

Allergen nomenclature

World Health Organization/IUIS Allergen Nomenclature

Subcommittee: Te Piao King, Chairman, Donald Hoffman,

Henning Lowenstein, David G. Marsh, Thomas A. E. Platts-Mills,
and Wayne Thomas

Rapid advances have been made in the past few years on allergen characterization and sequence determination by chemical and molecular biologic approaches. This is indicated by the list of allergens with known partial or complete amino acid sequences in Table I. A number of other important allergens are known in addition to those in Table I, but their sequences are as yet not known. A useful source for known allergens is the Allergen Database (ALBE) in which are compiled their known biochemical and immunologic properties together with their sequence data if known.¹

To take into account these advances, a revision of the current allergen nomenclature system² is given below. As in the current system, the proposed revisions are for allergens that induce IgE-mediated (atopic) allergy in human beings. In addition to the expected thorough immunochemical characterization of any newly discovered allergen, investigators are urged to obtain partial, or preferably complete, sequence data before using the official nomenclature system. Also, it is expected that investigators would screen a reasonable population size to establish the frequency of response to the newly discovered allergens among patients.*

Investigators frequently refer to allergens as major or minor. The generally accepted meaning of this terminology is that an allergen is designated as either major or minor depending on whether

more or less than 50% of patients tested have the corresponding allergen-specific IgEs.³⁻⁵

The revised nomenclature for allergens is given below together with the proposed nomenclature systems for (1) allergen genes, mRNAs, and cDNAs and (2) recombinant and synthetic peptides of allergenic interest.

REVISED ALLERGEN NOMENCLATURE Allergens

Allergens are designated according to the accepted taxonomic name of their source as follows: the first three letters of the genus, space, the first letter of the species, space, and an Arabic number. The numbers are assigned to the allergens in the order of their identification, and the same number is generally used to designate homologous allergens of related species. As two examples, Lol p 1 refers to the first pollen allergen identified from *Lolium perenne*, ryegrass, and Cyn d 1 refers to the homologous pollen allergen from *Cynodon dactylon*, Bermuda grass.

In some instances, the above system of the first three letters of a genus and the first letter of a species must be modified to include an additional letter for designation of the exact genus or species. For example, four of the many vespids that can cause insect allergy are *Vespula vulgaris*, *Vespula vidua*, *Vespula consobrina*, and *Vespa crabo*. The homologous major venom allergens, antigen 5s, from *Vespula vulgaris* and *Vespula vidua* are both designated as Ves v 5 in the existing nomenclature, and those from *Vespula consobrina* and *Vespa crabo* are designated as Ves c 5. To avoid these ambiguities, antigen 5s from *Vespula vulgaris* and *Vespula vidua* will be designated as Ves v 5 and Ves vi 5 respectively, and those from *Vespula consobrina* and *Vespa crabo* will be designated as Ves c 5 and Vesp c 5, respectively. In the examples given, the modified nomenclature is used for the allergens from *Vespula vidua* and *Vespa crabo*, because the allergens from *Vespula vulgaris* were character-

Current members: R. Aalberse, M. Chapman, D. R. Hoffman, T. A. E. Platts-Mills, Wayne Thomas, and H. Lowenstein (Chairperson).

This article was first published in the *Bulletin of the World Health Organization*, 72(5): 796-806 (1994), and is reproduced here by permission. Minor corrections have been made here. Reprints not available.

J ALLERGY CLIN IMMUNOL 1995;96:5-14.

Copyright © 1995 by Mosby-Year Book, Inc.

0091-6749/95 \$3.00 + 0 1/1/64027

*Investigators are invited to consult our committee members for assigning an allergen number before publication to avoid duplication.

TABLE I. Some allergens with known sequences

Allergen source	Allergens: Systematic and original names	MW (kd)	Sequence data	References*
A. Weed pollens				
Asterales				
<i>Ambrosia artemisiifolia</i> (short ragweed)	Amb a 1; antigen E	38	C	8, 20
	Amb a 2; antigen K	38	C	8, 21
	Amb a 3; Ra3	11	C	22
	Amb a 5; Ra5	5	C	11, 23
	Amb a 6; Ra6	10	C	24, 25
	Amb a 7; Ra7	12	P	26
	Amb a?	11	C	27
<i>Ambrosia trifida</i> (giant ragweed)	Amb t 5; Ra5G	4.4	C	9, 10, 28
<i>Artemisia vulgaris</i> (mugwort)	Art v 2	35	P	29
B. Grass pollens†				
Poales				
<i>Cynodon dactylon</i> (Bermuda grass)	Cyn d 1	32	C	30, 31
	Dac g 1; AgDg1	32	P	32
	Dac g 2	11	C	33
<i>Dactylis glomerata</i> (orchard grass)	Dac g 5	31	P	34
	Lol p 1; group I	27	C	35, 36
	Lol p 2; group II	11	C	37
<i>Lolium perenne</i> (ryegrass)	Lol p 3; group III	11	C	38
	Lol p 5	31	P	34
	Lol p 9; Lol p Ib	31/35	C	39
<i>Phleum pratense</i> (timothy)	Phl p 1	27	C	40, 41
	Phl p 5; Ag25	32	C	42, 43, 44, 45
<i>Poa pratensis</i> (Kentucky bluegrass)	Poa p 1; group I	33	P	46
	Poa p 5	31	P	34
	Poa p 9	32/34	C	47
<i>Sorghum halepense</i> (Johnson grass)	Sor h 1		C	48
C. Tree pollens				
Fagales				
<i>Alnus glutinosa</i> (alder)	Aln g 1	17	C	49
	Bet v 1	17	C	50
<i>Betula verrucosa</i> (birch)	Bet v 2; profilin	15	C	51
<i>Carpinus betulus</i> (hornbeam)	Car b 1	17	C	52
<i>Corylus avellana</i> (hazel)	Cor a 1	17	C	53
<i>Quercus alba</i> (white oak)	Que a 1	17	P	54
Pinales				
<i>Cryptomeria japonica</i> (sugi)	Cry j 1	41–45	C	55, 56
	Cry j 2		C	57, 58

