), but data on more specific identification are not available. Whether the high rate of sensitization is clinically relevant is not clear. There was no difference in the number of positive intradermal reactions to *Tyrophagus putrescentiae* (21) and *Lepidoglyphus destructor* (24) between normal dogs and dogs with atopic dermatitis, which is similar to what is observed in dogs sensitized to house dust mites (11). Prominent cross-reactivity has been reported between house dust and storage mite antigens in the dog (15), and exposure to storage mites leads to clinical signs in Beagles sensitized to house dust mites (25). This further complicates the interpretation of the clinical relevance of storage mite sensitivity.

Sensitization of dogs with atopic dermatitis against various plant-derived allergens such as from tree, grass and weed pollens was reported in several studies. In the largest study, the incidence of positive reactions to individual grass, tree and weed pollen extracts was between 10 and 25% (26). Those studies evaluating possible cross-reactivities between related and nonrelated allergen sources (27–29) came to the conclusion that concurrent positive reactions among botanically closely related plant allergens were significantly more common than those among nonrelated allergens. However, as more than 30% of the dogs did not show positive concurrent reactions to closely related allergens, cross-reactivity was not pronounced enough to warrant testing and desensitization with allergen extracts containing pollens from several different grasses, trees or weeds. No seasonal, sex- or age-dependent risk factors were observed in a recent comprehensive study of canine grass pollen sensitization in Western France (30). Importantly, as in humans, a significant increase in the number of dogs sensitized to grass pollen has been observed increasing from 14.4% (1999 and 2002) to 27.7% (2007 and 2010). More than 80% of the 262 tests were positive for at least one allergen, and 21% to at least one pollen allergen. Masuda et al. tested 42 Japanese atopic dogs by IDT and IgE test using 26 allergen extracts from 8 allergen sources (31). Japanese cedar (*Cryptomeria japonica*) pollen extract was the second most important allergen extract after house dust mite extract. Sensitization was observed in 24% of the

atopic dogs. Concentrations of IgE against Japanese cedar pollen were above 200 U/ml in 5 of the 10 positive dogs, whereas the other 5 remained under 60 U/ml. In a recent approach, the sensitization to single allergen molecules from Japanese cedar pollen was evaluated more precisely in 15 dogs. Besides IgE to Cry j 1, 76% showed IgE against Cry j 3, a major allergen in dogs (32).

Flea allergy is one of the most common allergies in the dog. On intradermal testing, positive reactions to fleas are more common than to any other insect (33). Serum antibodies against flea antigens were isolated in dogs many years ago. Up to half of the dogs in flea-infested environments develop IgE antibodies against flea antigens (34). Two proteins with a molecular weight of 8–12 and 40 kD were identified as relevant in dogs (35). A further protein of 18 kD was isolated from the saliva of the cat flea, *Ctenocephalides felis*, and elicited reactions in 100% of dogs sensitized to fleas and in 80% of clinically flea-allergic dogs. This antigen was considered a major allergen in dogs, cloned and named Cte f 1 (36).

Insect allergies other than flea allergies are relatively rare in dogs. Local and sometimes systemic anaphylactoid and anaphylactic reactions following hymenoptera stings have been described (37, 38). However, the incidence of anaphylactic reactions to bee or vespid stings is unknown in companion animals (39) and it is not always known whether the reactions are immune-mediated or due to massive envenomation. To our knowledge, it is also not known whether dogs are sensitized to the same venom allergens as human patients. There is only sparse published information available on hypersensitivity reactions to biting insects such as tabanids, black fly, mosquito, deer fly, horse fly, red ant and black ant, but clinical cases have been reported. Pruritic skin lesions are usually located on the thinly haired areas of the body, although there are definite regional areas of predisposition, such as the ear tips with some biting flies. Intradermal tests indicate sensitizations to horse flies, *Culicoides* spp. (midges), Simuliidiae (black flies) but also to other insects such as housefly, ant, deerfly and mosquito. However, intradermal test results with insect extracts have to be interpreted carefully, because positive reactions to intradermal tests with arthropods are often found in healthy control dogs at similar frequencies as in dogs with allergic skin disease (33). In one study, the only significant difference between control dogs and skin-allergic dogs was found with flea extract (33).

Sensitization to mould allergens occurs in dogs with atopic dermatitis (40). However, percentages of dogs with IgE against fungal allergens vary considerably among studies. These discrepancies may reflect lack of standardization in allergen extracts used in these studies or low specificity of available assays. Higher sensitization in North American studies (2) than in Europe (41), Australia (26) or Asia (42) suggested geographical influences. Mould proteases can degrade pollen allergens when stored in the same vial (43). There is evidence for clinical relevance in canine immunotherapy, as dogs with moulds in their SIT extract had a much lower success rate than dogs in the same environment for which the same mould extracts were stored in different vials (44). To the authors' knowledge, exact allergens relevant for canine allergology have not been identified and recombinant mould allergens have not been used in allergy testing in dogs.

Europe PMC Funders Author Manuscripts

## Allergens in feline medicine

House dust mite antigens (Der p 1, Der f 1 and group 2 allergens) were detected in households housing cats, at a concentration of > 2 mcg/g dust (45). This concentration is regarded as a risk factor for the development of sensitization in susceptible humans. Sensitization to house dust mites was documented by intradermal testing with extracts from *D. farinae* and *D. pteronyssinus* (46) and serum testing for dust mite-specific IgE (47). Both clinically allergic cats and cats with no clinical evidence of atopic disease showed the same concentrations of D.f.-specific IgE, in contrast to specific pathogen-free cats (48). When evaluating intradermal testing and testing for allergen-specific IgE using the Fc epsilon RI alpha to capture IgE in an asthmatic cat model, no cat showed positive results in either test prior to sensitization with house dust mite antigens, while the majority of cats developed positive skin test reactions after 28 days and dust mite-specific serum IgE after 50 days (49). However, although intradermal testing was positive more often in cats with allergic dermatitis than in nonallergic cats (46), serum concentrations of dust mite-specific IgE in normal cats were not different from cats with allergic skin disease (47). There is no information available about major and minor dust mite allergens in feline allergic skin disease, nor is there any conclusive evidence for or against the involvement of storage mites in feline allergic diseases.

