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A perspective on pea allergy and pea allergens

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PII: S0924-2244(21)00455-6

DOI: <https://doi.org/10.1016/j.tifs.2021.07.017>

Reference: TIFS 3481

To appear in: *Trends in Food Science & Technology*

Received Date: 6 November 2020

Revised Date: 18 June 2021

Accepted Date: 14 July 2021

Please cite this article as: Taylor, S.L., Marsh, J.T., Koppelman, S.J., Kabourek, J.L., Johnson, P.E., Baumert, J.L., A perspective on pea allergy and pea allergens, *Trends in Food Science & Technology* (2021), doi: <https://doi.org/10.1016/j.tifs.2021.07.017>.

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Background: Peas contain comparatively high levels of protein. With the recent trend for the development of alternative, high-protein food sources, pea flour, pea protein concentrate, and pea protein isolate have been incorporated into an increasing number of foods. Marketing materials sometimes claim that peas are hypoallergenic. Among the legume family, peanuts and soybeans are considered as commonly allergenic and regulations in many countries require special labeling and manufacturing control measures for foods containing peanuts or soybeans or ingredients derived from those two legumes. Peas are also legumes but are not on the lists of priority allergenic foods, so special labeling and manufacturing control measures are not needed for peas or pea-based ingredients. The increasing use of high-protein, pea-based ingredients in processed foods may necessitate further review of the placement of peas on the lists of priority allergenic foods. Additionally, peas are definitely allergenic and should not be marketed as hypoallergenic.

Scope and approach: The clinical allergy literature was searched for publications describing allergic reactions to peas, including both garden peas and field peas. The identification and characteristics of pea proteins are reviewed. The potential cross-reactivity of pea proteins with known allergens from peanut and soybean is assessed using a bioinformatics comparison.

Key findings and conclusions: Allergies to both garden peas and field peas are well documented. As consumer exposure to pea protein increases, an increase in allergies to peas should also be anticipated. Several allergenic proteins have been identified among

the pea protein fractions. Pis s 1, a vicilin in the globulin fraction, appears to be the immunodominant allergen but additional studies on pea allergens are warranted. Pis s 2, a convicilin from the globulin fraction, is also identified as a pea allergen. The albumin fraction contains the two less well characterized allergenic albumin protein(s) known as PA1 and PA2. Furthermore, a non-specific lipid transfer protein (nsLTP), a member of the pathogenesis-related protein family (PR14) involved in plant defenses has been identified as an allergen. Strikingly, pea seeds do not contain the classical type of 2S albumin proteins, with the conserved Cys motif, of high allergenic potency found in peanut (such as Ara h 2, 6, and 7), soybean (Gly m 8), and certain tree nuts, e.g. Ber e 1 in Brazil nut, Ana o 3 in cashew, and Jug r 1 in walnut. The effects of processing on the allergenicity of peas have not been thoroughly evaluated, although some evidence indicates that the allergenicity of peas can be reduced by blanching for at least some pea-allergic individuals and that the pea albumin allergens have some limited heat stability.

A Perspective on Pea Allergy and Pea Allergens

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Abstract

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Introduction

Peas (*Pisum sativum*) are a legume crop sold commercially as whole immature pods (snap peas and snow peas), green immature seeds (so-called garden peas) and dry mature peas (so-called field peas or duns). Globally, peas are consumed in many countries. The advent of high-protein pea ingredients such as pea protein concentrate

and pea protein isolate have drawn attention to peas as an alternative protein source in the diet for many countries. An assessment of the potential allergenicity of pea protein is needed to determine if increased exposure to pea protein will lead to increased pea allergy.

Peas as a Source of Dietary Protein

Peas are a potential source of plant protein with about 25% protein on a dry weight basis. Among the legumes, soybeans and lupins are higher in protein at about 35 – 42% (Rizzo and Baroni, 2018; Kumar and Pandey, 2020). While garden peas and field peas both contain about 25% protein on a dry weight basis (Pandey and Gritton, 1975; Dahl *et al.*, 2012), garden peas are typically consumed on a wet or fresh weight basis where the protein content is 4 – 5%. Field peas may also be cooked and consumed on a wet weight basis. Cooked field peas contain about 8% protein. As garden peas mature, the protein content on a dry weight basis begins to decrease while it increases on a wet weight basis (Pandey and Gritton, 1975). For field peas, the protein content increases throughout maturation (Pandey and Gritton, 1975). The protein content of field peas can fall in a range of 18 – 31% based on variety, growing season/climate, and other factors (Kumar and Pandey, 2020). Canadian scientists have bred field peas with increased protein content of approximately 30% (Lu *et al.*, 2019; Shen *et al.*, 2016).

In recent years, the use of legume proteins, including pea protein, in formulated foods has attracted enhanced attention for health, ethical and religious reasons (e.g.

vegetarian/vegan, allergies, genetic modifications) (Lam *et al.*, 2018). Among the legume sources of protein that could be considered as substitutes for animal proteins and/or soybeans, pea protein is recognized for its nutritional value, abundance and low allergenicity (Lam *et al.*, 2018). With heat processing, pea protein is readily digestible (Ma *et al.*, 2017). Pea flour is made by milling of dry, dehulled field peas. The protein content of pea flours is increased by processing into pea protein concentrates (PPC) or pea protein isolates (PPI). PPI contain the highest percentage of protein. PPI are made in a stepwise process (Sosulski and McCurdy, 1987; Boye *et al.*, 2010a; Aluko *et al.*, 2009; Cui *et al.*, 2020). First, protein is extracted from pea flour at alkaline pH followed by centrifugation or ultrafiltration to remove starch and fiber. Then the protein undergoes isoelectric precipitation at acidic pH (pH 4 – 5) and the resulting curd is separated by centrifugation or filtration. The curd is washed to remove additional solubles and dried. PPC is made using an air classification procedure (Boye *et al.*, 2010a; Rempel *et al.*, 2019). During air classification, the smaller protein-rich particles are separated from larger starch granules and fiber-rich particles. The protein content of PPI will typically exceed 80% while PPC have a somewhat lower protein level of 38 – 65% (Boye *et al.*, 2010b). The protein content of these products is dependent on the pea cultivar (Cui *et al.*, 2020) and can also vary due to alterations in processing conditions (Boye *et al.*, 2010b). Freeze-drying, spray drying and extrusion can be used to improve the technical properties of the pea protein isolates including enhancement of solubility and flavor characteristics (Lan *et al.*, 2019). In the U.S., demand for pea protein comes strongly from sports nutrition supplements and gluten-free products but pea protein can be used in a wide range of products including vegan

cheese, cereals, meat substitutes, beverages, and baked goods. Pea protein hydrolysates have also been developed and the resultant peptides have potential health benefits (Aluko, 2008). Finally, pea is also a good fiber source (Guillon and Champ, 2002). Pea hull fiber and pea cell wall fiber are both commercially available. Both pea fiber ingredients contain protein (Martin-Cabrejas *et al.*, 2003).

Labeling of Pea Protein and Marketing for Low Allergenicity

Beginning with guidance from the Codex Alimentarius Commission in 1999, many countries began to develop lists of priority allergenic foods (Taylor and Baumert, 2015). While these priority lists are variable between countries, eight foods or food groups (sometimes referred to as the Big 8) appear on most of these lists (milk, eggs, fish, crustacean shellfish, peanuts, tree nuts, soybeans, and wheat or cereal sources of gluten). Foods on these priority lists pose additional labeling requirements and necessitate the use of allergen control measures within food processing facilities. In the marketing of high protein foods, those with pea protein are sometimes referred to as “hypoallergenic”, especially by marketing representatives trying to sell high-protein, pea-based ingredients to the food industry. While not defined, that term is probably being used to signify that peas are not on any lists of priority allergenic foods such as the Big 8 (Taylor and Baumert, 2015). However, peas should NOT be portrayed as hypoallergenic because allergies to peas are well known and likely to increase in prevalence with increased exposure to pea proteins in the diet.

The Big 8 list of priority allergenic foods does contain two legumes, peanut and soybean. Regional lists in the EU and Australia/New Zealand include a third legume species, lupine (www.farrp.unl.edu/IRChart). Lupine also appears on the priority lists of other countries that rely on the EU list such as Norway, Iceland, and Switzerland. The placement of foods on these priority allergenic food lists should be based upon the prevalence, severity, and potency of the allergenic food (Houben *et al.*, 2016; National Academies of Science, 2016). While only a few foods meet those criteria for placement on these lists, many other foods, including peas, do have the potential to elicit allergic reactions. Increased exposure to high protein foods such as peas through their use in alternative high protein food products could potentially lead to an increase in the prevalence of pea allergy. This possibility should be monitored and the placement of peas on lists of priority allergenic foods should be considered if the prevalence of pea allergy increases sufficiently. Additionally, allergic cross-reactivity between peas and other more commonly allergenic legumes is also possible (Bernhisel-Broadbent and Sampson, 1989; Ibanez *et al.* 2003; Peeters *et al.*, 2009), although not commonly encountered.

Food manufacturers should be encouraged to always declare the presence of pea-based ingredients, by source, on the ingredient list for packaged food products. The food labeling regulations of many countries already require the declaration of all ingredients that have a technical or functional effect in the finished food product. The clear labeling of pea-based ingredients allows consumers with pea allergy to avoid these products. The possible addition of peas to the Codex Alimentarius Commission list of

priority allergenic foods or country-specific lists should be considered if the prevalence of pea allergy rises to a level equivalent to other foods presently on such lists.

Clinical Descriptions of Pea Allergy

Although peas are not a commonly allergenic foods based on prevalence, severity and potency, pea allergy is quite well documented (Hildebrand *et al.*, 2021). Pea allergy appears to be primarily associated with IgE-mediated, immediate hypersensitivity reactions (Hildebrand *et al.*, 2021; Ram *et al.*, 2015; Peeters *et al.*, 2009; Dreyer *et al.*, 2014, Crespo *et al.*, 1995; Yavuz *et al.*, 2011). Most studies have been conducted on young children. Pea-allergic adults also exist but have been less thoroughly documented. In a study of 39 peanut-allergic adults, 29% of these patients were considered to have clinically relevant pea allergy on the basis of history together with evidence of pea-specific IgE (Peeters *et al.*, 2009). Symptoms of pea allergy in children and adults involving the skin (urticaria, angioedema, pruritis, dermatitis), the gastrointestinal tract (nausea, vomiting, diarrhea), and the respiratory tract (asthma) have been described. More severe anaphylactic reactions are very rarely encountered but have been reported in children (Hompeš *et al.*, 2011; Richard *et al.*, 2015; Grabenhenrich *et al.*, 2016). In a small subset of individuals with IgE-mediated food allergy, food-dependent, exercise-induced allergic reactions (FDEIA) can occur if physical activities occur before, during or shortly after consuming the offending allergenic food. Pea has also been implicated in FDEIA in a small number of Italian patients, both adults and children (Romano *et al.*, 2012).

Peas have also been implicated in several forms of food allergy that do not involve IgE antibody recognition. Peas have been identified as a causative food in food protein-induced enterocolitis syndrome (FPIES) (Berin, 2015; Nowak-Wegrzyn, 2015; Jarvinen and Nowak-Wegrzyn, 2013; Ruffner *et al.*, 2013; Venter and Groetch, 2014), although peas are not a common food implicated in FPIES. FPIES occurs almost exclusively in young children. Although not commonly implicated, peas appear to play a role in the provocation of some adult cases of eosinophilic esophagitis (Molina-Infante *et al.*, 2014).

Diagnosis of Pea Allergy

IgE-mediated allergy to pea would typically be established on the basis of a history of allergic reactions to pea obtained from the patient along with a positive skin prick test (SPT) to a pea extract and possible documentation of the presence of pea-specific IgE in the blood serum by CAP-RAST or other suitable test. Clinical cross-reactivity among various foods from the legume family is rare (Bernhisel-Broadbent and Sampson, 1989). However, individuals allergic to a single legume often display positive skin prick tests to other legumes that they can safely ingest (Bernhisel-Broadbent and Sampson, 1989). As a result, both skin prick tests and pea-specific IgE tests can yield false positive results, especially in a patient who has allergies to other legumes. Thus, a confirmed diagnosis of pea allergy should be based, in part, on an oral challenge trial with pea. A demonstration of sensitization to pea by skin prick test

or presence of pea-specific serum IgE is insufficient without confirmation by an oral pea challenge except perhaps where a convincing history of reactivity to ingestion of pea is obtained from the patient.

Prevalence of Pea Allergy

Pea allergy is well documented in the clinical allergy literature but its prevalence is not precisely known (Hildebrand *et al.*, 2021). Although legumes (principally peanut, soybean and lupine) are a key class of foods responsible for IgE-mediated food allergies, the prevalence of pea allergy has received limited attention. **Table 1** contains a list of published studies that have addressed the prevalence of pea allergy to a limited extent. Many of these studies involved subsets of the general population such as individuals attending an allergy clinic, patients with known legume allergy, or patients with known or suspected food allergies. Such studies create selection bias and their results cannot be extended to the general population. One study (Falcao *et al.*, 2004) was a random telephone survey asking respondents if they had specific food allergies. Surveys of this type often over-estimate the prevalence of specific food allergies because the beliefs of the respondents are not clinically confirmed. However, in this case, the very low prevalence of pea allergy (0.7%) in the telephone survey (Falcao *et al.*, 2004) contrasts with the higher estimates from clinical studies using biased sub-populations. Additionally, few of these published studies attempted to confirm the pea allergy using oral challenge tests. Most of the studies relied primarily on SPT and/or serum pea-specific IgE determinations. These diagnostic procedures can create false

positives especially when used on patients with histories of allergies to other legumes (Bernhisel-Broadbent and Sampson, 1989). Kristjansson *et al.* (1999) conducted a survey of food allergy in Iceland and Sweden among children but followed up the positive responses to the survey with skin prick tests and oral challenge tests. They found a prevalence rate of 1.5% (5/324) for pea allergy in Iceland but no cases of pea allergy among 328 children in Sweden. In a population-wide representative survey on the prevalence of environmental and food allergies in Switzerland among adults, the prevalence of pea allergy was estimated at 0.8-1.0% (Hofer and Wuthrich, 1985; Wuthrich *et al.*, 1986). Population estimates suggest that up to 8% of children and 10% of adults have food allergies in the U.S. (Gupta *et al.*, 2011; Gupta *et al.*, 2019). If the prevalence of pea allergy in the U.S. is similar to the estimate from Switzerland, then the adult prevalence of pea allergy in the U.S. could be as high as 0.06-0.1%. Consistent with that low estimate of prevalence, few documented cases of pea allergy have been reported in the U.S. Ram *et al.* (2015) identified pea as a rare cause of food allergy confirmed by oral challenge in the USA, although that study was conducted only with children. However, little reason exists to indicate that the prevalence of pea allergy differs among adults and children, although further studies are warranted to more clearly examine that possibility.

Table 1

SUMMARY OF STUDIES ADDRESSING PREVALENCE OF PEA ALLERGY

Author, Year	Population	Basis	Country/Region	Prevalence of Pea Allergy
Crespo <i>et al.</i> , 1995	355 children with IgE-	Positive history and a positive SPT ^a and/or sIgE ^b	Spain	3.9%

	mediated food allergy			
Kristjansson <i>et al.</i> , 1999	324 children from Iceland and 328 children from Sweden	Regular 18-mo check-up with survey, SPT and some DBPCFC ^c	Iceland and Sweden	1.5% Iceland 0% Sweden
Mattila <i>et al.</i> , 2003	286 young adults evaluated; 172 with suspected FA	Self-report on survey with follow-up by SPT or sIgE	Finland	13.4% 19/23 with OAS ^d
Charles <i>et al.</i> , 2004	69 infants with FA	History and a positive SPT and/or sIgE and positive OFC ^e	France	5.8%
Falcao <i>et al.</i> , 2004	659 adults – general population	Random, digit dial telephone survey	Portugal	0.15%
Reis <i>et al.</i> , 2007	1160 individuals attending an allergy clinic	SPT	Portugal	0.7%
Kumar <i>et al.</i> , 2010	470 FA patients with asthma and allergic rhinitis	SPT confirmed by sIgE; DBPCFC confirmation in 1 individual	India	3.8%
Ferrari and Eng, 2011	151 children with IgE-mediated food allergy	History and positive SPT and sIgE	Switzerland	1.3% (two cases)
Yavuz <i>et al.</i> , 2011	315 children with FA	History and a positive SPT and/or sIgE	Turkey	1.9%
Gupta <i>et al.</i> , 2013	1634 parents of children with FA	Self-reports on survey	USA	3.7%
Dreyer <i>et al.</i> , 2014	26 children	History and a positive SPT and/or sIgE and positive OFC	France	30.8%
Bahr <i>et al.</i> , 2014	163 adults (half atopic)	SPT	Germany	7%
Richard <i>et al.</i> , 2015	23 patients with legume allergy	SPT	France	82.6% and 47.8% had positive SPT to dun pea and green pea, respectively
Somoza <i>et al.</i> , 2015	455 adults with FA	History and a positive SPT and/or sIgE	Spain	8%
Kilic and Taskin, 2015	186 children with FA	Review of clinical medical records – patient history, SPT, sIgE, DBPCFC	Turkey	1.5% (two cases)
Gonzalez-Estrada <i>et al.</i> , 2017	730 participants with diagnosed	Review of medical records – patient history, SPT, sIgE	USA	0.5% (single case)

	anaphylaxis from a clinic			
Rentzos <i>et al.</i> , 2019	1042 adults	Self-report on survey	Sweden	0.7%

^a SPT = skin prick test

^b sIgE = serum-specific IgE test

^c DBPCFC = double-blind, placebo-controlled food challenge (oral)

^d OAS = oral allergy syndrome also known as pollen-food allergy syndrome (PFAS)

^e OFC = oral food challenge, usually not blinded

In various countries, the comparative prevalence of allergies to different legumes is variable with allergies to lentils common in Spain and to chickpeas, lentils, and black gram in India (Martinez San Ireneo *et al.*, 2000; Kumari *et al.*, 2006; Dey *et al.*, 2014). While good comparative studies across the legume family have not been done in the U.S., peanut is surely the most common allergenic legume in the U.S. followed by soybean. In the U.S. and the EU among legume allergies, peanut predominates and soybean allergy is viewed as common also. The prevalence of peanut allergy in the U.S. was estimated at 0.75% of the entire population in one survey (Sicherer *et al.*, 2010), whereas the prevalence of peanut allergy among U.S. children was estimated at 2.0% (Gupta *et al.*, 2011) and among U.S. adults at 1.8% (Gupta *et al.*, 2019). In Europe, the prevalence of peanut allergy is variable among adults ranging from 0% in Iceland to 0.37% in Switzerland (Lyons *et al.*, 2019). For soybean allergy, the prevalence in the U.S. among children was estimated at 0.4% (Gupta *et al.*, 2011) compared to 0.6% among U.S. adults (Gupta *et al.*, 2019). In Europe, the prevalence of soybean allergy was again quite variable with 0% in Iceland, Greece, and Poland up to 0.08% in Switzerland (Lyons *et al.*, 2019). Allergies to other legumes are more rarely reported than peanut allergy. In a European anaphylaxis registry of severe allergic reactions, pea was the third leading cause of anaphylaxis among legumes after peanut

and soybean (Grabenherrich *et al.*, 2016). Lupine does appear on the priority allergen lists in several countries but the prevalence of lupine allergy is not precisely known and is likely less common than either peanut or soybean allergy. Pea allergy is not known to be especially common in any part of the world. As noted in Table 1, in a single, small French study of 26 children with allergies to at least one other vegetable and sensitized to pea, 30.8% had positive oral challenges to pea (Dreyer *et al.*, 2014). However, these patients were not likely to be a representative cross-section of French children. Cross-sensitization (positive skin tests often with no evidence of reactivity to oral challenge) is more common than cross-reactivity. Most cases of clinically documented pea allergy among adults in the EU are rare cases of cross-reactivity between peanut and pea or peanut, soybean, lupine and pea (Wensing *et al.*, 2003; Peeters *et al.*, 2007; Peeters *et al.*, 2009). As noted earlier, clinical cross-reactivity among legumes is rare.