Allergen source	Allergens: Systematic and original names	MW (kd)	Sequence data	References*
<i>Juniper sabinoides</i> (mountain cedar)	Jun s 1	50	C	58
<i>Juniper virginiana</i> (eastern red cedar)	Jun v 1	45–50	C	58
Oleales				
<i>Olea europea</i> (olive)	Ole e 1	16	C	59, 60
D. Mites				
<i>Dermatophagoides pteronyssinus</i> (mite)	Der p 1; antigen P ₁	25	C	61
	Der p 2	14	C	62
	Der p 3; trypsin	28/30	P	63
	Der p 4; amylase	60	P	64
	Der p 5	14	C	65
	Der p 6; chymotrypsin	25	P	66
	Der p 7	22–28	C	67
<i>Dermatophagoides microceras</i> (mite)	Der m 1	25	P	68
<i>Dermatophagoides farinae</i> (mite)	Der f 1	25	C	69
	Der f 2	14	C	70, 71
	Der f 3	30	P	72
<i>Lepidoglyphus destructor</i> (storage mite)	Lep d 1	15	P	73
E. Animals				
<i>Canis domesticus</i> ‡	Can d 1	25	C	74, 75
	Can d 2	27	C	74, 75
<i>Felis domesticus</i> (cat saliva)	Fel d 1; cat-1	38	C	15
<i>Mus musculus</i> (mouse urine)	Mus m 1; MUP	19	C	76, 77
<i>Rattus norvegicus</i> (rat urine)	Rat n 1	17	C	78, 79
F. Fungi				
<i>Aspergillus fumigatus</i>	Asp f 1	18	C	80
	Asp f ?	90	P	81
	Asp f ?	55	P	82
<i>Candida albicans</i>	Cand a ?	40	C	83
<i>Alternaria alternata</i>	Alt a 1	28	P	84–86
<i>Trichophyton tonsurans</i>	Tri t 1	30	P	87
G. Insects				
<i>Apis mellifera</i> (honeybee)	Api m 1; phospholipase A ₂	16	C	88
	Api m 2; hyaluronidase	44	C	89
	Api m 4; mellitin	3	C	90
<i>Bombus pennsylvanicus</i> (bumblebee)	Bom p 1; phospholipase	16	P	91
	Bom p 4; protease		P	91

TABLE I. Cont'd

Allergen source	Allergens: Systematic and original names	MW (kd)	Sequence data	References*
<i>Blattella germanica</i> (cockroach)	Bla g 2	20	C	92
<i>Chironomus thummi thummi</i> (midges)	Chi t 1; hemoglobin	16	C	93
<i>Dolichovespula maculata</i> (White-faced hornet)	Dol m 1; phospholipase A ₁	35	C	94
	Dol m 2; hyaluronidase	44	C	95
	Dol m 5; antigen 5	23	C	96, 97
<i>Dolichovespula arenaria</i> (yellow hornet)	Dol a 5; antigen 5	23	C	98
<i>Polistes annularis</i> (wasp)	Pol a 1; phospholipase A ₁	35	P	99
	Pol a 2; hyaluronidase	44	P	99
	Pol a 5; antigen 5	23	C	98
<i>Polistes exclamans</i> (wasp)	Pol e 1; phospholipase A ₁	34	P	101
	Pol e 5; antigen 5	23	C	98
<i>Polistes fuscatus</i> (wasp)	Pol f 5; antigen 5	23	C	100
<i>Polistes metricus</i> (wasp)	Pol m 5; antigen 5	23	P	100
<i>Vespula flavopilosa</i> (yellow jacket)	Ves f 5; antigen 5	23	C	100
<i>Vespula germanica</i> (yellow jacket)	Ves g 5; antigen 5	23	C	100
<i>Vespula maculifrons</i> (yellow jacket)	Ves m 1; phospholipase A ₁	33.5	C	102
	Ves m 2; hyaluronidase	44	P	103
	Ves m 5; antigen 5	23	C	98
<i>Vespula pennsylvanica</i> (yellow jacket)	Ves p 5; antigen 5	23	C	100
<i>Vespula squamosa</i> (yellow jacket)	Ves s 5; antigen 5	23	C	100
<i>Vespula vidua</i> (wasp)	Ves vi 5	23	C	100
<i>Vespula vulgaris</i> (yellow jacket)	Ves v 1; phospholipase A ₁	35	C	99
	Ves v 2; hyaluronidase	44	P	99
	Ves v 5; antigen 5	23	C	98
<i>Vespa crabro</i> (European hornet)	Vesp c 1; phospholipase	34	P	101
	Vesp c 5.0101; antigen 5	23	C	100
	Vesp c 5.0102; antigen 5	23	C	100
<i>Solenopsis invicta</i> (fire ant)	Sol i 2	13	C	104, 105
	Sol i 3	24	C	104
	Sol i 4	13	C	104
H. Foods				
<i>Gadus callarias</i> (cod)	Gad c 1; allergen M	12	C	106
<i>Gallus domesticus</i> (chicken)	Gal d 1; ovomucoid	28	C	107, 108
	Gal d 2; ovalbumin	44	C	107, 108
	Gal d 3; conalbumin (Ag22)	78	C	107, 108
	Gal d 4; lysozyme	14	C	107, 108

Allergen source	Allergens: Systematic and original names	MW (kd)	Sequence data	References*
<i>Penaeus aztecus</i> (shrimp)				
<i>Penaeus indicus</i> (shrimp)	Pen a 1; tropomyosin	36	P	109
	Pen i 1; tropomyosin	34	C	110
<i>Brassica juncea</i> (oriental mustard)	Bra j 1; 2S albumin	14	C	111
<i>Hordeum vulgare</i> (barley)	Hor v 1; BMAI-1	15	C	112
<i>Sinapis alba</i> (yellow mustard)	Sin a 1; 2S albumin	14	C	113
I. Others				
<i>Ascaris suum</i> (worm)	Asc s 1	10	P	114
<i>Hevea brasiliensis</i> (rubber)	Hev b 1; elongation factor	58	P	115

MW, Molecular weight; C, complete; P, partial.