Sensitization of cats against pollen antigens has been reported in a number of studies evaluating cats with skin disease, seasonal rhinitis and asthma. Sensitization was reported in 8.3% of asthmatic cats against orchard grass pollen, only in 4% against birch pollen, and ragweed or mugwort pollen sensitization was not reported (50). However, the proportion of cats showing symptoms of allergy with positive reactions on serum testing for allergen-specific IgE was not different to that of healthy cats in one study (51). Similarly, comparing the number of allergens with increased allergen-specific serum IgE in atopic cats with flea-allergic cats, cats with adverse food reactions or those with nonallergic pruritic skin disease, no significant differences were found between groups (52). IgE to environmental allergens including pollen could be even found in cats housed in a pathogen-free environment (53). Cats may also present with rhinitis, sporadically permitting the identification of causative pollen allergens (54).

Flea allergy is the most common allergy in the cat. In one study, the majority of cats reacting to a live flea challenge also showed an immediate hypersensitivity on intradermal testing with flea extracts from three manufacturers (55), although only a few reacted to the extracts of all manufacturers. Delayed-type reactions after 24 and 48 h were observed in fewer cats, again not often uniformly reacting to the extracts of all manufacturers (55).

Hymenoptera sting allergies seem to occur in cats (39), but the prevalence is probably low as the authors found no published reports on bee or vespid sting hypersensitivities in cats. Feline mosquito bite hypersensitivity is a predominantly facial-allergic skin disease characterized by papules, crusted papules and punctate ulcers. Lesions may also occur on the pawpads and pinnae. Histopathologically, severe eosinophilic inflammation in the dermis with lymphocytes, macrophage, neutrophil and/or mast cell infiltration and an associated eosinophilic folliculitis and furunculosis has been reported (56). Lesions have been shown to

occur at the exact site of previous mosquito bites. An elegant study showed that following controlled *Aedes albopictus* bite exposure, hypersensitive cats developed wheals within 20 min of exposure, followed by papules or small crusts after 12–48 h in some of the cats. Healthy control cats only showed slight and transient erythema after exposure. Similar results were obtained in intradermal tests. Furthermore, a Prausnitz–Küstner tests clearly confirmed the involvement of type I hypersensitivity reactions (56) in these mosquito bite-allergic cats. However, detailed information on the involved allergens is lacking.

The authors could not identify any reports regarding mould allergens in feline allergic skin disease.

## Allergens in equine medicine

House dust mites were reported to be present in horse rugs in one study (57) and in another study a variety of storage mite species were found in stables, but *Dermatophagoides* species could not be identified (58). Intradermal testing and serum testing for dust mite-specific IgE was reported in a number of studies with variable results. In most of those studies, crude extracts of a variety of storage mites and house dust mites were used. In a few studies, no difference could be observed in the sensitization to storage mite extracts between normal horses and horses suffering from chronic bronchitis (59), now called recurrent airway obstruction (RAO) or heaves, an asthma-like condition of horses, caused by hypersensitivity reactions to hay dust, or chronic urticaria based on intradermal testing (60) as well as serum testing (59, 60). Based on those studies, positive reactions to crude extracts are not useful in the diagnosis of allergic skin or respiratory disease. However, the concentrations of the crude extracts used varied and threshold concentrations for intradermal testing of horses with mite extracts have only recently been established (58). In a retrospective study at the University of California-Davis, successful immunotherapy, in which crude extracts have been used for both intradermal testing and desensitization of horses suffering from atopic dermatitis or urticaria, has been reported (61).

The authors are not aware of any reported allergic reactions following hymenoptera stings in horses. However, hypersensitivity reactions to insect bites occur relatively frequently in this species. The best characterized allergic reaction to insect bites in horses is an IgE-mediated dermatitis caused by bites of insects of the genus Culicoides, named insect bite hypersensitivity (IBH) or sometimes also Culicoides hypersensitivity, summer eczema or Queensland itch. The genus Culicoides consists of over 500 different biting *Culicoides* species. *Culicoides* spp. can be found worldwide, except in Iceland. The prevalence of IBH varies between 3 and 60% depending on the environment and genetic background of the horse (62). A number of studies have shown that IBH-affected horses more frequently have positive IDT results with *Culicoides* extract and sometimes also with other insect extracts than healthy control horses (62). The involvement of *Culicoides* allergens in IBH has also been demonstrated in functional *in vitro* tests such as sulfidoleukotriene release (CAST, Bühlmann laboratories AG) (63) or histamine release tests using *C. nubeculosus*, *C. sonorensis* or *C. obsoletus* extracts (64, 65). Furthermore, sulfidoleukotrienes and histamine are released significantly more frequently from IBH-affected horses than from healthy

controls following the stimulation of peripheral blood leucocytes with *Simulium vittatum* extract (63).