Green Peas vs. Mature Peas vs. High-Protein Pea Ingredients

IgE-mediated allergic reactions have been reported to both immature, green peas and mature, dry peas. Of course, mature dry peas will have higher amounts of pea proteins, including the allergenic pea proteins than green, immature peas. A few cases of pea allergy have been reported in the EU where consumption of pea flour and pea protein isolate may be somewhat higher than in the U.S. Thus, ingestion of dry peas would result in a higher level of exposure to the allergenic pea proteins. Not surprisingly, several cases in both children and adults have been described in individuals who can

safely consume green peas but have adverse allergic reactions to dry peas (Richard *et al.*, 2013; Lievre *et al.*, 2013; Abrams and Gerstner, 2015). These cases can likely be explained by the dose of exposure to the allergenic pea proteins. Recently pea flour, pea protein, pea protein isolate and pea protein concentrate have been introduced into foods. Those ingredients will also have quite high levels of the allergenic pea proteins.

The inclusion of concentrated pea protein in new food products carries a risk that some consumers will experience allergic reactions. Recently, reports of serious allergic reactions in six children were described after eating various products containing pea ingredients (Lavine and Ben-Shoshan, 2019). These reactions occurred in children who were known to be allergic to other legumes, primarily peanut, but who may not have realized that pea was also a legume or that the food contained a pea-based ingredient. Four of the six children had peanut allergy and several had reacted to other legumes including chickpea, lentils, kidney beans and peas (Lavine and Ben-Shoshan, 2019). Pea proteins are not required to be identified on the labels of packaged foods as an allergen in the U.S. or Canada. However, in both countries, the presence of pea protein would need to be on the ingredient statement of such products. In the Canadian cases (Lavine and Ben-Shoshan, 2019), the presence of a pea-based ingredient was acknowledged on the ingredient statement but may not have been noticed or anticipated by these consumers or their caregivers in products such as yogurt, cookies or processed meats. Two of the implicated products contained pea fiber which was probably pea cell wall fiber (as opposed to pea hull fiber), an ingredient that is rich in fiber but also contains pea proteins and is used in processed meat formulations.

Among frequent consumers of any new products containing pea protein, some will likely become sensitized and reactive to pea protein. The frequency of such occurrences cannot be predicted. Thus, in our expert opinion, the probability of allergic sensitization and clinical reactivity in the overall population of consumers of a new pea protein-containing product will be low and the use of pea protein in new products should not be abandoned if this product is properly labeled.

Effect of Processing on Pea Allergenicity

Only limited studies have been conducted on the effect of food processing unit operations on the allergenicity of peas. As noted above, recent allergic reactions to products containing new, higher-protein pea ingredients may be explained by the higher dose of exposure to the allergens and/or cross-reactivity with other legumes such as peanut. Pea flour, pea protein concentrate, and pea protein isolate are minimally processed; the peas are dried, milled, and physically separated into the desired fractions. While the allergenicity of these pea-based ingredients has not been specifically evaluated, the prediction would be that the allergenic proteins would remain in active form in ingredients subjected to such mild processing.

As noted earlier, case reports do exist of consumers who experience allergic reactions to dry peas but can safely consume garden peas (Richard *et al.*, 2013; Lievre *et al.*, 2013; Abrams and Gerstner, 2015), but that is likely attributable to the higher protein/allergen level in dried peas.

Heat processing is known to affect the allergenicity of certain allergens including those in other legumes (Nesbit *et al.*, 2012; Verma *et al.*, 2012; Comstock *et al.*, 2016; Tian *et al.*, 2018; Palmer *et al.*, 2020). The potential exists for either increasing or reducing allergenicity. Jensen *et al.* (2008) briefly mention that, among 75 peanut-allergic patients, they identified an unknown number who reacted to fresh but not blanched peas. An albumin protein fraction from pea was shown to maintain its skin test reactivity in pea-allergic patients when heated at 60C for 30 min boiling at 100C for 5 min, while autoclaving at 120C for 15 min eliminated skin test reactivity (Malley *et al.*, 1975). Unfortunately, to our knowledge, further studies on the heat stability of pea allergens have not been published. Other forms of processing also have possible effects on reducing the allergenicity of foods (Verhoeckx *et al.*, 2015). Since allergens are proteins, proteolysis, either chemical hydrolysis with strong acids or enzymatic (sometimes during fermentations), can be especially effective (Verhoeckx *et al.*, 2015). However, the pea allergens have not been investigated in this regard. Garden peas can be eaten either raw or cooked (usually by boiling). A brief mention was made in one publication that blanching (steaming) might eliminate the allergenicity of peas for some pea-allergic individuals (Jensen *et al.*, 2008)..

Allergic Cross-Reactivity Between Peas and Other Legumes

Globally, over 300 species of legumes are consumed including widely consumed species such as peanuts, peas, beans, and lentils. Allergies have been documented to many of these legume species. However, the prevalence of allergies to specific legumes

varies widely with only peanuts and soybeans on the global list of commonly allergenic foods (Taylor and Baumert, 2015). Clinical cross-reactivity between legume species is rare and, even where cross-reactivity occurs, it is limited to a few species of legumes (Martinez San Ireneo *et al.*, 2000; Wensing *et al.*, 2003; Peeters *et al.*, 2007; Peeters *et al.*, 2009; Kakleas *et al.*, 2020). Peanut-allergic individuals are typically allergic only to peanuts and similar mono-reactivity was noted for soybean and pea (Bernhisel-Broadbent and Sampson, 1989). Of 41 patients challenged with multiple legumes, only two demonstrated allergic reactivity to two legumes and it was peanut and soybean in both cases (Bernhisel-Broadbent and Sampson (1989). Cross-reactivity has been well documented between peanut and lupine but may be relatively uncommon (Shaw *et al.*, 2008; Peeters *et al.*, 2009; de Jong *et al.*, 2010). In contrast, in a Spanish study of 66 legume-allergic children, 39 were challenged with more than one legume and 21 (54%) reacted to more than one of the legumes (Martinez San Ireneo *et al.*, 2000; Ibanez *et al.*, 2003). The most frequent association was 15 children with both lentil and chickpea reactivity followed by 11 children with both lentil and pea reactivity, 9 children with chickpea and pea reactivity, and 8 children with lentil, chickpea and pea reactivity (Martinez San Ireneo *et al.*, 2000). In a Dutch study that primarily focused on cross-reactivity between peanut and lupine, 21/38 peanut-allergic patients were sensitized to pea but only 6/21 (29%) had a history of pea allergy; oral challenges were not conducted with pea (Peeters *et al.*, 2009). Kakleas *et al.* (2020) described 32 legume-allergic children of South Asian origin who had histories of allergic reactions to one up to as many as five different legumes but 22/32 reported tolerance to one or more other legumes. In the group of 6 children with reported allergies to foods containing high-

protein pea ingredients, 4 children had histories of peanut allergy and several had histories of allergies to other legumes including chickpea, lentil, kidney bean, and pea (Levine and Ben-Shoshan, 2019). As noted earlier, cross sensitization among legume species is common but usually not clinically significant; cross-sensitized individuals with documented allergy to one legume can often safely consume most other legumes (Bernhisel-Broadbent and Sampson, 1989). The reasons for the discrepancies among these clinical studies regarding the likelihood of cross reactions between pea and other legumes is not clear. Further clinical studies are encouraged.

While clinically significant cross-reactivity is rare, the seeds of many legume species contain similar seed storage proteins including albumins and globulins (vicilins and legumins). In peanut, specific proteins in the albumin and globulin fractions are identified as the major peanut allergens (Flinterman *et al.*, 2007; Palladino and Breiteneder, 2018; Marsh *et al.*, 2020). To assess the allergenicity of various legume species, a comparison of the protein composition of the seeds should be conducted. A comparison to the known allergens of other legumes, especially peanut, may allow predictions about allergenicity and clinically significant cross reactivity.

Evaluation of the Potential Allergenicity of Pea Protein

This review has established that allergic reactions to peas do occur in the population. The prevalence of pea allergy seems lower than for some other legumes especially peanut. However, peas have been mostly consumed as garden peas with a

comparatively lower protein content than peanut. While field peas are more similar to peanut in protein content, their consumption in most populations is modest. With the advent of relatively new pea ingredients with higher protein content, an assessment of the potential allergenicity of peas is important. Can the potential allergenicity of pea protein ingredients be predicted? How will pea protein allergenicity compare to the allergenicity of the commonly allergenic legumes, peanut and soybean?

Below, we will review knowledge of pea proteins and their properties. We will also review the limited information on the pea allergens. We will also conduct a preliminary bioinformatics comparison of various classes of pea proteins to similar proteins in peanuts and soybeans.

Pea Proteins

Within the protein fraction of peas, the proteins can be classified primarily as albumins (18 – 25%) and globulins (55 – 65%) with minor amounts of prolamins and glutelins (Lu *et al.*, 2019). The albumin fraction of pea contains several proteins with high cysteine content and a described pea allergen (Malley *et al.*, 1975). The globulin fraction contains legumins and vicilins (Lu *et al.*, 2019). The protein composition varies by cultivar. In an evaluation of 59 pea cultivars, the total protein content ranged from 14-31%, the globulin fraction from 49-82% of the total, and the albumin content from 6-24% of the total (Tzitzikas *et al.*, 2006). Within the globulin fraction, vicilin protein comprised of 26-52% of the total protein (Tzitzikas *et al.*, 2006). However, the

ratio of legumin to vicilin can be quite variable across pea cultivars ranging from 0.2 to 8.0 (Mertens *et al.*, 2012) so the vicilin fraction will not always predominate. The legumin to vicilin ratio is correlated to the total protein content of the cultivar and can also be affected by plant nutrition (Mertens *et al.*, 2012). When making high-protein pea protein concentrates or isolates, the protein content and legumin to vicilin ratio can impact technological performance (Barac *et al.*, 2010; O’Kane *et al.*, 2004a). Peas also contain several low molecular weight proteins from classifications that are documented as allergens in other plant species including several protease inhibitors (Domoney *et al.*, 1993), and a non-specific lipid transfer protein (LTP) (Bogdanov *et al.*, 2016; Popp *et al.*, 2019).

Pea Albumins

Albumins are less prevalent in pea than globulins. However, the percentages of total pea protein represented by the albumins are variable. Lu *et al.* (2019) indicated that the water-soluble albumin fraction accounts for 18-25% of pea proteins, while Tsitzikas *et al.* (2006) indicated that the percentage was 6-24%. Most of these pea proteins have not been identified nor characterized. The first systematic study of the pea albumins led to the identification and purification of two sulfur-rich proteins, originally designated as PMA-L and PMA-S (Croy *et al.*, 1984). The larger protein (PMA-L) is a homodimer of approximately 53 kDa having two subunits of 25 kDa each. The smaller protein (PMA-S) is also a homodimer of approximately 48 kDa having two subunits of

24 kDa each. The subunits of both proteins have high sequence identity but no mixed dimers were found.

The larger of these two pea albumins, now designated as PA2, has been sequenced and further studied (Higgins *et al.*, 1987). PA2 is a homodimer with two subunits, PA2a and PA2b, each of approximately 26 kDa with high sequence identity (Croy *et al.*, 1984; Higgins *et al.*, 1987). Immunodiffusion with antisera against PA2 showed lentils and chickpeas have proteins with antigenic cross-reactivity with PA2 while no such evidence was obtained with extracts of soybean, fava bean, pigeon pea or mung bean (Croy *et al.*, 1984).

Another high-sulfur protein of about 11 kDa, called PA1, has been identified among the pea albumin proteins (Higgins *et al.*, 1986). This protein is synthesized as a preproprotein (PA1) that is then post-translationally cleaved into two smaller albumin proteins, named PA1a and PA1b (Higgins *et al.*, 1986). PA1a is a protein of approximately 6 kDa with 53 amino acids, while PA1b is a protein of approximately 4 kDa with 37 amino acids (Higgins *et al.*, 1986). Both PA1a and PA1b have high cysteine content of 7.5% and 16.2%, respectively (Higgins *et al.*, 1986; Eyraud *et al.*, 2013). PA1a and PA1b are separate monomers with no evidence of cross-linking (Higgins *et al.*, 1986) as occurs with similar high-cysteine proteins of similar size in other legumes and certain tree nuts (Shewry *et al.*, 2002; Garino *et al.*, 2010). PA1b has bioinsecticidal activity (Eyraud *et al.*, 2013). The amino acid sequence of this protein has been determined (Gatehouse *et al.*, 1985). The levels of PA1 in pea seeds

can be variable and especially under conditions of sulfur deficiency in the soil (Chandler *et al.*, 1984; Higgins *et al.*, 1986).

In comparison to peanut, the albumin fraction of peanut is remarkably different from the pea albumin fraction. The albumin fraction of peanuts, certain other legumes (but not pea), several tree nuts, and mustard contains the so-called 2S albumin proteins. 2S refers to the Svedberg sedimentation coefficient used to classify proteins based on behavior in ultracentrifugation. The 2S albumins of peanut (Ara h 2, Ara h 6 and Ara h 7) are responsible for over 90% of peanut allergenicity (Porterfield *et al.*, 2009). The biochemical considerations as to why 2S albumins are such potent allergens is described in the text box. A key factor is the highly conserved cysteine motif; the cysteines form disulfide bridges that provide exceptional stability and protease resistance to 2S albumins, which may explain their allergenicity. Soybeans also contain an allergenic 2S albumin (Ebisawa *et al.*, 2013; Klemans *et al.*, 2013; Kattan and Sampson, 2015) but this protein is expressed at a lower level than for peanut.

While peas contain high-cysteine albumin proteins (Higgins *et al.*, 1986) including PA1 as described above, a 2S albumin protein bearing the cysteine motif has never been identified, nor has it been found in the closely related legumes, lentil and fava bean (tribe: *Viceae*). The lack of a 2S albumin cross-linked with disulfide bridges in peas allows us to speculate that peas will not be equivalent to peanut as an allergenic food.

[INSERT: Text for Box]

The remarkable 2S albumins: considerations for allergenicity

2S albumins have been recognized as major allergens in peanut, several other legumes, tree nuts, mustard (<http://www.allergen.org/>), but not pea. A key characteristic of these 2S albumins is their tight protein folding, supported by 4 or 5 disulfide bonds formed by cysteine residues found in the highly conserved motif C-X_a-C-X_b-CC-X_c-C-X_d-C-X_e-C (Shewry *et al.*, 2002). Well known allergenic 2S albumins are Ara h 2 (Burks *et al.*, 1992) and Ara h 6 (Suhr *et al.*, 2004) in peanut, Ber e 1 in Brazil nut (Nordlee *et al.*, 1996), Jug r 1 in walnut (Teuber *et al.*, 1998), Car i 1 in pecan (Sharma *et al.*, 2011), Ana o 3 in cashew (Robotham *et al.*, 2005), Pis v 1 in pistachio (Ahn *et al.*, 2009), Cor a 14 in hazelnut (Garino *et al.*, 2010; Masthoff *et al.*, 2013), and Sin a 1 in mustard (Menendez-Arias *et al.*, 1988). All of these proteins have the cysteine motif resulting in the formation of a disulfide bond-supported protein core, that confers stability to processing treatments and digestive proteases. This was shown for peanut 2S albumins, in comparison to other peanut proteins, are highly resistant towards denaturation by heat (Suhr *et al.*, 2004; de Jongh *et al.*, 2020) and digestion (Lehmann *et al.*, 2006; Koppelman *et al.*, 2010; Apostolovic *et al.*, 2016). Also, in peanut, the 2S albumins are rather abundant, making up 8-16% of the total peanut protein fraction (depending on the cultivar) (Koppelman *et al.*, 2016). Together, these factors make them the ideal food allergens. With their propensity to survive food processing steps as well as digestion, they may enter the gut immune system in a relatively native form and in high amounts. This high bio-accessibility of intact protein may be responsible for

the sensitizing potential of the 2S albumins. The protein structure is also important for eliciting allergic reactions: the reduction in the disulfide linkages in peanut Ara h 2 and Ara h 6 results in strongly diminished IgE-binding, effector cell activity, and reactions *in vivo* (Apostolovic *et al.*, 2013; Bencharitiwong *et al.*, 2015; van de Kleij *et al.*, 2019). These results suggest a main role for conformational epitopes in peanut 2S albumins. However, peanut 2S albumins also possess linear IgE-binding epitopes and these may also be important (Bernard *et al.*, 2015). The relevance of such linear epitopes varies across peanut 2S albumins, and may in part be explained by hydroxyproline (HyP) residues (Bernard *et al.*, 2015; Hazebrouck *et al.*, 2019). The presence of both conformational and linear epitopes in peanut 2S albumins provides a high allergenic potency. In combination with the high sensitizing potential provided by the extraordinary stability of the protein structure, and their high abundance, the peanut 2S albumins are potent allergens.