*References refer to those where partial (P) or complete (C) sequence data are available. The original references describing the initial characterization studies are not given because of limited space. Also, we apologize to our colleagues whose allergen sequence data we may have overlooked, or whose publications appeared after December 1993, for inclusion in this table.

†Sequence data for group 5 and 9 allergens from several grass pollens indicate that they are highly homologous proteins. Comparison of complete sequence data of group 5 and 9 allergens from a single grass species will clarify whether these two groups are the same protein.

‡*Canis domesticus* is also designated as *Canis familiaris*.

ized before those for *Vespa vidua* and *Vespa crabro*.

Another example is for allergens from the domestic dog (*Canis domesticus*) and the mold *Candida albicans*. To avoid ambiguity, the modified system is used to designate Can d and Cand a allergens from these two sources, respectively.

In the current nomenclature system² the letters are italicized and the numerals are Roman. In the revised system, only letters of normal type and Arabic numerals are used. The proposed changes conform to the accepted nomenclature used in bacterial genetics⁶ and the HLA system⁷ in that italicized and normal characters are used to represent genotypes and phenotypes, respectively.

Allergens and isoallergens

An allergen from a single species may consist of several very similar molecules. These similar molecules are designated as isoallergens when they share the following common biochemical properties: (1) similar molecular size; (2) identical biologic function, if known, (e.g., enzymatic action); and (3) $\geq 67\%$ identity of amino acid sequences.

It is recognized that the recommended 67% or greater sequence identity for two allergens to be assigned to the same group is only a guide. There are likely to be borderline cases. As an example,

the ragweed allergens Amb a 1 and 2 share 65% amino acid sequence identity.⁸ These allergens were assigned to different groups because of their different immunochemical properties before their sequences were known.

Allergens from different species of the same or different genera, which share the above-mentioned common biochemical properties, are considered to belong to the same group and the sequence identity requirement can be less than 67%, as is the case for allergens of the same species. For example, Amb a 5 and Amb t 5 from short and giant ragweed pollens have about 45% sequence identity⁹ and also have similar tertiary structures.^{10, 11} Other examples are the minor pollen allergens Amb a 10, Poa p 10, and Lol p 10 from ragweed,¹² Kentucky bluegrass,¹³ and ryegrass.¹⁴ Although their sequences are not known, they are assigned to the same allergen group because they clearly have the same biologic function of cytochrome c.

Isoallergens and variants

Complementary DNA cloning of allergens often shows nucleotide mutations, which are either silent or can lead to single or multiple amino acid substitutions. In the revised system, members of an allergen group that have 67% or greater amino acid sequence identity are designated as isoaller-

gens. Each isoallergen may have multiple forms of closely similar sequences, which are designated as variants.

Isoallergens and their variants that belong to the same allergen group are designated by suffixes of a period followed by four Arabic numerals. The first two numerals, 01 to 99, refer to a particular isoallergen; the two subsequent numerals, 01 to 99, refer to a particular variant of a particular isoallergen designated by the preceding two numerals. In cases in which there is only one known isoallergen but there are several variants, the system of a suffix of four numerals will still apply. These numerals will be chosen in the order of the identification of allergens and/or their cDNAs, irrespective of the physicochemical properties of the allergens. In cases of silent mutations, there can be more than one suffix of four numerals designating the same allergen, and in that case the suffix with the lowest number will be used to designate the allergen of interest.

The addition of suffixes of four numerals to designate isoallergens and their variants will permit their unambiguous designation. In many cases it is unnecessary to specify the isoallergen or variant, and the corresponding suffixes may be deleted; for example, Bet v 1 represents any Bet v 1 allergen and Bet v 1.0101 represents variant number 1 of isoallergen Bet v 1. Two other examples of this nomenclature system are given below.

On cDNA cloning, Amb a I showed multiple polymorphic forms, which differ from each other by 12% to 24% in their sequences.⁸ Four such forms of Amb a I are known; and they are designated as Amb a 1.01, 1.02, 1.03, and 1.04. Each isoallergen of the Amb a I group is found to have one to three variants with greater than 97% of sequence identity. These variants of the Amb a 1.01 group will be designated as Amb a 1.0101, 1.0102, and so on.

In contrast to Amb a I, only two forms of Amb a II were found on cDNA cloning. These forms differ in two polymorphic sites and they have greater than 99% amino acid sequence identity. They are designated as Amb a 2.0101 and 2.0102.

NOMENCLATURE FOR ALLERGEN GENES, mRNAs, AND cDNAs

At present, the genomic structures of allergens are known in at least two cases: cat allergen, Fel d 1, and mouse urinary allergen, Mus m 1. Knowledge of the genomic structure can provide an understanding of how the different polymorphic forms are generated by differential splicing and/or exon usage. By adopting the revised nomenclature

for allergens, we can reserve the italicized characters to designate an allergen gene. Normal characters are used for designation of mRNAs and cDNAs.

For example, Fel d 1 is a protein consisting of two polypeptide chains,¹⁵ which are encoded by two separate genes.¹⁶ The two allergen genes for chains 1 and 2 of Fel d 1 will be represented by *Fel d 1A* and *Fel d 1B*, respectively. Allelic forms of mRNAs and cDNAs of the *Fel d 1A* gene are designated as mRNA or cDNA Fel d 1A.0101, where the numerals are to correspond to those of the polymorphic allergens.