Since 2009, allergens from different *Culicoides* species (*C. sonorensis* [Cul s], *C. nubeculosus* [Cul n], *C. obsoletus* [Cul o]) have been characterized at the molecular level and expressed as recombinant protein (Table 1) (65–68). Some of these *Culicoides* allergens are homologous to known allergens in the human field, such as amylase/maltase (Cul s1, Cul n8, Cul o1), hyaluronidase (Cul n2, Cul o2) antigen-5 (Cul n 1, Cul o 3), D-7-related proteins (Cul n 9, Cul o 6, Cul o 2b), cysteine protease (Cul n 3) and serine protease inhibitor (Cul o 1b). Nevertheless, identities at the amino acid level between these *Culicoides* allergens and the homologous allergens relevant in human allergy are not very high with, for example, 44% for hyaluronidase (Api m2, a major allergen of bee venom) and cross-reactivity is probably rather unlikely to occur. In a pilot study, it was observed that sera from horses with high IgE levels to recombinant *C. nubeculosus* hyaluronidase did not bind to the corresponding allergen from bees (E. Marti, unpublished data). Additionally, *Culicoides* salivary gland proteins with yet unknown function have been identified as allergens relevant for IBH (Cul n 4- 7, Cul n 10, Cul o 5 and Cul o 7). All these recombinant allergens elicit immediate-type reactions in IBH-affected horses in intradermal tests indicating sensitization.

IDT, CAST and immunoblots have revealed that a proportion of the IBH-affected horses concurrently react with *Simulium* extracts. IgE-binding salivary gland proteins from *S. vittatum* were identified using phage surface display technology and expressed as recombinant proteins (69). These proteins showed sequence similarities to antigen 5-like protein (Sim v 1), to a serine protease inhibitor (Sim v 2) and to alpha-amylase (Sim v 3 and Sim v 4) (Table 1). Furthermore, three *S. vittatum* erythema proteins (SVEPs) were identified. IBH-affected horses had significantly higher IgE levels than controls against r-Sim v 1, 2, 3, 4, whereas the r-SVEP showed only marginal IgE binding. First studies using immunoblots suggested that the antigen 5-like proteins from *C. nubeculosus* (Cul n 1) and *S. vittatum* (Sim v 1) are cross-reactive, although they only display 49% identity at the amino acid level (69). Cross-reactivity was confirmed by extended inhibition ELISA experiments clearly showing that Sim v 1 in fluid phase is able to strongly inhibit binding of serum IgE to solid-phase-coated Cul n 1 in a concentration-dependent manner and vice versa (70). This study indicates that the reactivity to black flies observed in some of the IBH-affected horses is probably due to cross-reactivity and is secondary to Culicoides sensitization. Hypersensitivity reactions to other insects are much less well studied in horses, but they seem to play a role in equine recurrent urticaria and atopic dermatitis. Horses affected with these conditions show positive IDT reactions to insect extracts more frequently than control horses, although positive IDT reactions are also common in those controls (71). Depending on the study, positive reactions to *Aedes*, black ant, horse fly, black fly, deer fly or mosquito were found more frequently in patients than in healthy controls. To our knowledge, sera from these horses have never been tested for IgE binding to recombinant insect allergens.

Horses develop respiratory and skin diseases due to pollen allergens and show positive intradermal test results against tree, grass and weed pollens (61) as well as pollen-specific serum IgE (5, 72). Most reactions on intradermal testing with grass pollen extracts were

observed against Bermuda grass, with weed extracts against sage mix (both in approximately half the horses) and with tree pollen extracts against olive, cedar, orange and alder trees (61). Positive correlations between symptom severity and exogenous factors such as climatic conditions, rainfall or seasonal pollen counts were observed (73).

Exposure to mouldy hay plays a central role in equine recurrent airway obstruction (RAO). Challenge with mouldy hay or mould extracts leads to exacerbation of clinical symptoms. Although non-IgE-mediated mechanisms have been implicated in the pathogenesis of RAO, there is also evidence of sensitization to fungal allergens. Basophil histamine release in response to stimulation with fungal allergens or hay extract is higher in RAO-affected horses than in healthy controls (74). Histamine release from pulmonary mast cells after *in vitro* stimulation with fungal extracts was also significantly higher in RAO-affected horses than healthy controls. Schmallenbach et al. (1998) found increased *Aspergillus fumigatus* extract-specific IgE and IgG responses in bronchoalveolar lavage fluid of RAO-affected horses (75). Other studies detected IgE antibodies specific for crude extracts of *Aspergillus fumigatus, Alternaria alternata* and *Penicillium notatum*, and the recombinant allergens Asp f 7,8, 9 and Alt a 1 in BAL or serum (59, 76). IgE specific for crude mould extracts was not different between healthy and affected horses. In contrast, IgE against recombinant allergens was detectable only in some horses – more frequently in RAO-affected horses than in healthy controls. IgG antibodies specific for the *A. fumigatus* extract were also detected in both healthy and RAO horses with no significant differences between the two groups, while RAO horses had significantly higher IgG responses against Asp f 8 than healthy horses (59, 76). It is possible that IgE plays a role only in a subset of RAO patients with genetic predisposition. Scharrenberg et al. (2010) detected Asp f 7-specific IgE, IgGa, IgGb and IgG(T) in two families from RAO-affected sires. No differences in total IgE, but significant differences in Asp f 7-specific IgE levels were found between RAO-affected animals and controls, but also between the offspring of one stallion vs the other (77). Genetic analysis identified several quantitative trait loci associated with this phenotype. Although fungal extracts as well as recombinant allergens have been used to detect IgE responses against moulds in horses, it is not known which proteins are major allergens in horses. The authors could also not find reports of immunotherapy using fungal allergens in horses.