[End of Box]

Pea Globulins

Vicilin is a protein of 47-50 kDa that can form trimers of about 150 kDa (Gatehouse *et al.*, 1982). Some, but not all, vicilin proteins can undergo post-translational cleavage with two cleavage sites (Gatehouse *et al.*, 1981). Cleavage can occur at one or both sites yielding a range of fragments of 12 – 36 kDa (Tzitzikas *et al.*, 2006). The three primary fragments resulting from cleavage at both sites are the α fragment (20 kDa), the

β fragment (13 kDa), and the γ fragment (12-16 kDa) (Gatehouse *et al.*, 1982;
 Gatehouse *et al.*, 1983). Some vicilins can be *N*-glycosylated at sites (amino-acid
 motif: NXS/T) occurring near the C terminus (Badenoch-Jones *et al.*, 1981). Mature
 vicilins contain no cysteine residues and thus cannot form disulfide linkages (Lu *et al.*,
 2019). Cleaved forms (α ; β and γ fragment) of the vicilins predominate in peas
 comprising 18-41% of total protein (Tzitzikas *et al.*, 2006). The uncleaved forms of the
 vicilins comprise 3-14% of total protein (Tzitzikas *et al.*, 2006).

Convicilin is a protein of 70 kDa that can form trimers of about 210 kDa (Tzitzikas
et al., 2006). Heteromeric trimers consisting of both viclin and convicilin polypeptides
 have been identified (O’Kane *et al.*, 2004b). Convicilin does not undergo any post-
 translational modifications and is not glycosylated (Newbiggin *et al.*, 1990). Convicilin
 has extensive identity with vicilin especially in a lengthy segment at the C-terminal end
 (Newbiggin *et al.*, 1990; Brown *et al.*, 1988). The *N*-terminus of convicilin is quite
 different from vicilin with highly charged amino acids (Brown *et al.*, 1988; Newbiggin *et al.*,
 1990). Convicilin is present in peas at 3-8% of total protein (Tzitzikas *et al.*, 2006).

Legumin is a protein of 60 – 80 kDa that is typically present as a trimer-dimer.
 (Tzitzikas *et al.*, 2006). Three families of legumin polypeptides are recognized based
 on sequence similarities: Leg A (consisting of legA, A2, B, C, and E), Leg J
 (consisting of legJ, K, L, and M), and Leg S (consisting solely of leg S) (Matta *et al.*,
 1981; Casey and Domoney, 1999). The first two families (Leg A and Leg J) occur as
 proteins of 60-65 kDa, while the Leg S is a protein of 80 kDa. Legumins are expressed

with a signal peptide that is removed during transport into plant storage vacuoles where the legumins also form trimers (Muntz, 1998). A vacuolar enzyme cleaves the protein into polypeptides of 20 and 40 kDa known as the acidic and basic polypeptides that remain linked by disulfide bridges (Tzitzikas *et al.*, 2006). After this processing, the trimers form into the mature trimer-dimer, with the acidic and a basic of each monomer remaining linked by a single disulfide bond (Barac *et al.*, 2010). Legumins comprise 8-21% of the total protein of peas (Tzitzikas *et al.*, 2006).

Other globulin proteins exist that do not fall within the molecular weight ranges of the vicilin or convicilin proteins or their subunits according to densitometric scans of electrophoretic gels (Tzitzikas *et al.*, 2006). The other globulin proteins have not been specifically identified and characterized, but may be multimeric forms of the known globulins. However, these additional globulins make up 3 – 17% of total protein (Tzitzikas *et al.*, 2006).

Pea Prolamins and Glutelins

Peas also have small amounts of prolamins (alcohol-soluble) and glutelin (alcohol-insoluble) protein fractions (Adebiyi and Aluko, 2011; Lu *et al.*, 2019). The proteins in these fractions have not been well characterized.

Low Molecular Weight Pea Proteins

Peas also contain several other low molecular weight proteins from protein classes that have been identified as allergens in other plant species. Peas contain trypsin inhibitors (Griffiths, 1984; Park *et al.*, 2010). Peas have several types of trypsin inhibitors including at least two Bowman-Birk type (Domoney *et al.*, 1993). One of these Bowman-Birk trypsin inhibitors has been crystallized and its structure is well defined (de la Sierra *et al.*, 1999). Peas do not appear to contain a trypsin inhibitor of the classical Kunitz-type (Domoney *et al.*, 1993). The Bowman-Birk-type trypsin inhibitors have a very low molecular weight (7.8 kDa) and possess 7 disulfide bonds (de la Sierra *et al.*, 1999). While peas also have chymotrypsin inhibitor activity (Griffiths, 1984), the proteins responsible for that function have not been studied. Peas do not contain detectable levels of α -amylase inhibitors. Peas have very low levels of non-specific lipid transfer proteins, nsLTP (Bogdanov *et al.*, 2016; Popp *et al.*, 2019). As discussed below, this nsLTP has been identified as a pea allergen (Bogdanov *et al.*, 2016). Peas do contain a mitogenic lectin of 49 kDa composed of two pairs of two different subunits (Higgins *et al.*, 1983; Trowbridge, 1974). Peas also contain a lipoxygenase (Park *et al.*, 2010).

Pea Allergens

In 1975, Malley *et al.* determined that the albumin fraction of pea was the major allergenic fraction. The albumin content and allergenicity of peas increased with maturity (Malley *et al.*, 1975). Little allergenic activity was noted in the other pea protein fractions. The major albumin allergen in pea was isolated to a 1.8 kDa protein

(Malley *et al.*, 1976). This protein is very small and seems likely to represent a fragment of some larger protein. Sell *et al.* (2005) confirmed that the albumin fraction has the highest IgE-binding activity in peas and that the allergenicity of pea increases with maturity. However, Sell *et al.* (2005) were able to identify 17 IgE-binding proteins in peas; these proteins fell into a molecular weight range from <14-94 kDa. As noted previously, individuals with allergies to other legumes often have clinically insignificant but positive skin prick tests to multiple legumes that they can safely ingest (Bernhisel-Broadbent and Sampson, 1989). Sera from these same individuals will possess IgE antibodies that bind to numerous pea proteins including many of the ones identified by Sell *et al.* (2005). Additionally, the IgE-binding proteins in pea likely includes some proteins with cross-reactive carbohydrate determinants (CCDs) where the IgE antibodies are binding to carbohydrates on the glycoprotein rather than the protein itself. CCDs are recognized in a wide variety of plant species (Aalberse and van Ree, 1987). The clinical significance of CCDs remains controversial (Commins, 2015). The presence and role of CCDs in pea allergy remains to be elucidated. Further studies are needed to determine the significance of the 17 IgE-binding proteins observed by Sell *et al.* (2005). However, some of these IgE-binding proteins may not be true pea allergens.

Among the albumin fraction, lipid transfer proteins have been identified as important allergens from several plant foods and pollens (Asero *et al.*, 2018). The non-specific lipid transfer protein (nsLTP) of pea was described as an allergen (Pis s 3) involved in cases of pea allergy (Bogdanov *et al.*, 2016) including pea-dependent, exercise-induced anaphylaxis (Romano *et al.*, 2012). However, other investigators have

noted that the pea nsLTP is expressed at a very low level in pea seeds and does not have detectable binding to IgE from the sera of pea-allergic individuals (Popp *et al.*, 2019). nsLTPs do have 4 disulfide bonds and partially follow the cys-motif of the classical allergenic 2S albumins, such as Ara h 2, but the low level expression seems to dictate the pea LTP is not a major allergen (Popp *et al.*, 2019).

In contrast to the previous indications that the pea allergens were mostly present in the albumin fraction, other research suggests that the major pea allergens are in the globulin fraction, specifically the vicilins (Sanchez-Monge *et al.*, 2004; Popp *et al.*, 2019). Pis s 1 (vicilin) and Pis s 2 (convicilin) were identified as major pea allergens able to bind IgE from the sera of more than 50% of a group of 18 pea-allergic individuals (Sanchez-Monge *et al.*, 2004). Pis s 1 was confirmed as a major pea allergen able to bind IgE from 11 of 14 pea-allergic individuals (Popp *et al.*, 2019). In that study, Pis s 2 was a minor pea allergen able to bind IgE from the sera of only 2 of the 14 pea-allergic subjects (Popp *et al.*, 2019). These investigators attempted to determine if several proteins in the albumin fraction of peas were allergens. They found that PA1, the high-cysteine protein from peas, was unable to bind IgE from the sera of their pool of pea-allergic individuals (Popp *et al.*, 2019). However, they admitted that further investigation may be needed into the allergenicity of PA1 because its structural integrity may be important (Popp *et al.*, 2019).

Pis s 1, Pis s 2, and Pis s 3 are recognized as pea allergens by the International Union of Immunological Sciences. Additional pea allergens might also exist. In particular, the role of proteins in the albumin fraction requires further assessment.

Bioinformatics Comparison of Pea Proteins to Peanut and Soybean Proteins

Recently the peanut and soy genome have been fully sequenced. The pea genome has only been partially sequenced, but the data are available in a searchable format. These resources allowed bioinformatic searches to determine if any pea isoforms are similar to known peanut and soy allergens, potentially causing cross-reactivity in soy- and peanut-allergic individuals. A list of all the major peanut allergens derived from the peanut genome and confirmed by sequence data using LC-MS/MS, was recently published (Marsh *et al.*, 2020). The soy genome and translated protein sequences have been studied in far more detail and major soy allergen sequences have been identified (Taylor *et al.*, 2015).

The pea (*Pisum sativum*) genome was searched (tBlastn) using the pea albumin (PA1) sequence (NCBI: CAB82859); the pea vicilin (Pis s 1) sequence (NCBI: CAF25232 and CAF25233); the pea convicilin (Pis s 2) sequence (NCBI: CAB82855); the pea legumin sequence (UniProt: P02857) and the pea nsLTP (Pis s 3) sequence (NCBI: AJG44053) on the Unité de Recherche Génomique Info (URGI) bioinformatics platform (<https://urgi.versailles.inra.fr>). Twelve potential coding DNA sequences (cds) were detected for PA1. Five potential cds were detected for Pis s 1. Two potential cds

were detected for Pis s 2. Nine potential cds were detected for legumin. Thirty potential cds were detected for Pis s 3. The potential genes were run in intron prediction software (Augustus) and an alignment of these predicted translation products, with known sequences, were analyzed (see **Supplementary Table 1 and Supplementary Figure 1**). Alignments of the predicted translations are shown in **Supplementary Figure 2** allowing construction of a percent identity matrix of these translations against the soy and peanut homologues.

For the pea albumins, no 100% match to the published sequence of PA1 is seen, however, 5 pea cds show high sequence identity to this sequence (>90 %). Thus, at least six PA1 isoforms could be expressed in pea. The 5 genomic sequences are found on chromosome 1 as a gene cluster of less than 550k nt. A similar albumin gene cluster is seen in other legumes, like peanut. The known PA2 sequence showed a 100% identity match to one predicted sequence. A further gene with high identity (>97%) was also identified. Thus, at least two PA2 isoforms could be expressed. Five other sequences showed substantial identity to PA2 (>68%). We have tentatively termed these PA3. Four of the predicted sequences are identical, presumably due to gene duplication, thus at least three PA3 isoforms could be expressed. No isoforms of the “standard” 2S albumins were found in pea. Alignments of the sequences are shown in **Supplementary Figure 2**.

With respect to the nsLTPs, also found in the albumin fraction, 30 pea nsLTP cds sequences were identified. However, only 8 of these sequences showed a sequence

identity of >70% compared to the published sequence of Pis s 3. No 100% match to the published sequences of Pis s 3 was seen. Only the 8 LTPs showing high sequence identity with Pis s 3 were further evaluated.

For the vicilin fraction of the pea globulins, no 100% match to the published sequences of Pis s 1 (Pis s 1.0101 and Pis s 1.0102) were seen. However, 5 cds show high sequence identity to Pis s 1 (>75 %). Thus, at least seven Pis s 1 isoforms could be expressed. No 100% match to the published sequence of Pis s 2 was seen. However, 2 sequences show high sequence identity to this sequence (>92 %). Thus, at least three Pis s 2 isoforms could be expressed. The pea convicilins are >67 % identical to the pea vicilins, but show a *N*-terminal extension, that is absent from the vicilins. Of interest, only the *known* Pis s 1 sequences (Pis s 1_1 and Pis s 1_2), show a potential *N*-linked glycosylation site. None of the Pis s 2 sequences show a potential *N*-linked glycosylation site. Alignments of the sequences are shown in **Supplementary Figure 1**.

Although the legumin fraction of the pea globulin proteins does not contain any identified allergens, the sequence identity to peanut and soy legumins was assessed. Twelve pea legumin sequences are published in the UniProt database. Nine cds sequences were identified from the pea genome search. None of these cds sequences matched 100% with any of the 12 published legumin sequences from UniProt. Analyzing these sequences showed that 4 distinct homologous groups of legumins potentially express in pea. Thus, at least 21 legumin isoforms could be expressed. We

have termed the groups Leg1 to Leg4. A sequence identity of > 80% exists within each group. However, as a whole, the legumins show a much lower sequence identity, up to 35%. Peanut 11S globulins (Ara h 3) show a similar disparity. The full-length legumins exhibit a potential asparagine cleavage site, allowing an acidic and basic subunit to form, similar to the peanut 11S globulins and soy glycinins (Gly m 6). Alignments of the sequences are shown in **Supplementary Figure 2**.

Legume Cross-Reactivity Prediction Based on Bioinformatics

The globulin protein allergens in peas reportedly have about 60-70% sequence identity with the vicilin (Ara h 1) and legumin-type (Ara h 3) allergens of peanuts (Burks *et al.*, 1997; Rabjohn *et al.*, 1999). But this degree of identity is not sufficient to provoke cross-reactive clinical allergy in most peanut-allergic patients (Bernhisel-Broadbent and Sampson, 1989).

While serological cross-sensitization between members of the legume family is observed frequently, clinical symptomology is documented to be rare (Kazatsky and Wood, 2016). Broad clinical cross-reactivity within the legume family is documented to be rare, there could be some cases where it does exist. For peanut, clinical cross-reactivity has been demonstrated with soybean, lupine, and fenugreek (Bernhisel-Broadbent and Sampson, 1989; Cabanillas *et al.*, 2018; Chun *et al.*, 2017; Moneret-Vautrin *et al.*, 1999; Peeters *et al.*, 2009; Shaw *et al.*, 2008) but the prevalence of such cross-reactivity with other legumes among peanut-allergic patients is rare. Evidence for

serological cross-sensitization between pea and peanut or soybean or both has been shown (Peeters *et al.*, 2009; Bernhisel-Broadbent and Sampson, 1989), but little evidence exists for clinical cross-reactivity (Bernhisel-Broadbent and Sampson, 1989; Dreyer *et al.*, 2014; Peeters *et al.*, 2009; Wensing *et al.*, 2003). Additionally, several studies have identified cross-reactive IgE binding between the vicilin proteins from peas and related protein allergens from lentil (Len c 1) and peanut (Ara h 1) (Sanchez-Monge *et al.*, 2004; Richard *et al.*, 2015). The high sequence identity (~90%) between Pis s 1 from pea and Len c 1 from lentil suggests that clinical cross-reactivity is likely between lentil and pea (Cabanillas *et al.*, 2018). A high level of allergic cross-reactivity between lentil and pea has been observed in a Spanish study (Martinez San Ireneo *et al.*, 2000). Further confirmation of such clinically significant cross-reactivity is desirable.

Based on our own preliminary bioinformatics analysis, distinct differences exist between pea proteins and related proteins from peanut and soybean. To aid description, **Figure 1** summarizes the somewhat confusing nomenclature, used in the scientific literature, of the major seed protein families (2S (albumin), 7S (vicilin and convicilin), and 11S (legumin)) in the three legumes. All of these protein fractions from peanut and soybean contain known allergens recognized by the International Union of Immunological Science (IUIS). **Figure 1** also illustrates the number of potential isoforms (novel and known), highlighting the complexity of potential cross-reactivity. Using Clustal Omega, we aligned all these proteins (confirmed and predicted) and generated a percent identity matrix. Although crude, it allows identification of potential

cross-reactivities with pea proteins showing greater than 50 % identity to peanut and/or soy allergens.

As noted earlier, the most important distinction between pea and peanut or soybean is that the pea albumins (PA1 and PA2) show no significant identity to the peanut 2S albumins (conglutins) (Ara h 2, Ara h 6 and Ara h 7) or soy 2S albumins (Gly m 8).