NOMENCLATURE FOR RECOMBINANT AND SYNTHETIC PEPTIDES OF ALLERGENIC INTEREST

There is interest in the possible use of fragments of allergens as reagents to modulate allergen-specific immune responses. Such fragments may be prepared by recombinant technology or by chemical synthesis. Therefore it is useful to establish a generally accepted nomenclature for such peptides of allergenic interest.

The nomenclature for recombinant and synthetic peptides of allergenic interest is to be based on the nomenclature for naturally occurring allergens because it is well accepted by the scientific and clinical communities. An allergen that is prepared by recombinant (r) or chemical synthetic (s) means is to be differentiated from a natural (n) allergen by the addition of the prefix of r or s followed by a suffix of the amino acid residue positions, which are given in parentheses. As examples, a recombinant hornet venom allergen Dol m 5.0201, which contains the entire sequence of 204 residues, will be designated as rDol m 5.0201; and a recombinant or synthetic peptide of residue 151-165 of Dol m 5.0201 will be designated as r or sDol m 5.0201 (151-165), respectively.

Natural allergens may contain posttranslational modifications as many proteins do. These modifications include glycosylation, acylation, methylation, and other changes. Recombinant or synthetic allergen, designated by the prefix r or s, indicates that it does not contain the posttranslational modification of the natural allergen. If the recombinant or synthetic allergen does contain the exact same modification as that of the natural allergen, it will be designated with a prefix of rn or sn. For example, the honeybee venom allergen phospholipase A₂, Api m 1, is a glycoprotein with an oligosaccharide attached at the asparagine residue number 13.^{17,18} A syn-

thetic peptide of residues 1-20 of Api m 1 without the oligosaccharide at residue 13 will be designated as sApi m 1 (1-20), and a synthetic peptide of residue 1-20 with the exact same oligosaccharide as the natural allergen will be designated as snApi m 1 (1-20).

For recombinant or synthetic fragments, which are derivatives of sequences contained within the native allergen structure, an additional suffix enclosed in square brackets will be used to indicate that the peptide referred to is an analog. Substitutions or modifications of amino acid residues are given with the standard one-letter code, and superscript numbers indicate the residue positions at which modifications occur. The one-letter codes for L-amino acids are given in upper case letters and those for D-amino acids are given in lower case letters. The modifications, which can be substitution, insertion, or deletion are specified in parentheses within the brackets. Obviously, when there are many changes, it will not be practical to follow this nomenclature but to give the fully modified sequences. Examples of these analogs of sDol m 5.0201 (151-165) are given below:

Unmodified: sDol m 5.0201 (151-165)

Substitution: sDol m 5.0201 (151-165) [k¹⁵³]

- L-lysine residue at position 153 of sDol m 5.0201 (151-165) is substituted with D-lysine.
Insertion: sDol m 5.0201 (151-165) [+K¹⁵³]

- One residue of L-lysine is inserted between positions 153-154.

Deletion: sDol m 5.0201 (151-165) [-K¹⁵³]

- L-lysine residue at position 153 is deleted.
N-terminal modification: sDol m 5.0201 (151-165) [N-Ac]

- N-terminal amino group is acetylated.
C-terminal modification: sDol m 5.0201 (151-165) [C-NH₂]

- C-terminal carboxyl group is in the form of carboxamide.

The nomenclature proposed above is very similar to that used for synthetic peptides representative of immunoglobulin sequences.¹⁹

We thank Drs. Martin Chapman, Irwin Griffith, Shayam Mohapatra, Rosalia Rodriguez, and Alec Sehon for reviewing this document.

REFERENCES

- Marsh DG, Freidhoff LR. ALBE, an allergen database. Edition 1.0. Baltimore: IUIS, 1992.
- Marsh DG, Goodfriend L, King TP, Lowenstein H, Platts-Mills TAE. Allergen nomenclature. Bull WHO 1986;64:767-70.
- King TP, Norman PS, Cornell JT. Isolation and characterization of allergen from ragweed pollen. II. Biochemistry 1964;3:458-68.
- Lowenstein H. Timothy pollen allergens. Allergy 1980;35:188-191.
- Aukrust L. Purification of allergens in *Cladosporium herbarum*. Allergy 1980;35:206-7.
- Demerec M, Adelberg EA, Clark AJ, Hartman PE. A proposal for a uniform nomenclature in bacterial genetics. Genetics 1966;54:61-75.
- Bodmer JG, Albert ED, Bodmer WF, Dupont B, et al. Nomenclature for factors of the HLA system, 1990. Immunogenetics 1990;33:301-9.
- Griffith IJ, Pollock J, Klapper DG, Rogers BL, Nault AK. Sequence polymorphism of Amb a I and Amb a II, the major allergens in *Ambrosia artemisiifolia* (short ragweed). Int Arch Allergy Appl Immunol 1991;96:296-304.
- Roebber M, Klapper DG, Goodfriend L, Bias WB, Hsu SH, Marsh DG. Immunochemical and genetic studies of Amb t V (Ra5G), an Ra5 homologue from giant ragweed pollen. J Immunol 1985;134:3062-9.
- Metzler WJ, Valentine K, Roebber M, Friedrichs M, Marsh DG, Mueller L. Solution structures of ragweed allergen Amb t V. Biochemistry 1992;31:5117-27.
- Metzler WJ, Valentine K, Roebber M, Marsh DG, Mueller L. Proton resonance assignments and three-dimensional solution structure of the ragweed allergen Amb a V by nuclear magnetic resonance spectroscopy. Biochemistry 1992;31:8697-705.
- Goodfriend L, Choudhury AM, Del Carpio J, King TP. Cytochromes C: new ragweed pollen allergens [Abstract]. Fed Proc 1979;38:1415.
- Ekrasmoddollah AKM, Kisil FT, Sehon AH. Allergenic cross reactivity of cytochrome c from Kentucky bluegrass and perennial ryegrass pollens. Mol Immunol 1982;19:1527-34.
- Ansari AA, Killoran EA, Marsh DG. An investigation of human response to perennial ryegrass (*Lolium perenne*) pollen cytochrome c (Lol p X). J ALLERGY CLIN IMMUNOL 1987;80:229-35.
- Morgenstern JP, Griffith IJ, Brauer AW, et al. Amino acid sequence of Fel d I, the major allergen of the domestic cat: protein sequence analysis and cDNA cloning. Proc Natl Acad Sci U S A 1991;88:9690-4.
- Griffith IJ, Craig S, Pollock J, Yu X, Morgenstern JP, Rogers BL. Expression and genomic structure of the genes encoding FdI, the major allergen from the domestic cat. Gene 1992;113:263-8.
- Weber AL, Marz L, Altmann F. Characteristics of the asparagine-linked oligosaccharide from honey-bee venom phospholipase A2. Comp Biochem Physiol 1986;83B:321-4.
- Weber A, Schroder H, Thalberg K, Marz L. Specific interaction of IgE antibodies with a carbohydrate epitope of honey bee venom phospholipase A2. Allergy 1987;42:464-70.
- Stanworth DR, Dorrington KJ, Hugli TE, Reid K, Turner MW. Nomenclature for synthetic peptides representative of immunoglobulin chain sequences. Bulletin WHO 1990;68:109-11.
- Rafnar T, Griffith IJ, Kuo MC, Bond JF, Rogers BL, Klapper DG. Cloning of Amb a I (Antigen E), the major allergen family of short ragweed pollen. J Biol Chem 1991;266:1229-36.