## Outlook and future trends

The number of pets in total and thus also the number of animals with diagnosed allergies are continuously increasing and so are the awareness of and the interest in veterinary allergology. It can be assumed, that increased awareness of the differences will enhance the transfer of recent trends in human allergology to veterinary medicine. This will be facilitated by the increased economic impact of veterinary medicine for pets as well as for farm animals. This fact can be exemplified by the discovery of novel allergens playing a key role in Culicoides-mediated allergic skin disease of horses. The identification of these allergens was pursued over a 20-year period and enabled the discovery of new allergens in human medicine. The direct consequence of this availability is the development of component-specific diagnostics tools to identify insect-bite hypersensitivity in the horse and to perform research towards specific immunotherapies with recombinant insect allergens to desensitize horses suffering from this disease. More recent approaches, in silico based or derived from

the wet laboratory, such as integrated approaches using genomic, transcriptomic, proteomic and metabolomic data, will be more and more frequently used, as the overall price erosion of these high-throughput technologies will make them increasingly available for use in veterinary medicine. Identification of and testing for major allergens in each species may allow one to differentiate clinically nonrelevant extract-specific IgE from relevant IgE directed against the true allergens and thus improve the diagnostic accuracy of allergy testing and probably also the success of allergen-specific immunotherapy. The usage of recent technologies in veterinary medicine will thus provide novel insights into the basic immunological mechanisms of pet mammals, leading to the discovery of novel biomarkers, identification of new allergens, and thus to novel diagnostic tools and therapeutic concepts. The formation of a veterinary allergology special interest group within the EAACI is giving new impetus to the field of veterinary allergy, while human allergy may also benefit from the veterinary field as allergic diseases in domestic species can represent natural models of allergy. Unlike mouse models, dogs and cats kept as pets are generally exposed to the same environmental influences as humans and thus are much better mirrors of the human disease counterpart. New diagnostic and therapeutic tools successful in veterinary practice may be more applicable to the human field than those developed in the laboratory. Thus, there is great potential in the collaboration of human and veterinary allergology. An increased and facilitated interaction of specialists in both fields, one of the aims of the EAACI Interest Group ‘Comparative and Veterinary Allergology’, may benefit all and help in advancing allergology worldwide.

## Conclusion

Despite the increasing awareness of the importance of allergic diseases in animals, the discipline of veterinary allergology limps behind its human counterpart. There are several reasons for this. The full methodology available in human allergology often cannot be transferred to other species without adjustments. For example, simple development of an ELISA to detect allergen-specific IgE often suffered from the limited availability of well-characterized detection molecules such as monoclonal antibodies specific for the species of interest. However, for dogs and horses, some of those reagents are now available. For some animals, the exact interaction of defined immunoglobulin isotypes with their high- and low-affinity receptors on cells of the immune system is not elucidated to the same degree as in humans. Nevertheless, during the recent years, increasing effort led to novel reagents and technologies and stimulated research in the field of veterinary allergology, resulting in the identification of novel relevant allergens and deeper understanding of animal-specific pathogenesis of allergic diseases. This availability of methodologies for diagnosis and therapy, together with an increasing awareness for allergic diseases in veterinary practice as well as in the general population of companion animal owners, facilitated this development. Between one in two (UK and France) and one in three households (Germany) have pets (http://www.ifaheurope.org/companion-animals/about-pets.html: accessed 7.7.14), and the potential economical impact can easily be deduced from the large numbers of pets living in European households (260 Mio, without fish and reptiles). Veterinary allergology has become an important, dedicated veterinary discipline, and allergic disorders of man’s best

friend slowly gain the awareness they deserve beyond being mere models for human allergies.

## Acknowledgment

We would like to acknowledge the support of EAACI.

Funding

EAACI.

Conflicts of interest

EJJ was supported by the Austrian Science Fund FWF, grant SFB F4606-B19. EM was supported by the Swiss National Science Foundation grant no. 310030-160196/1.

## References

1. Marsella R, Girolomoni G. Canine models of atopic dermatitis: a useful tool with untapped potential. J Invest Dermatol. 2009; 129:2351–2357. [PubMed: 19516261]
2. Zur G, Ihrke PJ, White SD, Kass PH. Canine atopic dermatitis: a retrospective study of 266 cases examined at the University of California, Davis, 1992-1998. Part I. Clinical features and allergy testing results. Vet Dermatol. 2002; 13:89–102. [PubMed: 11972892]
3. Schamber P, Schwab-Richards R, Bauersachs S, Mueller RS. Gene expression in the skin of dogs sensitized to the house dust mite *Dermatophagoides farinae*. G3: Genes - Genomes - Genetics. 2014; 4:1787–1795. [PubMed: 25098772]
4. Hobi S, Linek M, Marignac G, Olivry T, Beco L, Nett C, et al. Clinical characteristics and causes of pruritus in cats: a multicentre study on feline hypersensitivity-associated dermatoses. Vet Dermatol. 2011; 22:406–413. [PubMed: 21410570]
5. Fadok VA. Update on equine allergies. Vet Clin North Am Equine Pract. 2013; 29:541–550. [PubMed: 24267673]
6. Loewenstein C, Mueller RS. A review of allergen-specific immunotherapy in human and veterinary medicine. Vet Dermatol. 2009; 20:84–98. [PubMed: 19320877]
7. Hardy JI, Hendricks A, Loeffler A, Chang Y-M, Verheyen KL, Garden OA, et al. Food-specific serum IgE and IgG reactivity in dogs with and without skin disease: lack of correlation between laboratories. Vet Dermatol. 2014; 25:447–470. [PubMed: 24890097]
8. Jeffers JG, Shanley KJ, Meyer EK. Diagnostic testing of dogs for food hypersensitivity. J Am Vet Med Assoc. 1991; 198:245–250. [PubMed: 2004984]
9. Jackson AP, Foster AP, Hart BJ, Helps CR, Shaw SE. Prevalence of house dust mites and dermatophagoides group 1 antigens collected from bedding, skin and hair coat of dogs in south-west England. Vet Dermatol. 2005; 16:32–38. [PubMed: 15725103]
10. Olivry T, Linder KE, Paps JS, Bizikova P, Dunston S, Donne N, et al. Validation of a novel epicutaneous delivery system for patch testing of house dust mite-hypersensitive dogs. Vet Dermatol. 2012; 23:525–e106. [PubMed: 23050930]
11. Lian TM, Halliwell RE. Allergen-specific IgE and IgGd antibodies in atopic and normal dogs. Vet Immunol Immunopathol. 1998; 66:203–223. [PubMed: 9880099]
12. Nelson RP Jr, DiNicolo R, Fernandez-Caldas E, Seleznick MJ, Lockey RF, Good RA. Allergen-specific IgE levels and mite allergen exposure in children with acute asthma first seen in an emergency department and in nonasthmatic control subjects. J Allergy Clin Immunol. 1996; 98:258–263. [PubMed: 8757201]
13. Squillace SP, Sporik RB, Rakes G, Couture N, Lawrence A, Merriam S, et al. Sensitization to dust mites as a dominant risk factor for asthma among adolescents living in central Virginia. Multiple regression analysis of a population-based study. Am J Respir Crit Care Med. 1997; 156:1760–1764. [PubMed: 9412552]