Pis s 3, the nsLTP from pea has been identified as an allergen (Bogdanov *et al.*, 2016) although the significance of Pis s 3 as a pea allergen has been questioned (Popp *et al.*, 2019). According to our bioinformatics analysis, the pea nsLTPs show greater than 50 % identity to two groups of peanut nsLTPs and two groups of soy nsLTPs (**Table 2**). The highest identities of 68% are recorded for both a soy nsLTP (Gm_ltp1GM01) to Pis s 3.7 and a peanut nsLTP (Ara h 9.4) to Pis s 3.8. Considering the small size of nsLTP and the high identity, one might expect some pea-allergic patients with sensitization to Pis s 3 to cross-react. However, the nsLTPs are reportedly expressed at low levels in pea seeds (Popp *et al.*, 2019). To determine relevance and risk, further research is needed to confirm specific isoform abundance for the pea nsLTPs.

Table 2: Percent Identity of Pea nsLTPs vs. Soy and Peanut nsLTPs

Pea	Soy		Peanut	
	Gly m nsLTP (Grp A)	Gly m nsLTP (Grp B)	Ara h 9 (Grp A)	Ara h 9 (Grp B)
Pis s 3	45-58 (51)	47-68 (58)	443.93-598.51 (53.30)	56.14-687.71 (61.13)

Range showing minimum and maximum identity (Average identity) of nsLTPs; -: Less than 50% identity

Pis s 3: Pis s 3_2; Pis s 3_3; Pis s 3_4; Pis s 3_1*; Pis s 3_5; Pis s 3_6; Pis s 3_7; Pis s 3_8

Gly m nsLTP (Grp A): Gm_ltp3GM01; Gm_ltp9GM03

Gly m nsLTP (Grp B): Gm_ltp2GM01; Gm_ltp10GM03; Gm_ltp7GM03; Gm_ltp8GM03; Gm_ltp1GM01

Ara h 9 (Grp A): Ara h 9_6_02; Ara h 9_13_12; Ara h 9_3_02; Ara h 9_12_12; Ara h 9_1_02; Ara h 9_10_12
Ara h 9 (Grp B): Ara h 9_2_02; Ara h 9_11_12; Ara h 9_9_12; Ara h 9_4_02; Ara h 9_14_12

As discussed earlier, the pea 7S vicilin (Pis s 1) is considered the major pea allergen (Popp *et al*, 2019) although further confirmation in additional patient groups would be desirable. **Table 3** shows the percent identities between Pis s 1 and the 7S globulins from peanut and soybean. Pis s 1 reaches over 50% identity to both peanut 7S globulins (Ara h 1) and soy 7S globulins (Gly m 5). The two isoforms of Ara h 1 show an average of 52% identity, while Gly m 5 shows an average 53% (Grp B) and 55% (Grp C and D) identity. Gly m 5 (Grp D) holds the most abundant soy conglycinin isoform (Gly m 5.0101) which shows the greatest identity of 57% to Pis s 1.1. Of note is that pea vicilin, unlike soy and peanut 7S globulins is cleaved *in planta*, into 3 subunits (Tzitzikas *et al.*, 2006). This may have significant effects on cross-reactivity in patients with IgE against Gly m 5 or Ara h 1.

As shown in **Table 3**, the pea convicilins (Pis s 2) do not reach 50 % identity with Ara h 1. However, identities of over 53% are seen against soy conglycinin Grp B (Gly m 5).

Table 3: Percent Identity of Pea 7S Globulins vs. Soy and Peanut 7S Globulins

Pea Vicilin/Convicilins	Peanut Cupin (Vicilin-type)	Soy Conglycinin			
	Ara h 1	Gly m 5 (Grp A)	Gly m 5 (Grp B)	Gly m 5 (Grp C)	Gly m 5 (Grp D)
Pis s 2	-	-	-	-	-
Pis s 1 (Grp A)	51-52 (52)	-	51-57 (54)	51-58 (55)	52-57 (55)
Pis s 1 (Grp B)	-	-	-	-	-
Pis s 1 (Grp C)	-	-	-	-	-

Range showing minimum and maximum identity (Average identity) of 7S globulins; -: Less than 50% identity.

Pis s 2 : Pis s 2_1*; Pis s 2_2; Pis s 2_3
Pis s 1 (Grp A): Pis s 1_1*; Pis s 1_2*
Pis s 1 (Grp B): Pis s 1_6; Pis s 1_4; Pis s 1_3; Pis s 1_5
Pis s 1 (Grp C): Pis s 1_7
Ara h 1: Ara h 1_1_09; Ara h 1_2_19
Gly m 5 (Grp A): Gm7s2_GM10
Gly m 5 (Grp B): Gm7s6_GM20; Gm7s7_GM20; Gm7s3_GM10; Glym5_like
Gly m 5 (Grp C): Gm7s5_GM20; Glym5_0301; Glym5_0302
Gly m 5 (Grp D): Gm7s1_GM10; Glym5_0201; Gm7s8_GM20; Gm7s9_GM20; Gly m 5_0101

Although the pea legumins have not been identified, so far, as allergens, our bioinformatics analysis revealed that some of these pea legumins show surprisingly high identities to peanut and soy allergens of the 11S globulin family (**Table 4**). The >60 % identity of Gly m 6 (Grp A) and Ara h 3 (Grp B) to Legumin (Grp A) suggests the possibility of cross-reactivity between these legume proteins in patients sensitized to Ara h 3 and/or Gly m 6. The peanut and soy legumin groups hold the most abundant seed-expressed isoforms. However, without an understanding of the pea legumin isoform abundance, caution must be taken in speculating about cross-reactivity. This finding again highlights the need for further research to confirm specific isoform abundance for pea proteins. Rabjohn *et al.* (1999) identified 4 regions on the Ara h 3 acidic subunit as significant IgE epitopes. **Figure 2** highlights these regions against an alignment of peanut Ara h 3.5 (within Ara h 3 (Grp A)) and pea Legumin 1.1 (within Legumin (Grp A)). Three of these regions show obvious identity, potentially leading to cross-reactivity.

Table 4: Percent Identity of Pea Legumins vs. Soy and Peanut 11S Globulins

Pea	Peanut Cupin (Legumin-type)				Soy Glycinin		
	Ara h 3 (Grp A)	Ara h 3 (Grp B)	Ara h 3 (Grp C)	Ara h 3 (Grp D)	Gly m 6 (Grp A)	Gly m 6 (Grp B)	Gly m 6 (Grp C)
Legumin (Grp A)	45-63 (57)	-	-	-	48-66 (60)	-	-

Legumin (Grp B)	-	44-60 (53)	-	40-53 (44)	-	46-66 (58)	44-73 (52)
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Range showing minimum and maximum identity (Average identity) of 11 s globulins;

:- Less than 50% identity

Legumin (Grp A): Leg1_7; Leg1_3*; Leg1_4; Leg1_2*; Leg1_1*; Leg1_5*; Leg1_6

Legumin (Grp B): Leg3_5*; Leg3_7*; Leg3_6; Leg4_3*; Leg3_1*; Leg2_1*; Leg2_2; Leg2_3; Leg3_4; Leg3_3; Leg4_2*; Leg4_1; Leg2_4*; Leg3_2*

Gly m 6 (Grp A): Gly m 6_0201; Gly m 6_0301; Gly m 6_0101

Gly m 6 (Grp B): Gly m 6_0401; Gly m 6_0501

Gly m 6 (Grp C): Gm11s2GM19

Ara h 3 (Grp A): Ara h 3_18_16; Ara h 3_19_16; Ara h 3_3_06; Ara h 3_6_06; Ara h 3_13_16;

Ara h 3_17_16; Ara h 3_20_16; Ara h 3_4_06; Ara h 3_5_06; Ara h 3_10_06; Ara h 3_7_06; Ara h 3_16_16

Ara h 3 (Grp B): Ara h 3_1_02; Ara h 3_11_12;

Ara h 3 (Grp C): Ara h 3_2_02; Ara h 3_12_12; Ara h 3_9_06; Ara h 3_14_16

Ara h 3 (Grp D): Ara h 3_8_06; Ara h 3_15_16

Immunotherapy with Pea Proteins

Individuals with food allergies must follow a strict avoidance diet to prevent allergic reactions because small doses of the allergenic foods are sometimes sufficient to elicit such allergic responses. Obviously, rigorous adherence to an avoidance diet has a deleterious effect on the quality of life of food-allergic individuals. Recently, oral immunotherapy (OIT) has been investigated as an alternative approach to desensitize food-allergic individuals. While permanent tolerance is not often achieved desensitization can be achieved and maintained with daily ingestion of the offending food. However, OIT carries safety concerns for the food-allergic patient as adverse reactions can occur during the dose escalation phase. Among the legumes, OIT for peanut allergy has been intensively investigated because allergic reactions to peanut tend to be severe. But, peanut OIT also carries the safety concerns during the dose escalation phase. OIT with peas for desensitization to peas has not been attempted to our knowledge. However, because peas contain certain proteins that are similar to proteins in peanuts, namely the vicilins and legumins, Polish investigators have

proposed that OIT with peas might desensitize patients to peanuts (Szymkiewicz and Chudzik-Kozłowska, 2014). Thus far, they have only demonstrated this effect in animal models so its applicability to humans remains unproven. However, because peas lack proteins that are homologous to the potent 2S albumin peanut allergens (Ara h 2, 6, and 7), this strategy seems unlikely to work with peanut-allergic patients sensitized to those allergens.

Conclusion

Pea allergy appears to be comparatively rare. However, the prevalence of pea allergy is variable in countries where it has been assessed. This variability could be due to differences in methodology for assessing prevalence or to different dietary habits (frequency and nature of pea intake) among different cultures. Pea allergy occurs in both children and adults; insufficient comparative data are available to assess if the prevalence of pea allergy is different between children and adults. Pea allergy can rarely be severe. Three allergenic proteins in pea have been characterized so far, but peas appear to have multiple allergens in the albumin and globulin fractions. The allergenicity of pea increases as the peas mature which is supported by observations of individuals who are allergic to dry mature peas but not to immature green peas. This clinical observation is likely related to the higher content of allergenic pea proteins in dry peas. The advent of pea flour, pea protein isolate and pea protein concentrate in formulated foods especially with high protein levels is somewhat worrisome because it

will increase consumer exposure to pea protein and increase the likelihood of sensitization and allergic reactivity.

With the increased consumer exposure, will peas become a more frequent form of food allergy? The short answer is yes. As exposure to allergenic proteins increases, the likelihood for development of allergic reactivity to the food containing those proteins will invariably increase. However, in our opinion, limited likelihood exists that pea allergy will rival peanut allergy in terms of prevalence, severity, and potency. Peanuts contain multiple allergenic proteins including four major ones (Ara h 1, Ara h 2, Ara h 3 and Ara h 6) (Palladino and Breiteneder, 2018; Marsh *et al.*, 2020). Peas contain vicilin and legumin proteins with some sequence identity to Ara h 1 and more sequence identity to Ara h 3 (Burks *et al.*, 1997; Rabjohn *et al.*, 1999). A pea protein homologous to the notorious peanut 2S albumins Ara h 2 and Ara h 6 has so far not been found in pea. Further elucidation of the role of the high-cysteine proteins in peas on allergic reactions to peas is needed along with comparisons to the 2S albumins of other foods especially legumes such as peanut and soybean. The greatest sequence identity exists with the legumins from pea, peanut (Ara h 3) and soybean (Gly m 6). However, the pea legumin has not yet been identified as a pea allergen. The effect of processing into more concentrated, high protein forms on the allergenicity of peas has not been well investigated. Based on the popularity of these pea-based ingredients in recent years, such studies should be conducted to determine both the levels and the activity of pea allergens in these ingredients.

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Figure Legends:

1505 Figure 1: Comparison of pea, peanut and soy proteins/allergens in various classes

1506 Figure 2: Alignment of the globulins from peanut (Ara h 3.5) and pea (Legumin 1.1)

1507

1508

FIGURE 1

Protein Family	7S Globulins		11S Globulins	2S Albumin like		
Species						
<i>Pisum sativum</i> ¹ (Pea)	Vicilin (Pis s 1)(2+4) ²	Convicilin (Pis s 2)(1+2) ³	Legumin (-)(21)	nsLTP (Pis s 3)(1+29) ⁴	2S Albumin (-)(0)	PA1 and PA2 (-)(13)
<i>Arachis hypogaea</i> (Peanut)	Cupin (Vicilin-type) (Ara h 1)(2)		Cupin (Legumin-type) (Ara h 3)(20)	nsLTP (Ara h 9)(25)	Conglutin (2S Albumin) (Ara h 2/6/7)(6)	
<i>Glycine max</i> (Soybean)	Conglycinin (Gly m 5)(5+7) ⁵		Glycinin (Gly m 6)(5+1) ⁶	nsLTP (-)(45)	2S Albumin (Gly m 8)(1+1) ⁷	

¹ Incomplete genome

² 2 isoform IUIS recognized, 4 extra in genome

³ 1 isoform IUIS recognized, 2 extra in genome

⁴ 1 isoform IUIS recognized, 29 extra in genome

⁵ 5 isoforms IUIS recognized, 7 extra in genome

⁶ 5 isoforms IUIS recognized, 1 extra in genome

⁷ 1 isoform IUIS recognized, 1 extra in genome

Comparison of pea, peanut and soy proteins/allergens in various classes
(Known allergen) (Number of isoforms –genomic predicted and other)

FIGURE 2

		R1	
Arah3_5_06	MAKLLALSVCFCFLVLGASSISFRQQPEENACQFQRLNAQ RPDNRLESEGGYIETWNPNN	60	
Leg1_1*	MAKLLALSLSFCFLLLGGC-FALREQPQQNECQLERLDALEPDNRIESEGGLIETWNPNN	59	
	*****:..****:*.. :.:*:***:* **::**:* .*****:***** *****		
	R2		
Arah3_5_06	QEFECAGVALSRLVL RRNALRRPFYSNAPQEIFIQQGRGYFGLIFPGCPSTYEPAQQGR	120	
Leg1_1*	KQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQGNGYFGMVFPGCPETFEEPQESEQ	119	
	:.*.***** .*:*****:*****.*****:*****.*:*** :. :		
	R3		
Arah3_5_06	RHQSQRAPRRFEGEDQSQQQQQDSHQKVRRFDEG DLIAVPTGVALWMYNDHDTDV VAVSL	180	
Leg1_1*	G-----EGRRYRDRHQVNRREFGDIIAVPTGIVFWMYNDQDTPVIAVSL	164	
	. :.: * ****.* ***:*****:..:*****:* *:****		
Arah3_5_06	TDTNNNDNQLDQFPRRFNLAGNHEQEFLRYQQQSRRRSLPYSPYSPQSQPRQEEREFSR	240	
Leg1_1*	TDIRSSNNQLDQMPRRFYLAGNHEQEFLQYQHQQG-----	199	
	** ...:*****:**** *****:***:*. .		
	R4		
Arah3_5_06	GQHSRRER AGQEEENE GGNIFSGFTPEFLAQAFQVDDRQIVQNL RGNESEEEGAIVTVK	300	
Leg1_1*	-----GKQEQENEGNNIFSGFKRDYLEDAFNVN-RHIVDRLQGRNEDEEKGAIVKVK	250	
	. **:*****.*****. :.* :***:* :*:***:.*:*.**.**:*****.**		
Arah3_5_06	GGLRILSPDRKRGAD EEEEYDEDEY ----- YEYDEEDRRRGRGRGRGN -	343	
Leg1_1*	GGLSIISPPEKQARHQGRSRQEEDDEDEEKQPRHQGRSRQEEDDEDEERQPRHQRRRGEE	310	
	*** *:*** .*:. :.. :.:* : **::.*: * .* **:		
Arah3_5_06	-----	343	
Leg1_1*	EEEDKKERGGSQKGKSRRQGDN	332	

Alignment of the globulins from peanut (Ara h 3.5) and pea (Legumin 1.1)

Epitopes identified by Rabjohn et al (1999) are underlined and labelled R1-R4. The core epitope region is indicated in red font. Signal peptide is indicated in grey italics.

Highlights

- Allergies to pea are well documented, although less common than allergies to several other legumes (peanuts and soybeans).
- High-protein pea ingredients are being formulated into food products at a rapid rate.
- Several pea allergens have been identified including proteins that share partial sequence identity with peanut and soybean proteins.
- Notably, peas lack a classical 2S albumin with the conserved Cys motif found in other highly potent legume allergens.
- With increased exposure to pea protein, will peas become a more frequently encountered allergenic food? Or will cross-reactions occur among peanut- and/or soy-allergic individuals?