21. Rogers BL, Morgenstern JP, Griffith IJ, et al. Complete sequence of the allergen Amb a II: recombinant expression and reactivity with T cells from ragweed allergic patients. *J Immunol* 1991;147:2547-52.
22. Klapper DG, Goodfriend L, Capra JD. Amino acid sequence of ragweed allergen Ra3. *Biochemistry* 1980;19:5729-34.
23. Ghosh B, Perry MP, Rafnar T, Marsh DG. Cloning and expression of immunologically active recombinant Amb a V allergen of short ragweed (*Ambrosia artemisiifolia*) pollen. *J Immunol* 1993;150:5391-9.
24. Roebber M, Hussain R, Klapper DG, Marsh DG. Isolation and properties of a new short ragweed pollen allergen, Ra6. *J Immunol* 1983;131:706-11.
25. Lubahn B, Klapper DG. Cloning and characterization of ragweed allergen Amb a VI [Abstract]. *J ALLERGY CLIN IMMUNOL* 1993;91:338.
26. Roebber M, Marsh DG. 1991. Isolation and characterization of allergen Amb a VII from short ragweed pollen. *J ALLERGY CLIN IMMUNOL* 1991;87:324.
27. Rogers BL, Pollock J, Klapper DG, Griffith IJ. Cloning, complete sequence, and recombinant expression of a novel allergen from short ragweed pollen [Abstract]. *J ALLERGY CLIN IMMUNOL* 1993;91:339.
28. Goodfriend L, Choudhury AM, Klapper DG, et al. Ra5G, a homologue of Ra5 in giant ragweed pollen: isolation, HLA-DR-associated activity and amino acid sequence. *Mol Immunol* 1985;22:899-906.
29. Nilsen BM, Sletten K, O'Neill M, Smestad Paulsen B, van Halbeek H. Structural analysis of the glycoprotein allergen Art v II from pollen of mugwort (*Artemisia vulgaris*). *J Biol Chem* 1991;266:2660-8.
30. Matthiesen F, Schumacher M, Lowenstein H. Characterization of the major allergen of *Cynodon dactylon* (Bermuda grass) pollen. *J ALLERGY CLIN IMMUNOL* 1991;88:763-74.
31. Smith PM, Singh MB, Knox RB. Characterization and cloning of the major allergen of Bermuda grass, Cyn d I. In: Kraft D, Schon A, eds. *Molecular biology and immunology of allergens*. Boca Raton, Florida: CRC Press, 1993:157-60.
32. Mecheri S, Peltre G, David B. Purification and characterization of a major allergen from *Dactylis glomerata* pollen: the Ag Dg 1. *Int Arch Allergy Appl Immunol* 1985;78:283-9.
33. Roberts AM, Bevan LJ, Flora PS, Jepson I, Walker MR. Nucleotide sequence of cDNA encoding the group II allergen of cocksfoot/orchard grass (*Dactylis glomerata*), Dac g II. *Allergy* 1993;48:615-23.
34. Klysner S, Welinder K, Lowenstein H, Matthiesen F. Group V allergens in grass pollen IV. Similarities in amino acid compositions and amino terminal sequences of the group V allergens from *Lolium perenne*, *Poa pratensis* and *Dactylis glomerata*. *Clin Exp Allergy* 1992;22:491-7.
35. Perez M, Ishioka GY, Walker LE, Chesnut RW. cDNA cloning and immunological characterization of the rye grass allergen Lol p I. *J Biol Chem* 1990;265:16210-5.
36. Griffith IJ, Smith PM, Pollock J, et al. Cloning and sequencing of Lol p I, the major allergenic protein of rye-grass pollen. *FEBS Lett* 1991;279:210-5.
37. Ansari AA, Shenbagamurthi P, Marsh DG. Complete amino acid sequence of a *Lolium perenne* (perennial rye grass) pollen allergen, Lol p II. *J Biol Chem* 1989;264:11181-5.