14. Masuda K, Tsujimoto H, Fujiwara S, Kurata K, Hasegawa A, Yasueda H, et al. IgE sensitivity and cross-reactivity to crude and purified mite allergens (Der f 1, Der f 2, Der p 1, Der p 2) in atopic dogs sensitive to Dermatophagoides mite allergens. Vet Immunol Immunopathol. 1999; 72:303–313. [PubMed: 10628674]
15. Saridomichelakis MN, Marsella R, Lee KW, Esch RE, Farmaki R, Koutinas AF. Assessment of cross-reactivity among five species of house dust and storage mites. Vet Dermatol. 2008; 19:67–76. [PubMed: 18336423]
16. Noli C, Bernadina WE, Willemse T. The significance of reactions to purified fractions of *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* in canine atopic dermatitis. Vet Immunol Immunopathol. 1996; 52:147–157. [PubMed: 8809997]
17. Nuttall TJ, Lamb JR, Hill PB. Characterisation of major and minor Dermatophagoides allergens in canine atopic dermatitis. Res Vet Sci. 2001; 71:51–57. [PubMed: 11666148]
18. McCall C, Hunter S, Stedman K, Weber E, Hillier A, Bozic C, et al. Characterization and cloning of a major high molecular weight house dust mite allergen (Der f 15) for dogs. Vet Immunol Immunopathol. 2001; 78:231–247. [PubMed: 11292526]
19. Weber E, Hunter S, Stedman K, Dreitz S, Olivry T, Hillier A, et al. Identification, characterization, and cloning of a complementary DNA encoding a 60-kd house dust mite allergen (Der f 18) for human beings and dogs. J Allergy Clin Immunol. 2003; 112:79–86. [PubMed: 12847483]
20. Arlian LG, Schumann RJ, Morgan MS, Glass RL. Serum immunoglobulin E against storage mite allergens in dogs with atopic dermatitis. Am J Vet Res. 2003; 64:32–36. [PubMed: 12518875]
21. Mueller RS, Fieseler KV, Rosychuk RA, Greenwalt T. Intradermal testing with the storage mite *Tyrophagus putrescentiae* in normal dogs and dogs with atopic dermatitis in Colorado. Vet Dermatol. 2005; 16:27–31. [PubMed: 15725102]
22. Farmaki R, Saridomichelakis MN, Leontides L, Papazahariadou MG, Gioulekas D, Koutinas AF. Dust mite species in the households of mite-sensitive dogs with atopic dermatitis. Vet Dermatol. 2012; 23:222–e245. [PubMed: 22575020]
23. Brazis P, Serra M, Selles A, Dethioux F, Biourge V, Puigdemont A. Evaluation of storage mite contamination of commercial dry dog food. Vet Dermatol. 2008; 19:209–214. [PubMed: 18494758]
24. Mueller RS. Intradermale Reaktionen gegen die Vorratsmilbe Lepidoglyphus destructor bei normalen Hunden und Hunden mit atopischer Dermatitis. Kleintierpraxis. 2011; 56:5–10.
25. Marsella R, Saridomichelakis MN. Environmental and oral challenge with storage mites in beagles experimentally sensitized to *Dermatophagoides farinae*. Vet Dermatol. 2010; 21:105–111. [PubMed: 20187916]
26. Mueller RS, Bettenay SV, Tideman L. Aeroallergens in canine atopic dermatitis in southeastern Australia based on 1000 intradermal skin tests. Aust Vet J. 2000; 78:392–399. [PubMed: 10920777]
27. Buckley L, Schmidt V, McEwan N, Nuttall T. Cross-reaction and co-sensitization among related and unrelated allergens in canine intradermal tests. Vet Dermatol. 2013; 24:422–427. [PubMed: 23745529]
28. Mueller RS, Chapman PL. Cross reactivity of airborne allergens based on 1000 intradermal test results. Aust Vet J. 2004; 82:351–354. [PubMed: 15267094]
29. Mueller RS, Chapman PL, Rosychuk RE, Bettenay SV, Fieseler KV. Evaluation of cross-reactivity of allergens by use of intradermal testing in atopic dogs. Am J Vet Res. 2002; 63:874–879. [PubMed: 12061535]
30. Roussel AJ, Bruet V, Bourdeau PJ. Characterisation of dog sensitisation to grass pollen in western France from 1999 to 2010. Vet Rec. 2013; 172:686. [PubMed: 23748582]
31. Masuda K, Sakaguchi M, Saito S, Deboer DJ, Fujiwara S, Kurata K, et al. In vivo and in vitro tests showing sensitization to Japanese cedar (*Cryptomeria japonica*) pollen allergen in atopic dogs. J Vet Med Sci. 2000; 62:995–1000. [PubMed: 11039597]
32. Kubota S, Miyaji K, Shimo Y, Shimakura H, Takase Y, Okamoto N, et al. IgE reactivity to a Cry j 3, an allergen of Japanese cedar (*Cryptomeria japonica*) pollen in dogs with canine atopic dermatitis. Vet Immunol Immunopathol. 2012; 149:132–135. [PubMed: 22749702]