Alignment of putative Pea Albumin 1 isoforms

Alignment of putative Pea Vicilin (Piss1) isoforms (N-glycan site indicated)

Piss1_1*	-----SRSDQENPFIFKSNRFQTLYENENGHIRLLQK	32
Piss1_2*	-----SRSDQENPFIFKSNRFQTLYENENGHIRLLQK	32
Piss1_6	-----	0
Piss1_5	-----MGTDFDL-----QKFEGPTFLKIFENLQKLPSFWNI	31
Piss1_4	-----MGTDFDFCRN	9
Piss1_3	MAATTMKASFLLMLMGI-SFLASVCVSSRSDPQNPFIFKSNKFQTLFENENGHIRLLQK	59
Piss1_7	MAATTMKASFLLMLMGI-SFLASVCVSSRSDPQNPFIFKSNKFQTLFENENGHIRLLQK	59
Piss1_1*	FDKRSKIFENLQNYRLLEYKSKPHTFLPQYTDADFILVVLGSKATLTVLKSNDNRNSFNL	92
Piss1_2*	FDKRSKIFENLQNYRLLEYKSKPHTFLPQCTDADFILVVLGSKATLTVLKSNDNRNSFNL	92
Piss1_6	-----KAILTVLKPNDNRNSFNI	17
Piss1_5	QSKHVFSFENLQNYRLLEYKSKPHTIFLPQHTDADYILVVLGSKAILTVLKPDDRNSFNL	91
Piss1_4	LTNVLKFVENLQNYRLLEYKSKPHTIFLPQHTDADYILVVLGSKAILTVLKPDDRNSFNL	69
Piss1_3	FDQRSKIFENLQNYRLLEYKSKPHTIFLPQHTDADYILVVLGSKAILTVLKPDDRNSFNL	119
Piss1_7	FDQRSKIFENLQNYRLLEYKSKPHTIFLPQHTDADYILVVLGSKAILTVLKPDDRNSFNL	119
	** ***** *****:	
Piss1_1*	ERGDAIKLPAGTIAYLANRDDNEDLRVLDLAIPVKNPGQLQSFLLSGTQNPQLSGFSK	152
Piss1_2*	ERGDTIKLPAGTIAYLANRDDNEDLRVLDLTIPVKNPGQLQSFLLSGTQNPQLSGFSK	152
Piss1_6	ERGDTIKLPAGTIAYLVNRDDDEDLRVLDLAIPVNRPGQLQSFLLSGNQNPQLSGFSK	77
Piss1_5	ERGDTVKLPAGTIAYLVNRDDNEELRVLDLAIPVNRPGQLQSFLLSGNQNPQLSGFSK	151
Piss1_4	EREDTIKLPAGTIAYLVNRDDNEELRVLDLAIPVNRPGQLQSFLLSGNQNPQLSGFSK	129
Piss1_3	ERGDTIKLPAGTIAYLVNRDDNKLRLVLDLAIPVNRPGQLQSFLLSGNKNQNPQLSGFSK	179
Piss1_7	ERGDTIKLPAGTIAYLVNRDDNEELRVLDLAIPVNRPGQLQGPLP-----	164
	** *.:*****.****.:.:*****:****:*****. *	
Piss1_1*	NILEAAFNTNYEEIEKVLLEQQEQEPQHRRSLKDRRQEINEENVIVKVSREQIEELSKNA	212
Piss1_2*	NILEAAFNTNYEEIEKVLLEQQEQEPQHRRSLKDRRQEINEENVIVKVSREQIEELSKNA	212
Piss1_6	NILEASFNTDYEEIEKILLEENEKETQHRRSLRDKRQQSQEDDVIVKLSKGQIEELSKNA	137
Piss1_5	NILEASFNTDYEEIEKVLLEEHEKETQHRRSLKDKEA-----	188
Piss1_4	NILEASFNTDYEEIEKVLLEEHEKETQHRRSLKDKRQQSQEENVIVKLSRGQIEELSKNA	189
Piss1_3	NILEASFNTDYEEIEKVLLEEHEKETQHRRSLKDKRQQSQEENVIVKLSRGQIEELSKNA	239
Piss1_7	-----	164
Piss1_1*	KSSSKKSVSSESGPFNLRSRNPISYSNKFGKFFEITPEKNQQLQDLDFVNSVDIKEGSL	272
Piss1_2*	KSSSKKSVSSESGPFNLRSRNPISYSNKFGKFFEITPEKNQQLQDLDFVNSVDIKEGSL	272
Piss1_6	KSSSKKSVSSESKPFNLRSRNPISYSNKFGKFYEITPEENSQQLQDLDFVNSVEIKEGSL	197
Piss1_5	-----ANRGPIYSNEFGKFFEITPEENPQLQDLDFVNSVEIKEGSL	231
Piss1_4	KSTSKKSVSSESEPFNLRSRPIYSNEFGKFFEITPEKNPQLQDLDFVNSVEIKEGSL	249
Piss1_3	KSTSKKSVSSESEPFNLRSRGPISYNEFGKFFEITPEKNPQLQDLDFVNSVEIKEGSL	299
Piss1_7	-----	164
Piss1_1*	LPNYSRAIVIVTVTEGKGFELVGQRNENQGKEND---KEEQEEETSKQVQLYRAKL	328
Piss1_2*	LPNYSRAIVIVTVTEGKGFELVGQRNENQGKEND---KEEQEEETSKQVQLYRAKL	328
Piss1_6	LPHYSRAIVIVTVNEGKGFELVGQRNENQQGKRKEDDEEEKNEEDTNKQVQNYKAKL	257
Piss1_5	LPHYSRAIVIVTVNEGKGFELVGQRNENQEQTKEDDEEEQGEIEINKQVQNYKAKL	291
Piss1_4	LPHYSRAIVIVTVNEGKGFELVGQRNENQEQRKEVDEEEQGEIEINKQVQNYKAKL	309
Piss1_3	LPHYSRAILIVTVNEGKGFELVDQRNENQEQRKEDDEEEQGEIEINKQVQNYKAKL	359
Piss1_7	-----	164
Piss1_1*	SPGDVFVIPAGHPVAINASSDLNLIGFGIN-----AENNERN	365
Piss1_2*	SPGDVFVIPAGHPVAINASSDLNLIGFGIN-----AENNERN	365
Piss1_6	SPGDVFVIPASHPVAVKASSNLHLGFGIN-----AQNNQRN	294
Piss1_5	SSGDVFVIPAGHPVSVKASSNLDLFGFGIN-----AENNQRN	328
Piss1_4	SSGDVFVIPAGHPVAVKASSNLDLFGFGINAENNQRNFLAGILNLDLFGFGINAENNQRN	369
Piss1_3	SSGDVFVIPAGHPVAVKASSNLDLFGFGIN-----AENNQRN	396
Piss1_7	-----	164
Piss1_1*	FLAGEEDNVISQVERPVKELAFPGSSHEVDRLLKNQKQSYFANAQPLQRE-----	415
Piss1_2*	FLAGEEDNVISQVERPVKELAFPGSSHEVDRLLKNQKQSYFANAQPLQRE-----	415
Piss1_6	FLAGKEDNVISQIQRPVKELTFPGSVQEIDKLLKNQKQSYFANAQPPQREIGSSETENRL	354
Piss1_5	FLAGDKDNVISQIQRPVKELAFPGSAQEVDRILENQKQSHFADAQPPQREIGSRETRDRL	388
Piss1_4	FLAGDEDNVISQIQRPVKELAFPGSAQEVDRILENQKQSHFTDAQPPQREIGSRETRDRL	429
Piss1_3	FLAGDEDNVISQIQRPVKELAFPGSAQEVDRILENQKQSHFADAQPPQREIGSRETRDRL	456

Piss1_7	-----	164
Piss1_1*	-----	415
Piss1_2*	-----	415
Piss1_6	SSILNAF	361
Piss1_5	SSV----	391
Piss1_4	SSV----	432
Piss1_3	SSV----	459
Piss1_7	-----	164

Alignment of putative Pea Convicilin (Piss2) isoforms

Piss2_2	MATTIKSRFPLLLLLGIIFLASVVSVTYANYDEGSEPRVPAQREGRQEGEKEEKRHGEW	60
Piss2_1*	MATTIKSRFPLLLLLGIIFLASVVCVTYANYDEGSEPRVPAQREGRQEGEKEEKRHGEW	60
Piss2_3	MATTVKSRFPLLLLLGIIFLAS-VCVTYANYDEGSETRVPGQREGRQEGEKEEKRHGEW	59
	****:*****:***** * . ***** ** . *****	
Piss2_2	RPSYEKEEDEEEGQREGRQEGEKEEKRHGEWGPSYEKQEDEEEKQKYRYQREKEDEEEK	120
Piss2_1*	RPSYEKEEDEEEGQREGRQEGEKEEKRHGEWRPSYEKQEDEEEKQKYRYQREKEDEEEK	120
Piss2_3	RPSYEKEEH-----EEEK	72
	***** . *****	
Piss2_2	QKYQYQREKKEQKEVQPGRRERWEREEDEEQVDEEWRGSQRREDPEERARLRHREERTKRD	180
Piss2_1*	QKYQYQREKKEQKEVQPGRRERWEREEDEEQVDEEWRGSQRREDPEERARLRHREERTKRD	180
Piss2_3	QKYRYQREKKEQKEVQPGRRERWEREEDEEQVEEWRGSQRREDPEERARLRHREERTKRD	132
	:**:*****:*****:*****	
Piss2_2	RRHQREGEEERSSESQERRNPFLFKSNKFLTLFENENGHIRLLQ-----	225
Piss2_1*	RRHQREGEEERSSESQERRNPFLFKSNKFLTLFENENGHIRLLQRFDKRSDLFENLQNY	240
Piss2_3	RRHQREGEEERSSESQEHNPFLFKSNKFLTLFENENGHIRRLQ-----	177
	*****:*****:***** *	
Piss2_2	-----RAKPHTIFLPQHIDADLILVVLNGKAILTVLSPNDRNSYNLERGDTIKLPAGTTS	280
Piss2_1*	RLVEYRAKPHTIFLPQHIDADLILVVLNGKAILTVLSPNDRNSYNLERGDTIKLPAGTTS	300
Piss2_3	-----RAKPHTIFLPQHIDADLILVVLNGKAILTVLSPNDRNSYNLERGDTIKLPAGTTS	232
	*****:*****:*****:*****:*****	
Piss2_2	YLVNQDDEEDLRLVDLVIPVNGPGKFEAFDLAKNKNQYLRGFSKNILEASYNTRYETIEK	340
Piss2_1*	YLVNQDDEEDLRLVDLVIPVNGPGKFEAFDLAKNKNQYLRGFSKNILEASYNTRYETIEK	360
Piss2_3	YLVNQDDEEDLRLVDFVIPVNRPGKFEAFGLSENKNQYLRGFSKNILEASLNTKYETIEK	292
	*****:***:***** *****:*.:***** **:*****	
Piss2_2	VLLEEQEKEPQQR-----RAIVKVSREQIEELRKLAKSSSKSLPSEFEPINL	388
Piss2_1*	VLLEEQEK-----DRKRRQQGEETDAIVKVSREQIEELRKLAKSSSKSLPSEFEPINL	414
Piss2_3	VLLEEQEKKPQQLRDKRTQQGEERDAIKVSREQIEELRKLAKSSSKSLPSEFEPINL	352
	***** **:*****:*****:*****:*****	
Piss2_2	RSHKPEYSNKFGLFEITPEKKYPQLQDLDFVSCVEINEGALMLPHYNSRAIVVLLVNE	448
Piss2_1*	RSHKPEYSNKFGLFEITPEKKYPQLQDLDFVSCVEINEGALMLPHYNSRAIVVLLVNE	474
Piss2_3	RSHKPEYSNKFGLFEITPEKKYPQLQDLDFVSCVEINEGALMLPHYNSRAIVVLLVNE	412
	*****:*****:*****:*****:*****	
Piss2_2	GKGNLELLGLKNEQQUERDRKERNNEVQRYEARLSPGDVVIIPAGHPVAITASSNLNLLA	508
Piss2_1*	GKGNLELLGLKNEQQUERDRKERNNEVQRYEARLSPGDVVIIPAGHPVAITASSNLNLLG	534
Piss2_3	GKGNLELLGLKNEQQUERDRKERNNEVQRYEARLSPGDVVIIPAGHPVAISASSNLNLLG	472
	*****:*****:*****	
Piss2_2	FGINAENNERNFLSGSDDNVISQIENPVKELTFPGSVQEIINRLIKNQKQSHFANAEPEQK	568
Piss2_1*	FGINAENNERNFLSGSDDNVISQIENPVKELTFPGSVQEIINRLIKNQKQSHFANAEPEQK	594
Piss2_3	FGINAKNNQRNFLSGSDDNVISQIENPVKELTFPGSSQEVNRLIKNQKQSHFASAEPEQK	532
	*****:*.:***** ***** *:*****:*****	
Piss2_2	EQGSQGRSPLSSILGTFY	587
Piss2_1*	EQGSQGRSPLSSILGTFY	613
Piss2_3	EEESQGRSPLSSVLDSEFY	551
	*: ** *****:*.:***	

Leg1_7	MATKLLALSLSFCFLLLGCCFALREQPQNECQLERLNALEPDNRIESEGGLIETWNPNN	60
Leg1_6	-MAKLLALSLSFCFLLLGCCFALTEQPQNECQLERLDALEPDNRIESEGGLIETWNPNN	59
Leg1_5	-----	0
Leg1_3	MATKLLALSLSFCFLLLGCCFALREQPQNECQLERLNALEPDNRIESEGGLIETWNPNN	60
Leg1_4	-MAKLLALSLSFCFLLLGCCFALTEQPQNECQLERLDALEPDNRIESEGGLIETWNPNN	59
Leg1_1	-MAKLLALSLSFCFLLLGCCFALREQPQNECQLERLDALEPDNRIESEGGLIETWNPNN	59
Leg1_2	-MAKLLALSLSFCFLLLGCCFALREQPQNECQLERLDALEPDNRIESEGGLIETWNPNN	59
Leg1_7	KQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQNGYFGMVFPGPCPETFEEPQESEQ	120
Leg1_6	KQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQNGYFGMVFPGPCPETFEEPQESEQ	119
Leg1_5	-----	0
Leg1_3	KQFRCAGVALSRATLQHNALRRPYYSNAPQEIFIQQNGYFGMVFPGPCPETFEEPQESEQ	120
Leg1_4	KQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQNGYFGMVFPGPCPETFEEPQESEQ	119
Leg1_1	KQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQNGYFGMVFPGPCPETFEEPQESEQ	119
Leg1_2	KQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQNGYFGMVFPGPCPETFEEPQESEQ	119
Leg1_7	GEGRRYRDRHQVKNRFREGDIIAVLPGSYWYCILDVQRPRHPVIAVSLTDIRSSITSLIR	180
Leg1_6	GEGRRYRDRHQVKNRFREGDIIAVPTGIVFWMYND---QDTPVIAVSLTDIRSSNNQLDQ	176
Leg1_5	-----	0
Leg1_3	GEGRRYRDRHQVKNRFREGDIIAVPTGIVFWMYND---QDTPVIAVSLTDIRSSNNQLDQ	177
Leg1_4	GEGRRYRDRHQVKNRFREGDIIAVPTGIVFWMYND---QDTPVIAVSLTDIRSSNNQLDQ	176
Leg1_1	GEGRRYRDRHQVKNRFREGDIIAVPTGIVFWMYND---QDTPVIAVSLTDIRSSNNQLDQ	176
Leg1_2	GEGRRYRDRHQVKNRFREGDIIAVPTGIVFWMYND---QDTPVIAVSLTDIRSSNNQLDQ	176
Leg1_7	-CLGFYLAGNHQEFLRYQHQQGGKQEQENEGNNIFSGFKRISW-----	223
Leg1_6	MPRRFYLAGNHQEFLRYQHQQGGKQEQENEGNNIFSGFKRDFLEDAFNVNRHIVDRLQG	236
Leg1_5	-----	0
Leg1_3	MPRRFYLAGNHQEFLRYQHQQGGKQEQENEGNNIFSGFKRDFLEDAFNVNRHIVDRLQG	237
Leg1_4	MPRRFYLAGNHQEFLRYQHQQGGKQEQENEGNNIFSGFKRDFLEDAFNVNRHIVDRLQG	236
Leg1_1	MPRRFYLAGNHQEFLRYQHQQGGKQEQENEGNNIFSGFKRDYLEDAFNVRNHIVDRLQG	236
Leg1_2	MPRRFYLAGNHQEFLRYQHQQGGKQEQENEGNNIFSGFKRDFLEDAFNVNRHIVDRLQG	236
Leg1_7	-----KMLSTIISPPEKQARHQGRSQRQEEDEVKMK-----RGS RATREAA	263
Leg1_6	RNEDEEKGAIVKVKGGLSIISPPEKQARHQGRSQRQEEDE--DEEKQPRHQGRSQRQEEED	294
Leg1_5	-----KGGLRIISPPEKQARHQ-----	17
Leg1_3	RNEDEEKGAIVKVKGGLSIISPPEKQARHQGRSQRQEEDEDEDERQPRHQGRSQRQEEED	297
Leg1_4	RNEDEEKGAIVKVKGGLSIISPPEKQARHQGRSQRQEEDE--DEEKQPRHQGRSQRQEEED	294
Leg1_1	RNEDEEKGAIVKVKGGLSIISPPEKQARHQGRSQRQEEDE--DEEKQPRHQGRSQRQEEED	294
Leg1_2	RNEDEEKGAIVKVKGGLSIISPPEKQARHQGRSQRQEEDE--DEEKQPRHQGRSQRQEEED	294
	* *****	
Leg1_7	DKRKRKMKMKGSRVIKGEERRKKKTRKSAAAAK-----KA-----	300
Leg1_6	EDEERQPRHQ----RRGEEEEEDKKERRGSQKGKSRRGQDNGLXSFVALVNARPASSSP	350
Leg1_5	-----RSGKGKSRRGQDNGLEETVCTAKLRLNIGPS	49
Leg1_3	EDEERQPRHQ----RRGEEEEEDKKERRGSQKGKSRRGQDNGLEETVCTAKLRLNIGPS	353
Leg1_4	EDEERQPRHQ----RRGEEEEEDKKERRGSQKGKSRRGQDNGLEETVCTAKLRLNIGPS	350
Leg1_1	EDEERQPRHQ----RRGEEEEEDKKERRGSQKGKSRRGQDNGLEETVCTAKLRLNIGPS	350
Leg1_2	EDEERQPRHQ----RRGEEEEEDKKERRGSQKGKSRRGQDNGLEETVCTAKLRLNIGPS	350
	: .* :	
Leg1_7	-----KAE-----GKETMGLRKQMCLCFVPHYNLNANSI	328
Leg1_6	STRCLVNEGPMFNRS LAVQT VSS SPLS PAF C CL FGCR --- RPSS VFF -- FLL SSS PL	404
Leg1_5	SSPDIYNPEAGR-----IKTVTSLDL-PVLRLWLKLSAEHGSLHKNTMFVPHYNLNANSI	102
Leg1_3	SSPDIYNPEAGR-----IKTVTSLDL-PVLRLWLKLSAEHGSLHKNAMFVPHYNLNANSI	406
Leg1_4	SSPDIYNPEAGR-----IKTVTSLDL-PVLRLWLKLSAEHGSLHKNAMFVPHYNLNANSI	403
Leg1_1	SSPDIYNPEAGR-----IKTVTSLDL-PVLRLWLKLSAEHGSLHKNAMFVPHYNLNANSI	403
Leg1_2	SSPDIYNPEAGR-----IKTVTSLDL-PVLRLWLKLSAEHGSLHKNAMFVPHYNLNANSI	403
	: : : *. *:.. :	
Leg1_7	IYALKGRARLOVVNCNGNT-----PAFKTNDRAG	357
Leg1_6	MTRLPLFI FIF L FL LSAASLV RGC FS SS --SSL SAAS LV AR LAS RF SY V AF K TN DR AG	461
Leg1_5	IYALKGRARLOVVNCNGNTVF D GLEA GRALT VP Q NY A VA AK SL N DR FS Y V AF K TN DR AG	162
Leg1_3	IYALKGRARLOVVNCNGNTVF D GE LEA GRALT VP Q NY A VA AK SL S DR FS Y V AF K TN DR AG	466
Leg1_4	IYALKGRARLOVVNCNGNTVF D GE LEA GRALT VP ON Y A VA AK SL S DR FS Y V AF K TN DR AG	463