38. Ansari AA, Shenbagamurthi P, Marsh DG. Complete primary structure of a *Lolium perenne* (perennial rye grass) pollen allergen, Lol p III: comparison with known Lol p I and II sequences. *Biochemistry* 1989;28:8665-70.
39. Singh MB, Hough T, Theerakulpisut P, et al. Isolation of cDNA encoding a newly identified major allergenic protein of rye-grass pollen: intracellular targeting to the amyloplast. *Proc Natl Acad Sci* 1991;88:1384-8.
40. Matthiesen F, Nielsen AK, Sogaard TJ, Klysner S, Lowenstein H. NH₂-terminal sequences of four immunoaffinity purified grass pollen allergens: Phl p I, Poa p I, Sec c I and Cyn d I [Abstract]. *Allergy* 1992;47(suppl):31.
41. Laffer S, Vrtala S, Kraft D, Scheiner O. cDNA cloning of a major allergen of rye (*Secale cereale*) and timothy grass (*Phleum pratense*). Presented at XVth European Congress of Allergology and Clinical Immunology; 1992; Paris, France.
42. Matthiesen F, Lowenstein H. Group V allergens in grass pollens. I. Purification and characterization of the group V allergen from *Phleum pratense* pollen, Phl p V. *Clin Exp Allergy* 1991;21:297-307.
43. Vrtala S, Laffer S, Duchene M, Kraft D, Scheiner O, Valenta R. 1992. cDNA cloning of a major grass pollen allergen from timothy grass (*Phleum pratense*): identification as Phl p V, a protein with possible targeting to the amyloplast. Presented at XVth European Congress of Allergology and Clinical Immunology; 1992; Paris, France.
44. Peterson A, Becker WM, Schlaak M. Characterization of isoforms of the major allergen Phl p V by immunoblotting and microsequencing. *Int Arch Allergy Immunol* 1992;98:105-9.
45. Bufe A, Becker WM, Peterson A, Schramm G, Schlaak M. Partial mRNA sequence of Phl p V. 1993;EMBL accession number X70942.
46. Esch RE, Klapper DG. Isolation and characterization of a major cross-reactive grass group I allergenic determinant. *Mol Immunol* 1989;26:557-61.
47. Olsen E, Zhang L, Hill RD, Kisil FT, Schon AH, Mohapatra S. Identification and characterization of the Poa p IX group of basic allergens of Kentucky bluegrass pollen. *J Immunol* 1991;147:205-11.
48. Avjioglu A, Singh M, Knox RB. Sequence analysis of Sor h I, the group I allergen of Johnson grass pollen and its comparison to rye-grass Lol p I [Abstract]. *J ALLERGY CLIN IMMUNOL* 1993;91:340.
49. Breiteneder H, Ferreira F, Reikerstorfer A, et al. Complementary DNA cloning and expression in *Escherichia coli* of Aln g I, the major allergen in pollen of alder (*Alnus glutinosa*). *J ALLERGY CLIN IMMUNOL* 1992;90:909-17.
50. Breiteneder H, Pettenburger K, Bito A, et al. The gene coding for the major birch pollen allergen Bet v I is highly homologous to a pea disease resistance response gene. *EMBO J* 1989;8:1935-8.
51. Valenta R, Duchene M, Ebner C, et al. Profilins constitute a novel family of functional plant pan-allergens. *J Exp Med* 1992;175:377-85.
52. Larsen JN, Sturman P, Ipsen H. PCR based cloning and sequencing of isogenes encoding the tree pollen major allergen Car b I from *Carpinus betulus*, hornbeam. *Mol Immunol* 1992;29:703-11.
53. Breiteneder H, Ferreira F, Hoffman-Sommergruber K, et al. Four recombinant isoforms of Cor a I, the major allergen of hazel pollen. *Eur J Biochem* 1993;212:355-62.
54. Ipsen H, Hansen BC. The NH₂-terminal amino acid