33. Willis EL, Kunkle GA, Esch RE, Grier TJ, Kubilis PS. Intradermal reactivity to various insect and arachnid allergens among dogs from the southeastern United States. J Am Vet Med Assoc. 1996; 209:1431–1434. [PubMed: 8870740]
34. Ichikawa Y, Beugnet F. Epidemiological survey of anti-flea IgE in dogs in Japan by using an antigen-specific IgE quantitative measurement method. Parasite. 2012; 19:173–176. [PubMed: 22550629]
35. Lee SE, Johnstone IP, Lee RP, Opdebeeck JP. Putative salivary allergens of the cat flea, *Ctenocephalides felis* felis. Vet Immunol Immunopathol. 1999; 69:229–237. [PubMed: 10507308]
36. McDermott MJ, Weber E, Hunter S, Stedman KE, Best E, Frank GR, et al. Identification, cloning, and characterization of a major cat flea salivary allergen (Cte f 1). Mol Immunol. 2000; 37:361–375. [PubMed: 11074254]
37. Cowell AK, Cowell RL, Tyler RD, Nieves MA. Severe systemic reactions to Hymenoptera stings in three dogs. J Am Vet Med Assoc. 1991; 198:1014–1016. [PubMed: 2032903]
38. Waddell LS, Drobatz KJ. Massive envenomation by *Vespula* spp in two dogs. Veterinary Emergency and Critical Care. 1999; 9:67–71.
39. Fitzgerald KT, Flood AA. Hymenoptera stings. Clin Tech Small Anim Pract. 2006; 21:194–204. [PubMed: 17265905]
40. Hill PB, DeBoer DJ. The ACVD task force on canine atopic dermatitis (IV): environmental allergens. Vet Immunol Immunopathol. 2001; 81:169–186. [PubMed: 11553378]
41. Willemse A, van den Brom WE. Investigations of the symptomatology and the significance of immediate skin test reactivity in canine atopic dermatitis. Res Vet Sci. 1983; 34:261–265. [PubMed: 6878876]
42. Masuda K, Sakaguchi M, Fujiwara S, Kurata K, Yamashita K, Odagiri T, et al. Positive reactions to common allergens in 42 atopic dogs in Japan. Vet Immunol Immunopathol. 2000; 73:193–204. [PubMed: 10690934]
43. Rosenbaum MR, Esch RE, Schwartzman RM. Effects of mold proteases on the biological activity of allergenic pollen extracts. Am J Vet Res. 1996; 57:1447–1452. [PubMed: 8896682]
44. Schnabl B, Bettenay SV, Dow K, Mueller RS. Results of allergen-specific immunotherapy in 117 dogs with atopic dermatitis. Vet Rec. 2006; 158:81–85. [PubMed: 16428661]
45. Loft KE, Rosser EJ Jr. Group 1 and 2 Dermatophagoides house dust mite allergens in the microenvironment of cats. Vet Dermatol. 2010; 21:152–158. [PubMed: 19725913]
46. Schleifer SG, Willemse T. Evaluation of skin test reactivity to environmental allergens in healthy cats and cats with atopic dermatitis. Am J Vet Res. 2003; 64:773–778. [PubMed: 12828264]
47. Taglinger K, Helps CR, Day MJ, Foster AP. Measurement of serum immunoglobulin E (IgE) specific for house dust mite antigens in normal cats and cats with allergic skin disease. Vet Immunol Immunopathol. 2005; 105:85–93. [PubMed: 15797478]
48. Gilbert S, Halliwell RE. Feline immunoglobulin E: induction of antigen-specific antibody in normal cats and levels in spontaneously allergic cats. Vet Immunol Immunopathol. 1998; 63:235–252. [PubMed: 9656458]
49. Lee-Fowler TM, Cohn LA, DeClue AE, Spinka CM, Ellebracht RD, Reinero CR. Comparison of intradermal skin testing (IDST) and serum allergen-specific IgE determination in an experimental model of feline asthma. Vet Immunol Immunopathol. 2009; 132:46–52. [PubMed: 19819027]
50. Stursberg, U. Felines Asthma und Chronische Bronchitis: Untersuchungen zu Anamnese, Allergiediagnostik und Therapie mit Propentofyllin. Ludwig Maximilian University; Munich: 2010.
51. Diesel A, DeBoer DJ. Serum allergen-specific immunoglobulin E in atopic and healthy cats: comparison of a rapid screening immunoassay and complete-panel analysis. Vet Dermatol. 2011; 22:39–45. [PubMed: 20584155]
52. Belova S, Wilhelm S, Linek M, Beco L, Fontaine J, Bergvall K, et al. Factors affecting allergen-specific IgE serum levels in cats. Can J Vet Res. 2012; 76:45–51. [PubMed: 22754094]
53. Loft, KE.; Pedersen, K. North American Veterinary Dermatology Forum; 2007. Veterinary Dermatology; Lihue, USA: 2007. The presence of pollen and house dust mite allergen-specific IgE in serum of 15 SPF cats and prevalence of house dust mite allergens (dermatophagoides pteronyssinus 1, Dermatophagoides farinae 1, and mite group 2) in their microenvironment; p. 184