Leg2_3	MIAITMARHFLSSFSCLFLLFTACLAHHSESDFRNCQQLDSINALEPDHRVESEAGLTE	60
Leg2_2	MITITMARHFLSSFSCLFLLFTTACLAHHSESDFRNQCQLDSINALEPDHRVESEAGLTE	60
Leg2_1	-----MARHFLSSFSCLFLLFTTACLAHHSESDFRNQCQLDTINALLEPDHRVESEAGLTE	55
Leg2_4	-----	0
Leg2_3	TWNPNHPELKCAGVSLIRRTIDPNGLHLPSYSPSQLFIFIIQG-KGVVLGLAVPGCPETYE	119
Leg2_2	TWNPNHPELKCAGVSLIRRTIDPNGLHLPSYSPSQLFIFIIQGWKGVVLGLAVPGCPETYE	120
Leg2_1	TWNPNHPELKCAGVSLIRRTIDPNGLHLPSYSPSQLFIFIIQG-KGVVLGLAVPGCPETYE	114
Leg2_4	-----	0
Leg2_3	EPRSQRQQQQRDSSHQKIRRFSGKDVIATPPGIPYWTYNHHGEPLVAITLLDTSNTLNQ	179
Leg2_2	EPRSQRQQQQRDSSHQKIRRFSGKDVIATPPGIPYWTYNHHGEPLVAITLLDTSNTLNQ	180
Leg2_1	EPRSQRQQQQRDSSHQKIRRFSGKDVIATPPGIPYWTYNHHGEPLVAITLLDTSNTLNQ	174
Leg2_4	-----	0
Leg2_3	LDSTPRVFYLVGGNPEIEFPETQEKGHEGLQQRHSFLVGRRGGQQE-VESEEQKEGNSVLS	238
Leg2_2	LDSTPRVFYLVGGNPEIEFPETQQKQHEPRQQRYSFVLVGRGGQQEEEEEEQNNEGNSVLS	240
Leg2_1	LDSTPRVFYLVGGNPEIEFPETQQKQHEPRQQRYSFVLVGRGGQQEEEEEEQNNEGNSVLS	234
Leg2_4	-----GNVSLS *****	6
Leg2_3	GFNVEFLAHSINTKEDTAKRLRSPQDERGQIVKVVDGLHIISPELQEE-EQSHRQREEEEE	297
Leg2_2	GFNVEFLAHSINTKEDTAKRLRSPQDERGQIVKVVDGLHIISPELQEEEEQSHSQRKEEE	300
Leg2_1	GFNVEFLAHSINTKEDTAKRLRSPQDERGQIVKVVDGLHIISPELQEEEEQSHSQRKEEE	294
Leg2_4	GFNVEFLAHSINTKEDTAKRLRSPQDERGQIVKVVDGLHIISPELQEEEEQSHSQRKEEE ***** : * :	66
Leg2_3	EEEREQRHRKRSEKEDDEDEDEEE-EEREQRQRKHSEKEEEEEDEPLIHEIKKKWKKTTE	356
Leg2_2	EEEQEQRHRKHSKKEDEDEDEEEEEEREQRHRKHSEKE-EEDEDEPRSYETRKKWKKHHTA	359
Leg2_1	EEEQEQRHRKHSKKEDEDEDEEEEEEREQRHRKHSEKE-EEDEDEPRSYETRKKWKKHHTA	353
Leg2_4	EEEQEQRHRKHSKKEDEDEDEEEEEEREQRHRKHSEKE-EEDEDEPRSYETRKKWKKHHTA *: ***** : *: ***** : ***** : * : ***** :	125
Leg2_3	EKKRESHGRGEEKEQVEEKEEEEEEEEEIHGQHSKGRNGLEETICS AKIRENIARPSRA	416
Leg2_2	EKKRESHGQEEEEELEK---EEEEEEETQRQHSKGRKNGLEETICS AKIRENIARPSRG	416
Leg2_1	EKERESHGQEEEEELEK---EEEEEEETQRQHSKGRKNGLEETICS AKIRENIARPSRG	410
Leg2_4	EKKRESHGQEEEEELEK---EEEEEEETQRQHSKGRKNGLEETICS AKIRENIARPSRG *: ***** : *: *: ***** : ***** : ***** :	182
Leg2_3	DLYNPAGRISTVNSLTLPILRNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGQGVK	476
Leg2_2	DLYNSGAGRISTVNSLTLPILRNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGEGRV	476
Leg2_1	DLYNSGAGRISTVNSLTLPILRNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGEGRV	470
Leg2_4	DLYNSGAGRISTVNSLTLPILRNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGEGRV **** ***** : *	242
Leg2_3	RIVNSQGNVAFDDKVRKGQLVVVPQNFVVSQQAGNEEGFEYVVFKTNDRAAVSHVKQVFR	536
Leg2_2	RIVNSEGNKFVDDKVRKGQLVVVPQNFVVAQQAGNEEGFEYVVFKTNDRAAVSHVNQVFR	536
Leg2_1	RIVNSEGNKFVDDKVSGLQVVVPQNFVVAQQAGNEEGFEYVVFKTNDRAAVSHVNQVFR	530
Leg2_4	RIVNSEGNKFVDDKVSGLQVVVPQNFVVAQQAGNEEGFEYVVFKTNDRAAVSHVNQVFR ***** : ***** : ***** : ***** : ***** : ***** : *****	302

Leg2_3	ATPGEVLANAFGLRKSEVAQIKYNGNRGPLVQSQPQ	572
Leg2_2	ATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQPQSQ	572
Leg2_1	ATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQPQSQ	566
Leg2_4	ATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQPQSQ	338
	*****.*.****** *	

Alignment of putative Pea Legumin 3 isoforms (Asn cleavage site indicated)

Leg3_5	MSKPSSLFSLSLLLFASACLATRSEFDRLNQCQLDNINALEPDHRVESEAGLTETWNP	60
Leg3_6	MSKPSSLFSLSLLLFASACLATSSEFDRLNQCQLDSINALEPDHRVESEAGLTETWNP	60
Leg3_4	MSKPSSLFSLFSLSLLLFASACLATRSEFDRLNQCQLDNINALEPDHRVESEAGLTETWNP	60
Leg3_3	MSKPSSLFSLFSLSLLLFASACLATHSEFDRLNQCQLDNINALEPDHRVESEAGLTETWNP	60
Leg3_2	-----	0
Leg3_1	MSKPSSLFSLSLSLLLFASACLATSSEFDRLNQCQLDSINALEPDHRVESEAGLTETWNP	60
Leg3_7	-----	0
Leg3_5	NPELKCAGVSLIRRTIDPNGLHLPSFSPSPQLIFIIQGKVLGLSLPGCPETYEPRSSQ	120
Leg3_6	HPELKCAGVSLIRRTIDPNGLHLPSFSPSPQLIFIIQGKVLGLSLPGCPETYEPRSSQ	120
Leg3_4	NPELKCAGVSLIRRTIDPNGLHLPSFSPSPQLIFIIQGKVLGLSLPGCPETYEPRSSQ	120
Leg3_3	NPELKCTGVSLIRRTIDPNGLHLPSFSPSPQLIFIIQGKVLGLSLPGCPETYEPRSSQ	120
Leg3_2	-----	0
Leg3_1	HPELKCAGVSLIRRTIDPNGLHLPSFSPSPQLIFIIQGKVLGLSLPGCPETYEPRSSQ	120
Leg3_7	-----	0
Leg3_5	SRQGSRQQQGDSDSHQKIRRF-----	139
Leg3_6	SRQESRQQQGDSDSHQKIRRFKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIANQLDS	180
Leg3_4	SKQGSRQQQGDSDSHQKIRRFKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIANQLDS	180
Leg3_3	SRQGSRQQQGDSDSHQKIRRFKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIANQLDS	180
Leg3_2	-----IPYWTYNHGDEPLVAISLLDTSNIANQLDS	30
Leg3_1	SRQESRQQQGDSDSHQVRRFRKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIANQLDS	180
Leg3_7	-----S	1
Leg3_5	-----	139
Leg3_6	TPRVFYLGGNPETEFPEPTEQEEQQGRHRQKHSYPVGRRSBGHHQEEEESEEQNEGNSVLSGF	240
Leg3_4	TPRVFYLGGNPETEFPEPTEQEEQQGRHRQKHSYPVGRRSBGHHQEEEESEEQNEARG-----	235
Leg3_3	TPRVFYLGGNPETEFPEPTEQEEQQGRHRQKHSYPVGRRSBGHHQEEEESEEQNEGNSVLSGF	240
Leg3_2	TPRVFYLGGNPETEFPEPTEQEEQQGRHRQKHSYPVGRRSBGHHQEEEESEEQNEGNSVLSGV	90
Leg3_1	TPRVFYLGGNPETEFPEPTEQEEQQGRHRQKHSYPVGRRSBGHHQEEEESEEQNEGNSVLSGF	240
Leg3_7	TPRVFYLGGNPETEFPEPTEQEEQQGRHRQKHSYPVG-----	36
Leg3_5	-----	139
Leg3_6	SSEFLAQTFNTEEDTAKRLRSPRDESRQIVRVEGGLRIINPKGKEEEEE-EQSHSHSHRE	299
Leg3_4	-----AHERSQIVRVEGGLRIINPKGKEEEEEKEQSHSHSHRE	273
Leg3_3	SSEFLAQTFNTEEDTAKRLRSPRDESRQIVRVEGGLRIINPKGKEEEEE-KEQSHSHSHRE	299
Leg3_2	SSEFLAQTFNTEEDTAKRLRSPRDESRQIVRVEGGLRIINPKGKEEEEEKEQSHSHSHRE	150
Leg3_1	SSEFLAQTFNTEEDTAKRLRSPRDESRQIVRVEGGLRIINPKGKEEEE-EKEQSHSHSHRE	299
Leg3_7	-----	36
Leg3_5	-----	139
Leg3_6	EKEEXLWSRSWM-----WTSL-----IFYP-----	319
Leg3_4	EGE-----EEEEDEEKQRSEERKNGLEETICSAKIRENIADAARADLYNPRAGRISTANSL	329
Leg3_3	-----EEEEEEKQRSEERKNGLEETICSAKIRENIADAARADLYNPRAGRISTANSL	352
Leg3_2	EEE-----EEEEDEEKQRSEERKNGLEETICSAKIRENIADAAGADLYNPRAGRIRTANSL	206
Leg3_1	EKEEEEEEEEEDEEEKQRSEERKNGLEETICSAKIRENIADAARADLYNPRAGRISTANSL	359
Leg3_7	-----	36
Leg3_5	-----	139
Leg3_6	-----	319
Leg3_4	TLPLVRLRLRLSAEYVRLYRNGIYAPHWNINANSLLYVIRGEGRVRIVNCQGDVAFDNKVR	389
Leg3_3	TLPLVRLRLRLSAEMVYMLHTG-----TINANSLLYVIRGEGRVRIVNCQGNVFDNKVR	406
Leg3_2	TLPLVRLRLRLSAEYVRLYRNGIYAPHWNINANSLLYVIRGEGRVRIVNFQGDVAFDNKVR	266
Leg3_1	TLPLVRLRLRLSAEYVRLYRNGIYAPHWNINANSLLYVIRGEGRVRIVNCQGNVFDNKVR	419
Leg3_7	-----	36

Leg3_5	-----	139
Leg3_6	-----	319
Leg3_4	KGQLVVVPQNFVVAEQAGEEEGLEYYVFKTNDRAAEEGLEYYVFKTNDRAAVSHVQQVLR	449
Leg3_3	KGQLVVVPQNFVVAEQAGEEEGLEYYVCSR-----QMTPELLLATYNRCLG	450
Leg3_2	KGQLVVVPQNFVVAEQAGEEEGLEYYVFK-----TNDRAAVSHVQQVLR	310
Leg3_1	KGQLVVVPQNFVVAEQAGEEEGLEYYVFK-----TNDRAAVSHVQQVFR	463
Leg3_7	-----	36

Leg3_5	-----	139
Leg3_6	-----	319
Leg3_4	ATPAEVL-----NAFGLRQRQVTELKLSGNRGPLVHPQSQSQSH	489
Leg3_3	PLLQRFLQMLLVFVNASHGVKAQ---WKWPWSPGSPSVSISISLR--	491
Leg3_2	ATPAEVL-----NAFGLRQRQVTELKLSGNRGPLVHPQSQSQSH	350
Leg3_1	ATPSEVL-----NAFGLRQRQVTELKLSGNRGPLVHPRSQSQSQSH	503
Leg3_7	-----	36

Alignment of putative Pea Legumin 4 isoforms (Asn cleavage site indicated)

Leg4_3	-----RQLPRQPSELYECQLDTHAREPDNRYDSEAGFTET	36
Leg4_1	MANPNSYCFSLLSVLLLFTSACSARQLPRQPSELYECQLDTHAREPDNRYDSEAGFTET	60
Leg4_2	-----	0
Leg4_3	WDXTXPDLCAGVSVLKLTINP-----	58
Leg4_1	WDSTRPDLCAGVSVLKRTINPNGLNLPYVAYPELHFVEQGMGVLGMAIPGCAETYEPP	120
Leg4_2	-----	0
Leg4_3	-----	58
Leg4_1	QWERRGRPQLQDRHQKVRVYKQGDLIAIPPGVPYWTYNYGNTPLVIVSLLDTSNKNLQL	180
Leg4_2	-----	0
Leg4_3	-----	58
Leg4_1	DQVPRRFYLGGNPEVEHSVKQSGRKHGDEDNNMFSGFDSRFLGEVLKVKEIIRKLQSP	240
Leg4_2	-----	0
Leg4_3	-----	58
Leg4_1	EDGQGHQIIHVKGGLSLIRPPEPEIRSEEEKTRRKREEKVVEEEEEVEDEPGKREH	300
Leg4_2	-----	0
Leg4_3	-----	58
Leg4_1	REWRKETRKQKEGESEGEAEVVKETKTKEHRRHHGERESSRHGERRQEEEEEDVK	360
Leg4_2	-----	0
Leg4_3	-----	58
Leg4_1	EKQTRTTTKEREGQKGFLEETVCTLKLHEDLAGSSQADVFNPRAGRITSVNSLTLPVL	420
Leg4_2	-----FLEETVCTLKLHEDLAGSSQADVFNPRAGRITSVNSLTLPVL	42
Leg4_3	-----	58
Leg4_1	KLLHLSAQWVKLYKDGIFMPHWNMNANSVMYVTRGRGRVQVVNSEGKSVFNGEVRRGKLL	480
Leg4_2	KLLHLSAQWVKLYKNGIFMPHWNLNANS-----	70
Leg4_3	-----	58
Leg4_1	VVPQNFVAEQAQNEGLEYYVFKTNDRAEMNTLVGRDSAISATPAEVLGHVFLSPQEVN	540
Leg4_2	-----	70
Leg4_3	-----58	
Leg4_1	ELKNNRNEGLATPDSRIQDDFIEMV566	
Leg4_2	-----70	