- sequence of the immunochemically partial identical major allergens of alder (*Alnus glutinosa*) Aln g I, birch (*Betula verrucosa*) Bet v I, hornbeam (*Carpinus betulus*) Car b I and oak (*Quercus alba*) Que a I pollens. Mol Immunol 1991;28:1279-88.
55. Taniai M, Ando S, Usui M, et al. N-terminal amino acid sequence of a major allergen of Japanese cedar pollen (Cry j I). FEBS Lett 1988;239:329-32.
56. Griffith IJ, Lussier A, Garman R, Koury R, Yeung H, Pollock J. The cDNA cloning of Cry j I, the major allergen of *Cryptomeria japonica* (Japanese cedar) [Abstract]. J ALLERGY CLIN IMMUNOL 1993;91:339.
57. Sakaguchi M, Inouye S, Taniai M, Ando S, Usui M, Matuhashi T. Identification of the second major allergen of Japanese cedar pollen. Allergy 1990;45:309-12.
58. Griffith I. Personal communication; Immulogic Pharmaceutical Corp.
59. Cardaba B, Hernandez D, Martin E, et al. Antibody response to olive pollen antigens: association between HLA class II genes and IgE response to Ole e I [Abstract]. J ALLERGY CLIN IMMUNOL 1993;91:338.
60. Villalba M, Batanero E, Lopez-Otin C, et al. Amino acid sequence of Ole e I, the major allergen from olive tree pollen (*Olea europaea*). Eur J Biochem 1993;216: 863-9.
61. Chua KY, Stewart GA, Thomas WR. Sequence analysis of cDNA encoding for a major house dust mite allergen, Der p I. J Exp Med 1988;167:175-82.
62. Chua KY, Doyle CR, Simpson RJ, Turner KJ, Stewart GA, Thomas WR. Isolation of cDNA coding for the major mite allergen Der p II by IgE plaque immunoassay. Int Arch Allergy Appl Immunol 1990;91:118-23.
63. Stewart GA, Ward LD, Simpson RJ, Thompson PJ. The group III allergen from the house dust mite *Dermatophagoides pteronyssinus* is a trypsin-like enzyme. Immunol 1992;75:29-35.
64. Lake FR, Ward LD, Simpson RJ, Thompson PJ, Stewart GA. House dust mite-derived amylase: allergenicity and physicochemical characterization. J ALLERGY CLIN IMMUNOL 1991;87:1035-42.
65. Tovey ER, Johnson MC, Roche AL, Cobon GS, Baldo BA. Cloning and sequencing of a cDNA expressing a recombinant house dust mite protein that binds human IgE and corresponds to an important low molecular weight allergen. J Exp Med 1989;170:1457-62.
66. Yasueda H, Shida T, Ando T, Sugiyama S, Yamakawa H. Allergenic and proteolytic properties of fourth allergens from *Dermatophagoides* mites. In: Todt A, ed. Dust mite allergens and asthma. Report of the 2nd international workshop. Brussels, Belgium: UCB Institute of Allergy, 1991:63-4.
67. Shen H-D, Chua K-Y, Lin K-L, Hsieh K-H, Thomas WR. Molecular cloning of a house dust mite allergen with common antibody binding specificities with multiple components in mite extracts. Clin Exp Allergy 1993;23:934-40.
68. Lind P, Hansen OC, Horn N. The binding of mouse hybridoma and human IgE antibodies to the major fecal allergen, Der p I of *D. pteronyssinus*. J Immunol 1988;140: 4256-62.
69. Dilworth RJ, Chua KY, Thomas WR. Sequence analysis of cDNA coding for a major house dust allergen Der f I. Clin Exp Allergy 1991;21:25-32.
70. Nishiyama C, Yunki T, Takai T, Okumura Y, Okudaira H. Determination of three disulfide bonds in a major house dust mite allergen, Der f II. Int Arch Allergy Immunol 1993;101:159-66.
71. Trudinger M, Chua KY, Thomas WR. cDNA encoding the major dust mite allergen Der f II. Clin Exp Allergy 1991;21:33-8.
72. Heymann PW, Chapman MD, Aalberse RC, Fox JW, Platts-Mills TAE. Antigenic and structural analysis of group II allergens (Der f II and Der p II) from house dust mites (*Dermatophagoides* spp). J ALLERGY CLIN IMMUNOL 1989;83: 1055-67.
73. van Hage-Hamsten M, Bergman T, Johansson E, et al. N-terminal amino acid sequence of major allergen of the mite lepidoglyphus destructor [Abstract]. J ALLERGY CLIN IMMUNOL 1993;91:353.
74. de Groot H, Goei KGH, van Swieten P, Aalberse RC. 1991. Affinity purification of a major and a minor allergen from dog extract: serologic activity of affinity-purified Can f I and of Can f I-depleted extract. J ALLERGY CLIN IMMUNOL 1991;87:1056-65.
75. Konieczny A. Personal communication; Immulogic Pharmaceutical Corp.
76. McDonald B, Kuo MC, Ohman JL, Rosenwasser LJ. A 29 amino acid peptide derived from rat alpha 2 euglobulin triggers murine allergen specific human T cells [Abstract]. J ALLERGY CLIN IMMUNOL 1988;83:251.
77. Clarke AJ, Cissold PM, Shawi RA, Beattie P, Bishop J. Structure of mouse urinary protein genes: differential splicing configurations in the 3'-non-coding region. EMBO J 1984;3:1045-52.
78. Longbottom JL. Characterization of allergens from the urines of experimental animals. London: McMillan Press, 1983:525-9.
79. Laperche Y, Lynch KR, Dolans KP, Feigelsen P. Tissue-specific control of alpha 2u globulin gene expression: constitutive synthesis in submaxillary gland. Cell 1983;32: 453-60.
80. Arruda LK, Mann BJ, Chapman MD. Selective expression of a major allergen and cytotoxin, Asp f I in *Aspergillus fumigatus*. J Immunol 1992;149:3554-9.
81. Kumar A, Reddy LV, Sochanik A, Kurup VP. Isolation and characterization of a recombinant heat shock protein of *Aspergillus fumigatus*. J ALLERGY CLIN IMMUNOL 1993; 91:1024-30.
82. Teshima R, Ikebuchi H, Sawada J, et al. Isolation and characterization of a major allergenic component (gp55) of *Aspergillus fumigatus*. J ALLERGY CLIN IMMUNOL 1993;92: 698-706.
83. Shen HD, Choo KB, Lee HH, Hsieh JC, Han SH. The 40 kd allergen of *Candida albicans* is an alcohol dehydrogenase: molecular cloning and immunological analysis using monoclonal antibodies. Clin Exp Allergy 1991;21:675-81.
84. Matthiesen F, Olsen M, Lowenstein H. Purification and partial sequencing of the major allergen of *Alternaria alternata*, Alt a I [Abstract]. J ALLERGY CLIN IMMUNOL 1992;89:241.
85. Curran IHA, Young NM, Burton M, Vijay HM. Purification and partial characterization of a low molecular weight antigen from *Alternaria alternata* [Abstract]. J ALLERGY CLIN IMMUNOL 1992;89:283.
86. Vijay HM, Young NM, Curran IHA, Copeland DF, Bernstein IL. A major antigen of *Alternaria alternata* with potential for safe and effective immunotherapy. J ALLERGY CLIN IMMUNOL 1993;91:826-8.
87. Deuell B, Arruda LK, Hayden ML, Chapman MD, Platts-