54. Masuda K, Kurata K, Sakaguchi M, Yamashita K, Hasegawa A, Ohno K, et al. Seasonal rhinitis in a cat sensitized to Japanese cedar (*Cryptomeria japonica*) pollen. J Vet Med Sci. 2001; 63:79–81. [PubMed: 11217069]
55. Bond R, Hutchinson MJ, Loeffler A. Serological, intradermal and live flea challenge tests in the assessment of hypersensitivity to flea antigens in cats (*Felis domesticus*). Parasitol Res. 2006; 99:392–397. [PubMed: 16572336]
56. Nagata M, Ishida T. Cutaneous reactivity to mosquito bites and its antigens in cats. Vet Dermatol. 1997; 8:19–26.
57. Wallace JC, Vogelnest LJ. Evaluation of the presence of house dust mites in horse rugs. Vet Dermatol. 2010; 21:602–607. [PubMed: 20529010]
58. Roberts HA, Hurcombe SD, Hillier A, Lorch G. Equine intradermal test threshold concentrations for house dust mite and storage mite allergens and identification of stable acari fauna. Vet Dermatol. 2014; 25:124–134. [PubMed: 24800265]
59. Eder C, Crameri R, Mayer C, Eicher R, Straub R, Gerber H, et al. Allergen-specific IgE levels against crude mould and storage mite extracts and recombinant mould aller gens in sera from horses affected with chronic bronchitis. Vet Immunol Immunopathol. 2000; 73:241–253. [PubMed: 10713338]
60. Tahon L, Baselgia S, Gerber V, Doherr MG, Straub R, Robinson NE, et al. In vitro allergy tests compared to intradermal testing in horses with recurrent airway obstruction. Vet Immunol Immunopathol. 2009; 127:85–93. [PubMed: 19027178]
61. Stepnik CT, Outerbridge CA, White SD, Kass PH. Equine atopic skin disease and response to allergen-specific immunotherapy: a retrospective study at the University of California-Davis (1991-2008). Vet Dermatol. 2012; 23:29–35. [PubMed: 21777308]
62. Schaffartzik A, Hamza E, Janda J, Crameri R, Marti E, Rhyner C. Equine insect bite hypersensitivity: what do we know? Vet Immunol Immunopathol. 2012; 147:113–126. [PubMed: 22575371]
63. Baselgia S, Doherr MG, Mellor P, Torsteinsdottir S, Jermann T, Zurbriggen A, et al. Evaluation of an in vitro sulphidoleukotriene release test for diagnosis of insect bite hypersensitivity in horses. Equine Vet J. 2006; 38:40–46. [PubMed: 16411585]
64. Langner KF, Darpel KE, Drolet BS, Fischer A, Hampel S, Heselhaus JE, et al. Comparison of cellular and humoral immunoassays for the assessment of summer eczema in horses. Vet Immunol Immunopathol. 2008; 122:126–137. [PubMed: 18155778]
65. van der Meide NM, Meulenbroeks C, van Altena C, Schurink A, Ducro BJ, Wagner B, et al. Culicoides obsoletus extract relevant for diagnostics of insect bite hypersensitivity in horses. Vet Immunol Immunopathol. 2012; 149:245–254. [PubMed: 22906994]
66. Langner KF, Jarvis DL, Nimtz M, Heselhaus JE, McHolland LE, Leibold W, et al. Identification, expression and characterisation of a major salivary allergen (Cul s 1) of the biting midge *Culicoides sonorensis* relevant for summer eczema in horses. Int J Parasitol. 2009; 39:243–250. [PubMed: 18708061]
67. Peeters LM, Janssens S, Goddeeris BM, De Keyser K, Wilson AD, Kaufmann C, et al. Evaluation of an IgE ELISA with *Culicoides* spp. extracts and recombinant salivary antigens for diagnosis of insect bite hypersensitivity in Warmblood horses. Vet J. 2013; 198:141–147. [PubMed: 23891138]
68. Schaffartzik A, Marti E, Torsteinsdottir S, Mellor PS, Crameri R, Rhyner C. Selective cloning, characterization, and production of the *Culicoides nubeculosus* salivary gland allergen repertoire associated with equine insect bite hypersensitivity. Vet Immunol Immunopathol. 2011; 139:200–209. [PubMed: 21071100]
69. Schaffartzik A, Weichel M, Crameri R, Bjornsdottir TS, Prisi C, Rhyner C, et al. Cloning of IgE-binding proteins from *Simulium vittatum* and their potential significance as allergens for equine insect bite hypersensitivity. Vet Immunol Immunopathol. 2009; 132:68–77. [PubMed: 19836085]
70. Schaffartzik A, Marti E, Crameri R, Rhyner C. Cloning, production and characterization of antigen 5 like proteins from *Simulium vittatum* and *Culicoides nubeculosus*, the first cross-reactive allergen associated with equine insect bite hypersensitivity. Vet Immunol Immunopathol. 2010; 137:76–83. [PubMed: 20537727]

71. Jose-Cunilleras E, Kohn CW, Hillier A, Saville WJ, Lorch G. Intradermal testing in healthy horses and horses with chronic obstructive pulmonary disease, recurrent urticaria, or allergic dermatitis. J Am Vet Med Assoc. 2001; 219:1115–1121. [PubMed: 11700711]

72. Kalina WV, Pettigrew HD, Gershwin LJ. IgE ELISA using antisera derived from epsilon chain antigenic peptides detects allergen-specific IgE in allergic horses. Vet Immunol Immunopathol. 2003; 92:137–147. [PubMed: 12730014]