Piss3_2	MARSMKLACVVLAMCML-VAPMAEAAFSCATVMTDLRPLCTYLEAANNASPPCCAGVK	59
Piss3_3	MARSMKLACVVLVICMVVIAPMAEAAALSCGAVTGDLAPCVTYLQAPNNASPPPPCCAGVK	60
Piss3_4	-----MCCFGDV--HGSYCA YEAAALSCGAVTGDLAPCLTYLQAPNNASPPPPCCAGVK	52
Piss3_1*	MARSMKLACVALVICMVVIAPMAEAAALSCGTVSADMAPCVTYLQAPNNASPPPPCCAGVK	60
Piss3_5	MARSMKLACVVLVICMVVIAPMAEAAALSCGTVSADMAPCVTYLQAPNNASPPPPCCAGVK	60
Piss3_6	MARSMKLACVVLVICMVVIAPTAEAAALSCGTVSGDLAPCLTYLEAPNNASPPPPCCAGVK	60
Piss3_7	-----MAEAAALSCGTVSGDLAPCLTYLQAPNNASPPPPCCAGVK	39
Piss3_8	-----MAEAAALSCGTVSGDLAPCLTYLQAPNNASPPPPCCAGVK	39
	****.*.:* *.:**.*.* ***** *	
Piss3_2	NIQAAAPTVDQRQAACNCLKSTAGAISNLNANNAAALPGKCGVNIPIYKISASTNCNTI--	117
Piss3_3	KLLGAATTTTPDRQAACNCLKSAAGSISKLNTNNVAALPGNCGVSIPIYKISTNCNTYVL	120
Piss3_4	KLLGAATTTTPDRQAACNCLKSAAGSISKLNTNNAALPGKCGVSIPIYKISTNCNTVKF	112
Piss3_1*	KLLAAATTTTPDRQAACNCLKSAAGSIPKLNTNNAALPGKCGVSIPIYKISTNCNTVRF	120
Piss3_5	KLLAAATTTTPDRQAACNCLKSAAGSIPKLNTNNAALPGKCGVSIPIYKISTNCNTVRF	120
Piss3_6	KLLGAATTTTPDRQAACNCLKSAAGSISKLNTNNAALPGKCGVSIPIYKISTNCNTIKF	120
Piss3_7	KLLAAATTTTPDRQAACNCLKSAAGSISRNTNNAALPGKCGVSIPIYKISTNCNTVRF	99
Piss3_8	KLLGAATTTTPDRQAACNCLKSAAGSISRNTNNAALPGKCGVSIPIYKISTNCNTIKF	99
	:* .** . *****.*.* .**.*.*.*.*.*.*.*.*.*.*.*.*.*.*	
Piss3_2	-----	117
Piss3_3	LLLCFCHGSH	130
Piss3_4	-----	112
Piss3_1*	-----	120
Piss3_5	-----	120
Piss3_6	-----	120
Piss3_7	-----	99
Piss3_8	-----	99

Supplementary Table 1

Nomenclature of predicted translations, accessions and gene location of putative *Pisum sativum* (*Psat*) allergens. Percentage identity of cds sequences to known sequences (*) are shown

	Nomenclature in manuscript	Accession/Gene site	Identity to PA1_1/notes
Pisum sativum Albumin	PA1_1*	CAB82859	100.00
	PA1_2	Psat1g073600	96.15
	PA1_3	Psat1g073800	95.38
	PA1_4	Psat1g073640	93.08
	PA1_5	Psat1g073680	98.46 (Insertion Repeat)
	PA1_6	Psat1g073760	91.54
			Identity to PA2_1/notes
	PA2_1*	P08688	Ident to PA2_2
	PA2_2	Psat0s876g0120	100.00 (Ident to PA2_1)
	PA2_3	Psat0s876g0040	97.84
	PA3_1	Psat0s1021g0280	79.13
	PA3_2	Psat5g117840	72.61 (Ident to PA3_3)
	PA3_3	Psat5g117800	72.61 (Ident to PA3_2)
	PA3_4	Psat0s3494g0040	68.56 (Ident to PA3_5)
	PA3_5	Psat1g110680	68.56 (Ident to PA3_4)
Pisum sativum Vicilin			Identity to Piss1.0101/Notes
	Piss1_1*	Piss1.0101	100.00/partial sequence
	Piss1_2*	Piss1.0102	99.04/partial sequence
	Piss1_3	Psat0s4851g0160	82.65
	Piss1_4	Psat5g199920	79.59
	Piss1_5	Psat0s5g0160	75.75
	Piss1_6	Psat5g216000	80.59/partial sequence
Pisum sativum Convicilin	Piss1_7	Psat0s7016g0040	86.86/partial sequence
			Identity to Piss2
	Piss2_1*	CAB82855	100.00
Pisum sativum Legumins	Piss2_2	Psat6g206160.1t1	98.80
	Piss2_3	Psat6g206200.1	92.84
			Identity to Leg1_1 (P02857)
	Leg1_1*	P02857 (LegA)	100.00
	Leg1_2*	Q9T0P5 (LegA)	99.81
	Leg1_3*	P15838 (LegA)	98.07
	Leg1_4	Psat3g058800	99.03
	Leg1_5*	Q41036 (LegB)	95.83/partial
	Leg1_6	Psat3g055960	81.30
	Leg1_7	Psat0s1923g0200	80.80
			Identity to Leg2_1 (O24294)
	Leg2_1*	O24294 (Leg)	100.00
	Leg2_2	Psat6g138040	99.12
	Leg2_3	Psat6g125840	90.94
	Leg2_4*	P14594 (LegB)	99.41/partial
			Identity to Leg3_1 (P05692)
	Leg3_1*	P05692 (LegJ)	100
	Leg3_2*	P05693 (LegK)	96.28/partial
	Leg3_3	Psat6g054880	85.30
	Leg3_4	Psat6g055080	94.92
	Leg3_5*	Q41035 (Leg)	94.24/partial
	Leg3_6	Psat6g054960	94.34
	Leg3_7*	Q41032 (LegJ)	100/partial
			Identity to Leg4_1
	Leg4_1	Psat3g056000	100.00
	Leg4_2*	Q7M1N3 (LegL)	97.14/partial
	Leg4_3*	Q7M1N4 (LegL)	94.83/partial
Pisum sativum Lipid Transfer Protein	Piss3_1*		100.00
	Piss3_2	Psat7g234720	76.07
	Piss3_3	Psat7g234680	90.00

	Piss3 4	Psat7g234480	82.14
	Piss3 5	Psat0s4675g0040	99.17
	Piss3 6	Psat7g234440	90.83
	Piss3 7	Psat7g234640	94.95
	Piss3 8	Psat7g234520	91.92

Supplementary Figure 1

Predicted translations of *Pisum sativum* (*Psat*) cds sequences

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>PA1_1*
MASVKLASLIVLFATLGMFLTKNVGAASCNGVCSPFEMPPCGSSACRCIPVGLVVG YCRHPSGVFLRTNDEHPNLCESDADCRKKGSGNFCGHYPNP
DIEYGWCFASKSEAEDFFSKITPKDLLKSVSTA
>PA1_2
MASVKLASLIVLFATLGMFLTKNVGAASCNGVCSPFEMPPCGTSACRCIPVGLVIGYCRNPSGVFLRTNDEHPNLCESDADCRKKGSGKFCGHYPNP
DIEYGWCFASKSEAEDFFSKITQKDLLKSVSTA
>PA1_3
MASVKLASLIVLFATLGMFLTKNVGAASCNGVCSPFEMPPCGTSACRCIPVGLFIGYCRNPSGVFLKANDHEHPNLCESDADCRKKGSGNFCGHYPNP
DIEYGWCFASKSEAEDFFSKITPKDLLKSVSTA
>PA1_4
MASVKLASLIVLFATLGMFLTKNVGAASCNGVCSPFEMPPCGSSACRCIPVGLLIGYCRNPSGVFLKGNDEHPNLCESDADCKKKGSGNFCGHYPNP
DIEYGWCFASKSEAEDVFSKITPKDLLKSVSLISISKTKTMYALL
>PA1_5
MASVKLASLMVLFATLGMFLTKNVGAASCNGVCSPFEMPPCGSSACRCIPVGLVVG YCRHPSGVFLRTNDEHPNLCESDADCRKKGSGNFCGHYPNP
DIEYGSADACRKKGSGNFCGHYPNP DIEYGWCFASKSEAEDFFSKITQKDLLKSVSTA
>PA1_6
MASVKLASLIVLFATLGMFLTKNVGAISCNGVCSPFDIPPCGSPLCRCIPAGLVIGNCRNPYGVFLRTNDEHPNLCESDADCRKKGSGTFCGHYPNP
DIEYGWCFASKSEAEDFFSKITPKDLLKSVSTA
>PA2_1* PA2_2
MTKTGYINAAFRSSQNEAYLFINDKYVLLDYAPGTSNDKVLYGPTPVRDGFKSLNQTIVFGSYGVDCSFDTDNDEAFIFYEKFCALIDYAPHSNKDK
IILGPKKIADMPFFEGTVFENGIDAAYRSTRGKEVYLFKGDQYARIDYETNSMVNKEIKSIRNGFPFCFRNTIFESGTDAAFASHKTNEVYFFKGDY
YARVTVTPGATDDQIMDGVKRTL DYWPSLRGIIPLEN
>PA2_3
MTKTGYINAAFRSSRNNEAYLFINDKYVLLDYAPGTSNDKVLYGPTPVRDGFKSLNQTIFGSYGIDCSFDTDNDEAFIFYEKFCALIDYAPHSNKDK
IILGPKKIADMPFFEGTVFENGIDAAYRSTRGKEVYLFKGDQYARIDYGTNSMVNKEIKSISNGFPFCFRNTIFESGTDAAFASHKTNEVYFFKGDY
YARVTVTPGATDDQIMDGVKRTL DYWPSLRGIIPLEN
>PA3_1
MTKSGYINAAIRSSNTNEAYFFINDNYILLDYAPGTTNDKLLYGPIPLRDGFKSLNHTIFGSYGIDCSFDTDNQAFIFYENFCALIDYAPHSDKDK
IVSGPKKIADTFPFFKGT V FENGVDAA YRSSGKEVYLFKGNQYARIDYGSNKL VQNI R SITGGFTCFKGTIFENGMDAAFASHKTNEVYFFKDDY
ARVAVTPGASNDVIMDGVKRTL DYWPSLRGVVPLKN
>PA3_2 PA3_3
MTKPGYINAAFRSSFNGEAYLFIDDKYVLVDYAPGTGDDKLLNGPLPLPAGFGKSLDGT VFGTYGVDCAFD TDNDEAFIFYENFTALINYAPHTYNDK
IISGPKKISDMFPFFKGT V FENGIDA AFRSTRGKEVYLFKGDLYARIDYGNKLVQS IKNISTGFPCFTGT V FENGVDAA FASHRTNEAYFFKGDY
ALVKISPGGIDDIYIGGVKPILENNWPSLRGIIPQKS
>PA3_4 PA3_5
MTKHGYIRAAFRSSRHNEAYIFINDKYVLLDYAPGTTNDKILHGPVLVSEGFKSLAPTI FGSYPIDCAFDTDNNEAFLFHENFCAHINYAPFSGVDK
LISGPKKIVDMFPFFKGT V FESGIDAAYKSTRGKEAYLFKGDQYARIDYGTNNLVQS IKS IKGFTSLHGTIFESGSFDAAFASHKPNEVYIFKGEHY
IRIGVTPGVAKDNVISRASRIVDYWKGLGSILPLKN
>Piss1_1*
SRSDQENPFIFKSNRFQTL YENENGHIRLLQKFDKRSKIFENLQNYRLL EYKSKPHTFLFPQYTDADFILVVL S GKATLTVLKSNDRNSFNLERGDA
IKLPAGTIAYLANRDDNEDLRVLDLAI PVNKPQQLQS FLLSGTQNQPSLLSGFSKNILEAAFNNTNYEEIEKVLL EQQE PQHRRSLKDRRQ E INEE
NVIVKVSREQIEELSKNAKSSSKSVSSES GPFNLRSRNPIYSNKF GKF FEITPEKNQQLQDLDI FVNSVDIKEGSLLLPNYNSRAIVIVTVTEGKG
DFELVGQRNENQ GKENDKEEEQEETS KQVQLYRAKLS PGDV FVIPAGHPVAINASSDLNLIGFGINAENNERNFLAGEEDNVISQVERPVKELAFP
GSSHEVDRLLNKQKQSYFANAQPLQRE
>Piss1_2*
SRSDQENPFIFKSNRFQTL YENENGHIRLLQKFDKRSKIFENLQNYRLL EYKSKPRTLFLPQCTDADFILVVL S GKATLTVLKSNDRNSFNLERGDT
IKLPAGTIAYLANRDDNEDLRVLDLTI PVNKPQQLQS FLLSGTQNQPSLLSGFSKNILEAAFNNTNYEEIEKVLL EQQE PQHRRSLKDRRQ E INEE
NVIVKVSREQIEELSKNAKSSSKSVSSES GPFNLRSRNPIYSNKF GKF FEITPEKNQQLQDLDI FVNSVDIKEGSLLLPNYNSRAIVIVTVTEGKG
DFELVGQRNENQ GKENDKEEEQEETS KQVQLYRAKLS PGDV FVIPAGHPVAINASSDLNLIGFGINAENNERNFLAGEEDNVISQVERPVKELAFP
GSSHEVDRLLNKQKQSYFANAQPLQRE
>Piss1_3
MAATTMKASFPLMLMGISFLASVCVSSRSDQNPFI FKS NKFTLFENENGHIRLLQKFDQRSKIFENLQNYRLL EYKSKPHTIFLPQHTDADYIL
VVL S G KAILTVLKPDDRNSFNLERGDTIKLPAGTIAYLVNRDDNKLRLVLDLAI PVNRPQQLQS FLLSGNKNQNYLSGFSKNILEASFNTDYEEIE
KVLLEEHEKETQHRRSLKDKRQQSQEENVIVKLSRGQIEELSKNAKSTSKKSVSSESEPFNLRSRGPIYSNEFGKF FEITPEKNPQLQDLDI FVNSV
EIKEGSLLLPHYNSRAILIVTVNEGKGDFELVDQRNENQQEQRKEDDEEEQE GEEINKQVQNYKAKLSSGDV FVIPAGHPVAVKASSNLDDLGLFGI
NAENNQRNFLAGEDDNVISQIQRPVKELAFPGSAQEVDRILENQKQSHFADAPQQRERGRSRETRDRLSSV
>Piss1_4
MGTFDFCRNLTNVLKFVENLQNYRLL EYKSKPHTIFLPQHTDADYILVVL S G KAILTVLKPDDRNSFNLEREDTIKLPAGTIAYLVNRDDNEELRVL
DLAIPVNRPGQLQS FLLSGNQNQSYLSGFSKNILEASFNTDYEEIEKVLL EHEKETQHRRSLKDKRQQSQEENVIVKLSRGQIEELSKNAKSTSK
KSVSSESEPFNLRSRAP IYSNEFGKF FEITPEKNPQLQDLDI FVNSVEIKEGSLLLPHYNSRAIVIVTVNEGKGDFELVGQRNENQQEQRKEDDEEE
EQGEEINKQVQNYKAKLSSGDV FVIPAGHPVAVKASSNLDDLGLFGINAENNQRNFLAGILNLDLGLFGINAENNQRNFLAGEDDNVISQIQRPVKE
LAFPGSAQEVDRILENQKQSHFDAQPQQRERGRSRETRDRLSSV
>Piss1_5
MGTFDFLQKFEGPTFLKIFENLQKLP SFWN IQSKHVFSFENLQNYRLL EYKSKPHTIFLPQHTDADYILVVL S G KAILTVLKPDDRNSFNLERGDTV
KLPAGTIAYLVNRDDNEELRVLDLAI PVNRPQQLQS FLLSGNQNQSYLSGFSKNILEASFNTDYEEIEKVLL EHEKETQHRRSLKDK E AANRGP I
YSNEFGKF FEITPEENPQLQDLDI FVNSVEIKEGSLLLPHYNSRAIVIVTVNEGKGDFELVGQRNENQQEQTKEDDEEEQE GEEINKQVQNYKAKL
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SSGDV FV I P A G H P V S V K A S S N L D L F G F G I N A E N N Q R N F L A G D K D N V I S Q I Q R P V K E L A F P G S A Q E V D R I L E N Q K Q S H F A D A Q P Q Q R E I G S R E T R D R L S S V

>Piss1_6

K A I L T V L K P N D R N S F N I E R G D T I K L P A G T I A Y L V N R D D E D L R V L D L A I P V N R P G Q L Q S F L L S G N Q N Q Q S I L S G F S K N I L E A S F N T D Y E E I E K I L L E E N E K E T Q H R R S L R D K R Q Q S Q E D D V I V K L S K G Q I E B E L S K N A K S S S K S V S S E S K P F N L R S R N P I Y S N K F G K F Y E I T P E E N S Q L Q D L D I F V N S V E I K E G S L L L P H Y N S R A I V I V T V N E G R G D F E L V G Q R N E N Q Q G K R K E D D E E E K N E E D E T N K Q V Q N Y K A K L S P G D V F V I P A S H P V A V K A S S N L H L L G F G I N A Q N N Q R N F L A G K E D N V I S Q I Q R P V K E L T F P G S V Q E I D K L L E N Q K Q S Y F A N A Q P Q Q R E I G S S E T E N R L S S I L N A F

>Piss1_7

M A A T T M K A S F L L M L M G I S F L A S V C V S S R S D P Q N P F I F K S N K F Q T L F E N E N G H I R L L Q K F D Q R S K I F E N L Q N Y R L L E Y K S K P H T I F L P Q H T D A D Y I L V V L S G K A I L T V L K P D D R N S F N L E R G D T I K L P A G T I A Y L V N R D D N E E L R V L D L A I P V N R P G Q L Q G P L P

>Piss2_1*

M A T T I K S R F P L L L L L G I I F L A S V V C V T Y A N Y D E G S E P R V P A Q R E R G R Q E G E K E E K R H G E W R P S Y E K E E D E E E G Q R E R G R Q E G E K E E K R H G E W R P S Y E K Q E D E E E K Q K Y R Y Q R E K E D E E E K Q K Y Q Y Q R E K K E Q K E V Q P G R E R W E R E E D E E Q V D E E W R G S Q R R E D P E E R A R L R H R E E R T K R D R R H Q R E G E E E E R S S E S Q E R R N P F L F K S N K F L T L F E N E N G H I R L L Q R F D K R S D L F E N L Q N Y R L V E Y R A K P H T I F L P Q H I D A D L I L V V L S G K A I L T V L S P N D R N S Y N L E R G D T I K L P A G T T S Y L V N Q D D E E D L R L V D L V I P V N G P G K F E A F D L A K N K N Q Y L R G F S K N I L E A S Y N T R Y E T I E K V L L E E Q E K D R K R R Q Q G E E T D A I V K V S R Q I E E L K K L A K S S S K S L P S E F E P I N L R S H K P E Y S N K F G K L F E I T P E K K Y P Q L Q D L D L F V S C V E I N E G A L M L P H Y N S R A I V V L L V N E G K N L E L L G L K N E Q Q E R E D R K E R N N E V Q R Y E A R L S P G D V V I I P A G H P V A I T A S S N L N L L G F G I N A E N N E R N F L S G S D D N V I S Q I E N P V K E L T F P G S V Q E I N R L I K N Q K Q S H F A N A E P E Q K E Q G S Q G K R S P L S S I L G T F Y