- Mills TAE. *Trichophyton tonsurans* allergen I. J Immunol 1991;147:96-101.
88. Kuchler K, Gmachl M, Sippl MJ, Kreil G. Analysis of the cDNA for phospholipase A2 from honey bee venom glands: the deduced amino acid sequence reveals homology to the corresponding vertebrate enzymes. Eur J Biochem 1989;184:249-54.
 89. Gmachl M, Kreil G. 1993. Bee venom hyaluronidase is homologous to a membrane protein of mammalian sperm. Proc Natl Acad Sci U S A 1993;90:3569-73.
 90. Habermann E. Bee and wasp venoms. Science 1972;177:314-22.
 91. Jacobson RS, Hoffman DR. Characterization of bumblebee venom allergens [Abstract]. J ALLERGY CLIN IMMUNOL 1993;91:187.
 92. Arruda LK, Vailes LD, Chapman MD. Molecular cloning of cockroach (*B. germanica*) allergens [Abstract]. J ALLERGY CLIN IMMUNOL 1993;91:188.
 93. Mazur G, Baur X, Liebers V. Hypersensitivity to hemoglobins of the Diptera family Chironomidae: structural and functional studies of their immunogenic/allergenic sites. Monog Allergy 1990;28:121-37.
 94. Soldatova L, Kochoumian L, King TP. Sequence similarity of a hornet (*D. maculata*) venom allergen phospholipase A1 with mammalian lipases. FEBS Lett 1993;320:145-9.
 95. Lu G, Kochoumian L, King TP. Whiteface hornet venom allergen hyaluronidase: cloning and its sequence similarity with other proteins [Abstract]. J ALLERGY CLIN IMMUNOL 1994;93:224.
 96. Fang KSF, Vitale M, Fehlner P, King TP. cDNA cloning and primary structure of a white-faced hornet venom allergen, antigen 5. Proc Natl Acad Sci USA 1988;85:895-9.
 97. King TP, Moran DC, Wang DF, Kochoumian L, Chait BT. Structural studies of a hornet venom allergen antigen 5, Dol m V and its sequence similarity with other proteins. Prot Seq Data Anal 1990;3:263-6.
 98. Lu G, Villalba M, Coscia MR, Hoffman DR, King TP. Sequence analysis and antigen cross reactivity of a venom allergen antigen 5 from hornets, wasps and yellowjackets. J Immunol 1993;150:2823-30.
 99. King TP. 1992. Unpublished data.
 100. Hoffman DR. Allergens in Hymenoptera venom XXV: the amino acid sequences of antigen 5 molecules and the structural basis of antigenic cross-reactivity. J ALLERGY CLIN IMMUNOL 1993;92:707-16.
 101. Hoffman DR. 1992. Unpublished data.
 102. Hoffman DR. The complete amino acid sequence of a yellowjacket venom phospholipase [Abstract]. J ALLERGY CLIN IMMUNOL 1993;91:187.
 103. Jacobson RS, Hoffman DR, Kemeny DM. The cross-reactivity between bee and vespid hyaluronidases has a structural basis [Abstract]. J ALLERGY CLIN IMMUNOL 1992;89:292.
 104. Hoffman DR 1993. Allergens in Hymenoptera venom XXIV: the amino acid sequences of imported fire ant venom allergens Sol i II, Sol i III, and Sol i IV. J ALLERGY CLIN IMMUNOL 1993;91:71-8.
 105. Schmidt M, Walker RB, Hoffman DR, McConnell TJ. Nucleotide sequence of cDNA encoding the fire ant venom protein Sol i II. FEBS Lett 1993;319:138-40.
 106. Elsayed S, Apold S, Aas K, Bennich H. The allergenic structure of allergen M from cod. Tryptic peptides of fragment TM1. Int Arch Allergy Appl Immunol 1976;52:59-63.
 107. Hoffman DR. Immunochemical identification of the allergens in egg white. J ALLERGY CLIN IMMUNOL 1983;71:481-6.
 108. Langeland T. A clinical and immunological study of allergy to hen's egg white. IV. Specific IgE antibodies to individual allergens in hen's egg white related to clinical and immunological parameters in egg-allergic patients. Allergy 1983;38:493-500.
 109. Daul CB, Slattey M, Morgan JE, Lehrer SB. Common crustacea allergens: identification of B cell epitopes with the shrimp specific monoclonal antibodies. In: Kraft D, Sehon A, eds. Molecular biology and immunology of allergens Boca Raton, Florida: CRC Press, 1993;291-3.
 110. Shanti KN, Martin BM, Nagpal S, Metcalfe DD, Rao PV. Identification of tropomyosin as the major shrimp allergen and characterization of its IgE-binding epitopes. J Immunol 1993;151:5354-63.
 111. Monsalve RI, Gonzalez de la Pena MA, Menendez-Arias L, Lopez-Otin C, Villalba M, Rodriguez R. Characterization of a new mustard allergen, Bra j IE. Detection of an allergenic epitope. Biochem J 1993;293:625-32.
 112. Mena M, Sanchez-Monge R, Gomez L, Salcedo G, Carbonero P. 1992. A major barley allergen associated with baker's asthma disease is a glycosylated monomeric inhibitor of insect α -amylase: cDNA cloning and chromosomal location of the gene. Plant Mol Biol 1992;20:451-8.
 113. Menendez-Arias L, Moneo I, Dominguez J, Rodriguez R. Primary structure of the major allergen of yellow mustard (*Sinapis alba* L.) seed, Sin a I. Eur J Biochem 1988;177:159-66.
 114. Christie JF, Dunbar B, Davidson I, Kennedy MW. N-terminal amino acid sequence identity between a major allergen of *Ascaris lumbricoides* and *Ascaris suum* and MHC-restricted IgE responses to it. Immunology 1990;69:596-602.
 115. Czuppon AB, Chen Z, Rennert S, et al. The rubber elongation factor of rubber trees (*Hevea brasiliensis*) is the major allergen in latex. J ALLERGY CLIN IMMUNOL 1993;92:690-7.