73. Ward MP, Couetil LL. Climatic and aeroallergen risk factors for chronic obstructive pulmonary disease in horses. Am J Vet Res. 2005; 66:818–824. [PubMed: 15934609]

74. Dirscherl P, Grabner A, Buschmann H. Responsiveness of basophil granulocytes of horses suffering from chronic obstructive pulmonary disease to various allergens. Vet Immunol Immunopathol. 1993; 38:217–227. [PubMed: 7507274]

75. Schmallenbach KH, Rahman I, Sasse HH, Dixon PM, Halliwell RE, McGorum BC, et al. Studies on pulmonary and systemic *Aspergillus fumigatus*-specific IgE and IgG antibodies in horses affected with chronic obstructive pulmonary disease (COPD). Vet Immunol Immunopathol. 1998; 66:245–256. [PubMed: 9880102]

76. Kunzle F, Gerber V, Van Der Haegen A, Wampfler B, Straub R, Marti E. IgE-bearing cells in bronchoalveolar lavage fluid and allergen-specific IgE levels in sera from RAO-affected horses. J Vet Med A Physiol Pathol Clin Med. 2007; 54:40–47. [PubMed: 17359454]

77. Scharrenberg A, Gerber V, Swinburne JE, Wilson AD, Klukowska-Rotzler J, Laumen E, et al. IgE, IgGa, IgGb and IgG(T) serum antibody levels in offspring of two sires affected with equine recurrent airway obstruction. Anim Genet. 2010; 41(Suppl 2):131–137. [PubMed: 21070286]

78. Masuda K, Tsujimoto H, Fujiwara S, Kurata K, Hasegawa A, Taniguchi Y, et al. IgE-reactivity to major Japanese cedar (*Cryptomeria japonica*) pollen allergens (Cry j 1 and Cry j 2) by ELISA in dogs with atopic dermatitis. Vet Immunol Immunopathol. 2000; 74:263–270. [PubMed: 10802293]

79. van der Meide NM, Roders N, Sloet van Oldruitenborgh-Oosterbaan MM, Schaap PJ, van Oers MM, Leibold W, et al. Cloning and expression of candidate allergens from *Culicoides obsoletus* for diagnosis of insect bite hypersensitivity in horses. Vet Immunol Immunopathol. 2013; 153:227–239. [PubMed: 23561552]

Europe PMC Funders Author Manuscripts

## Table 1

Allergens of documented importance in domestic animals that have been characterized at the molecular level

| Allergen source | Allergen name | Identity/homology | MW(kDa) | Relevant in species | References |
|---|---|---|---|---|---|
| *Dermatophygoides farinae* | Der f 15 | Chitinase | 98/109 | Dog | (18) |
| | Der f 18 | Chitinase | 60 | Dog | (19) |
| *Cryptomeria japonica* | Cry j 1 | Pectate lyase | 41 | Human Dog | (32) |
| *Cryptomeria japonica* | Cry j 2 | Polygalacturonase | 56 | Human Dog | (78) |
| *Cryptomeria japonica* | Cry j 3 | Thaumatin-like protein | 24 | Human Dog | (32) |
| *Ctenocephalides felis* | Cte f 1 | None | 18 | Dog | (36) |
| *Culicoides nubeculosus* | Cul n 1 | Antigen-5 like | 25 | Horse | (70) |
| | Cul n 2 | Hyaluronidase | 46.7 | Horse | (68) |
| | Cul n 3 | Cysteine endopeptidase | 44.6 | Horse | (68) |
| | Cul n 4 | None | 17.5 | Horse | (68) |
| | Cul n 5 | None | 45.7 | Horse | (68) |
| | Cul n 6 | None | 16.9 | Horse | (68) |
| | Cul n 7 | None | 20.9 | Horse | (68) |
| | Cul n 8 | Maltase | 68.7 | Horse | (68) |
| | Cul n 9 | D7-related | 15.5 | Horse | (68) |
| | Cul n 10 | None | 47.8 | Horse | (68) |
| | Cul n 11 | Trypsin | 30.1 | Horse | (68) |
| *Culicoides obsoletus* | Cul o 1* | Maltase | 66.8 | Horse | (79) |
| | Cul o 2* | Hyaluronidase | 42.3 | Horse | (79) |
| | Cul o 3 | Antigen-5 like | 27.9 | Horse | (79) |
| | Cul o 4 | Trypsin | 27.1 | Horse | (79) |
| | Cul o 5 | None | 17.9 | Horse | (79) |
| | Cul o 6 | D7-related | 15.2 | Horse | (79) |
| | Cul o 7 | None | 15 | Horse | (79) |
| | Cul o1* | Kunitz protease inhibitor | 23.3 | Horse | (67) |
| | Cul o 2* | D7-related | 17.5 | Horse | (67) |
| *Culicoides sonorensis* | Cul s 1 | Maltase | 66 | Horse | (66) |
| *Simulium vittatum* | Sim v 1 | Antigen 5 like | 29.8 | Horse | (69) |
| | Sim v 2 | Kunitz protease Inhibitor | 9.6 | Horse | (69) |
| | Sim v 3 | A-amylase | 28 | Horse | (69) |
| | Sim v 4 | a-amylase | 26 | Horse | (69) |
| *Aspergillus fumigatus* | Asp f 7 | None | 27.4 | Human, horse | (59, 75) |
| | Asp f 8 | Acidic P 2 ribosomal proteins | 11 | Human, horse | (59, 60, 75) |

*Nomenclature needs modification. These allergen sequences were submitted to GenBank at the same time by different groups.