>Piss2_2

M A T T I K S R F P L L L L L G I I F L A S V V S V T Y A N Y D E G S E P R V P A Q R E R G R Q E G E K E E K R H G E W R P S Y E K E E D E E E G Q R E R G R Q E G E K E E K R H G E W G P S Y E K Q E D E E E K Q K Y R Y Q R E K E D E E E K Q K Y Q Y Q R E K K E Q K E V Q P G R E R W E R E E D E E Q V D E E W R G S Q R R E D P E E R A R L R H R E E R T K R D R R H Q R E G E E E E R S S E S Q E R R N P F L F K S N K F L T L F E N E N G H I R L L Q R A K P H T I F L P Q H I D A D L I L V V L N G K A I L T V L S P N D R N S Y N L E R G D T I K L P A G T T S Y L V N Q D D E E D L R L V D L V I P V N G P G K F E A F D L A K N K N Q Y L R G F S K N I L E A S Y N T K Y E T I E K V L L E E Q E K E P Q Q R R A I V K V S R E Q I E E L R K L A K S S S K S L P S E F E P I N L R S H K P E Y S N K F G K L F E I T P E K K Y P Q L Q D L D L F V S C V E I N E G A L M L P H Y N S R A I V V L L V N E G K N L E L L G L K N E Q Q E R E D R K E R N N E V Q R Y E A R L S P G D V V I I P A G H P V A I T A S S N L N L L A F G I N A E N N E R N F L S G S D D N V I S Q I E N P V K E L T F P G S V Q E I N R L I K N Q K Q S H F A N A E P E Q K E Q G S Q G K R S P L S S I L G T F Y

>Piss2_3

M A T T V K S R F P L L L F L G I I F L A S V C V T Y A N Y D E G S E T R V P G Q R E R G R Q E G E K E E K R H G E W R P S Y E K E E H E E E K Q K Y R Y Q R E K K E Q K E V Q P G R E R W E R E E D E E Q V E E E W R G S Q R R E D P E E R A R L R H R E E R T K R D R R H Q R E G E E E E R S S E S Q E H R N P F L F K S N K F L T L F E N E N G H I R R L Q R A K P H T I F L P Q H I D A D L I L V V L N G K A I L T V L S P N D R N S Y N L E R G D T I K I P A G T T S Y L V N Q D D E E D L R V D V F V I P V N R P G K F E A F G L S E N K N Q Y L R G F S K N I L E A S L N T K Y E T I E K V L L E E Q E K K P Q Q L R D R K R T Q Q G E E R D A I I K V S R E Q I E E L R K L A K S S S K S L P S E F E P F N L R S H K P E Y S N K F G K L F E I T P E K K Y P Q L Q D L D I L V S C V E I N K G A L M L P H Y N S R A I V V L L V N E G K N L E L L G L K N E Q Q E R E D R K E R N N E V Q R Y E A R L S P G D V V I I P A G H P V A I S A S S N L N L L G F G I N A K N N Q R N F L S G S D D N V I S Q I E N P V K E L T F P G S S Q E V N R L I K N Q K Q S H F A S A E P E Q K E E E S Q R K R S P L S S V L D S F Y

>Leg1_1

M A K L L A L S L S F C F L L L G G C F A L R E Q P Q Q N E C Q L E R L D A L E P D N R I E S E G G L I E T W N P N N K Q F R C A G V A L S R A T L Q R N A L R R P Y S N A P Q E I F I Q Q G N G Y F G M V F P G C P E T F E E P Q E S E Q G E G R R Y R D R H Q K V N R F R E G D I I A V P T G I V F W M Y N D Q D T P V I A V S L T D I R S S N N Q L D Q M P R R F Y L A G N H E Q E F L Q Y Q H Q Q G G K Q E Q E N E G N N I F S G F K R D F L E D A F N V N R H I V D R L Q G R N E D E E K G A I V K V K G G L S I I S P P E K Q A R H Q R G S R Q E E D E D E E K Q P R H Q R G S R Q E E E D E D E E R Q P R H Q R R R G E E E E D D K K E R G S Q K G K S R R Q G D N G L E E T V C T A K L R L N I G P S S S P D I Y N P E A G R I K T V T S L D L P V L R W L K L S A E H G S L H K N A M F V P H Y N L N A N S I I Y A L K G R A R L Q V V N C N G N T V F D G E L E A G R A L T V P Q N Y A V A A K S L S D R F S Y V A F K T N D R A G I A R L A G T S S V I N N L P L D V V A A T F N L Q R N E A R Q L K S N N P F K F L V P A R E S E N R A S A

>Leg1_2

M A K L L A L S L S F C F L L L G G C F A L R E Q P Q Q N E C Q L E R L D A L E P D N R I E S E G G L I E T W N P N N K Q F R C A G V A L S R A T L Q R N A L R R P Y S N A P Q E I F I Q Q G N G Y F G M V F P G C P E T F E E P Q E S E Q G E G R R Y R D R H Q K V N R F R E G D I I A V P T G I V F W M Y N D Q D T P V I A V S L T D I R S S N N Q L D Q M P R R F Y L A G N H E Q E F L Q Y Q H Q Q G G K Q E Q E N E G N N I F S G F K R D F L E D A F N V N R H I V D R L Q G R N E D E E K G A I V K V K G G L S I I S P P E K Q A R H Q R G S R Q E E D E D E E K Q P R H Q R G S R Q E E E D E D E E R Q P R H Q R R R G E E E E D D K K E R G S Q K G K S R R Q G D N G L E E T V C T A K L R L N I G P S S S P D I Y N P E A G R I K T V T S L D L P V L R W L K L S A E H G S L H K N A M F V P H Y N L N A N S I I Y A L K G R A R L Q V V N C N G N T V F D G E L E A G R A L T V P Q N Y A V A A K S L S D R F S Y V A F K T N D R A G I A R L A G T S S V I N N L P L D V V A A T F N L Q R N E A R Q L K S N N P F K F L V P A R E S E N R A S A

>Leg1_3

M A T K L L A L S L S F C F L L L G G C F A L R E Q P E Q N E C Q L E R L N A L E P D N R I E S E G G L I E T W N P N N K Q F R C A G V A L S R A T L Q H N A L R R P Y S N A P Q E I F I Q Q G N G Y F G M V F P G C P E T F E E P Q E S E Q G E G R R Y R D R H Q K V N R F R E G D I I A V P T G I V F W M Y N D Q D T P V I A V S L T D I R S S N N Q L D Q M P R R F Y L A G N H E Q E F L R Y Q H Q Q G G K Q E Q E N E G N N I F S G F K R D F L E D A F N V N R H I V D R L Q G R N E D E E K G A I V K V K G G L S I I S P P E K Q A R H Q R G S R Q E E D E D E E K Q P R H Q R G S R Q E E E D E D E E R Q P R H Q R R R G E E E E D D K K E R R G S Q K G K S R R Q G D N G L E E T V C T A K L R L N I G P S S S P D I Y N P E A G R I K T V T S L D L P V L R W L K L S A E H G S L H K N A M F V P H Y N L N A N S I I Y A L K G R A R L Q V V N C N G N T V F D G E L E A G R A L T V P Q N Y A V A A K S L S D R F S Y V A F K T N D R A G I A R L A G T S S V I N N L P L D V V A A T F N L Q R N E A R Q L K S N N P F K F L V P A R Q S E N R A S A

>Leg1_4

M A K L L A L S L S F C F L L L G G C F A L R E Q P Q Q N E C Q L E R L D A L E P D N R I E S E G G L I E T W N P N N K Q F R C A G V A L S R A T L Q R N A L R R P Y S N A P Q E I F I Q Q G N G Y F G M V F P G C P E T F E E P Q E S E Q G E G R R Y R D R H Q K V N R F R E G D I I A V P T G I V F W M Y N D Q D T P V I A V S L T D I R S S N N Q L D Q M P R R F Y L A G N H E Q E F L R Y Q H Q Q G G K Q E Q E N E G N N I F S G F K R D F L E D A F N V N R H I V D R L Q G R N E D E E K G A I V K V K G G L S I I S P P E K Q A R H Q R G S R Q E E D E D E E K Q P R H Q R G S R Q E E E D E D E E R Q P R H Q R R R G E E E E D D K K E R R G S Q K G K S R R Q G D N G L E E T V C T A K L R L N I G P S S S P D I Y N P E A G R I K T V T S L D L P V L R W L K L S A E H G S L H K N A M F V P H Y N L N A N S I I Y A L K G R A R L Q V V N C N G N T V F D G E L E A G R A L T V P Q N Y A V A A K S L S D R F S Y V A F K T N D R A G I A R L A G T S S V I N N L P L D V V A A T F N L Q R N E A R Q L K S N N P F K F L V P A R Q S E N R A S A

>Leg1_5

K G G L R I I S P P E K Q A R H Q R G S Q K G K S R R Q G D N G L E E T V C T A K L R L N I G P S S S P D I Y N P E A G R I K T V T S L D L P V L R W L K L S A E H G S L H K N T M F V P H Y N L N A N S I I Y A L K G R A R L Q V V N C N G N T V F D G K L E A G R A L T V P Q N Y A V A A K S L N D R F S Y V A F K T N D R A G I A R L A G T S S V I N D L P L D V V A A T F K L Q R D E A R Q L K S N N P F K F L V P A R Q S E N R A S A

>Leg1_6

M A K L L A L S L S F C F L L L G G C F A L T E Q P Q Q N E C Q L E R L D A L E P D N R I E S E G G L I E T W N P N N K Q F R C A G V A L S R A T L Q R N A L R R P Y S N A P Q E I F I Q Q G N G Y F G M V F P G C P E T F E E P Q E S E Q G E G R R Y R D R H Q K V N R F R E G D I I A V P T G I V F W M Y N D Q D T P V I A V S L T D I R S S N N Q L D Q M P R R F Y L A G N H E Q E F L R Y Q H Q Q G G K Q E Q E N E G N N I F S G F K R D F L E D A F N V N R H I V D R L Q G R N E D E E K G A I V K V K G G L S I I S P P E K Q A R H Q R G S R Q E E D E D E E K Q P R H Q R G S R Q E E E D E D E E R Q P R H Q R R R G E E E E D D K K E R R G S Q K G K S R R Q G D N G L X S F V A L V N A R P A S S S P S T R C L V N E D G P M F N R S L A V Q T V S S S P L S P A F C F C L F G C

RRPSSVFFFLSSSPLMTRLPLFIFIFLFLLSAASLVRGCFSSSSSSLSAASLVARLASRFSYVAFKTNDRAGIARLAGTSSVINNLPLDVVAATFN
LQRNEARQLKSNPNFKFLVPARESENRA

>Leg1_7

MATKLLALSLSFCFLLLGGCFALREQPEQNECQLERLNALEPDNRIESEGGLIETWNPNNKQFRCAGVALSRATLQRNALRRPYYSNAPQEIFIQQG
NGYFGMVFPGPCPETFEEPQEQEGGRRYRDRHQKVNRFREGDIIAIVLPGSYWYCILDVQRPRHPVIAVSLTDIRSSITSLIRCLGFYLAGNHEQEF
LRYQHQQGGKQEQENEGNNI FSGFKRISWKMLSTIISPPEKQARHQGRSQREEDEVKMKRGRSRAADKRRKMKMKRGRSVIKGEEERRKKKTR
KSAAAAKKAKAEGKETMGLRKQMLCFVPHYNLNANSIIYALKGRARLQVVNCNGNTPAFKTNDRAGIARLAGTSSVINNLPLDVVAATFNLQRNEAR
QLKSNPNFKFLVPARQSENRA

>Leg2_1

MARHFLSSFSCLFLLFTTACLAHHSERDRFNQCQLDTINALEPDHRVESEAGLTETWNPNHPELKCAGVSLIRRTIDPGLHLPSYSPPQLIFIIQ
GKGVGLGLAVPGCPETYEPRSQSRRQQQQRDSHQKIRRFSGKGDVIAIPPGIPYWTYNHGHEPLVAITLLDTSNTLNQLDSTPRVFYLGGNPEIEFPE
TQQKQHEPRQQRYSFVLVGRRGQQQEESEEQNEGNSVLSGFNVEFLAHSNTKEDTAKRLRSPQDERGQIVKVEDGLHIIISPELQEEEEEQSHSQRK
EEEEEEQEQRRHRKHKKEDDEDEDEEEEREQRHRKHSEKEEDEDEPRSYETRRKWKKHATAEKERESHGQEEEEEELEKEEEEEEGIQRQHSKGRK
NGLEETICSAKIRENIARPSRGDLVNSGAGRISTVNSLTLPILRLNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGEGRVIRVNSEGKVFDDKV
SLGQLVVVPQNFVVAQQAGNEEGFEYVVFKTNDRAAVSHVNQVFRATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQPQSQ

>Leg2_2

MITITMARHFLSSFSCLFLLFTTACLAHHSERDRFNQCQLDSINALEPDHRVESEAGLTETWNPNHPELKCAGVSLIRRTIDPGLHLPSYSPPQL
IFI IQGKGVGLGLAVPGCPETYEPRSQSRRQQQQRDSHQKIRRFSGKGDVIAIPPGIPYWTYNHGHEPLVAITLLDTSNTLNQLDSTPRVFYLGGNP
EIEFPETQQKQHEPRQQRYSFVLVGRRGQQQEESEEQNEGNSVLSGFNVEFLAHSNTKEDTAKRLRSPQDERGQIVKVEDGLHIIISPELQEEEEQ
SHSQRKEEEEEEQEQRRHRKHKKEDDEDEDEEEEREQRHRKHSEKEEDEDEPRSYETRRKWKKHATAEKERESHGQEEEEEELEKEEEEEEGIQRQ
HSKGRKNGLEETICSAKIRENIARPSRGDLVNSGAGRISTVNSLTLPILRLNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGEGRVIRVNSEGK
VFDDKVRKQLVVVPQNFVVAQQAGNEEGFEYVVFKTNDRAAVSHVNQVFRATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQPQSQ

>Leg2_3

MIAITMARHFLSSFSCLFLLFATACLAHHSERDRFNQCQLDSINALEPDHRVESEAGLTETWNPNHPELKCAGVSLIRRTIDPGLHLPSYSPPQL
IFI IQGKGVGLGLAVPGCPETYEPRSQSRRQQQQRDSHQKIRRFSGKGDVIAIPPGIPYWTYNHGHEPLVAITLLDTSNTLNQLDSTPRVFYLGGNP
IEFPETQEQHEGLQQRHSFLVGRRGQQQEEVESEEQKEGNSVLSGFNVEFLAHSNTKEDTAKRLRSPQDERGQIVKVEDGLHIIISPELQEEEEQSHR
QREEEEEEREQRHRKRSEKEDDEDEDEEEEREQRQRKHSEKEEEEEDEPLIHEIIKKWKKKTEKKRESHGREGKEEQVEEKEEEEEEEEEIHGQ
HSKGRNGLEETICSAKIRENIARPSRADLYNPRAGRISTVNSLTLPILRLNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGQGVIRIVNSQGNA
VFDDKVRKQLVVVPQNFVVSQQAGNEEGFEYVVFKTNDRAAVSHVKQVFRATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQSQSQ

>Leg2_4

GSVLSGFNVEFLAHSNTKEDTAKRLRSPQDERGQIVKVEDGLHIIISPELQEEEEQSHSQRKEEEEEEQEQRRHRKHKKEDDEDEDEEEEREQRH
RKHSEKEEDEDEPRSYETRRKWKKHATAEKERESHGQEEEEEELEKEEEEEEEIQRQHSKGRKNGLEETICSAKIRENIARPSRGDLVNSGAGRIST
VNSLTLPILRLNLRLSAEYVLLYRNGIYAPHWNINANSLLYVIRGEGRVIRVNSEGKVFDDKVSGLQLVVVPQNFVVAQQAGNEEGFEYVVFKTNDR
AAVSHVNQVFRATPGEVLANAFGLRHSQVAQIKSNGNRGPLVQPQSQ

>Leg3_1

MSKPFLLSLLSLSLLLFASACLATSEFDRNLNQCQLDSINALEPDHRVESEAGLTETWNPNHPELKCAGVSLIRRTIDPGLHLPSFSPSPQLIFIIQ
GKGVGLGLSFPGPCPETYEPRSSQSRQESRQQQGDSDHQKVRFRKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIAQLDSTPRVFYLGGNPETE
FPETQEEQQGRHRQKHSYPVGRRSBGHHQQEESEEQNEGNSVLSGFSSEFLAQTFNTEEDTAKRLRSPRDRSQIVRVEGGLRIINPKGKEEEEEKEQ
SHSHSHREEKEEEEEEEDEEEKQRSEERKNGLEETICSAKIRENIADAARADLYNPRAGRISTANSLTLPVLRYLRLSAEYVRLYRNGIYAPHWNI
NANSLLYVIRGEGRVIRVNCQNTVFDNKVRKQLVVVPQNFVVAEQAGEEEGLEYYVVFKTNDRAAVSHVQVFRATPSEVLANAFGLRQRQVTELK
LSGNGRPLVHPRSQSQSH

>Leg3_2

IPYWTYNHGDEPLVAISLLDTSNIAQLDSTPRVFYLGGNPETEFPETQEEQQGRHRQKHSYPVGRRSBGHHQQEESEEQNEGNSVLSGVSSEFLAQ
TFNTEEDTAKRLRSPRDRSQIVRVEGGLRIINPKGKEEEEEKEQSHSHSHREEEEEEEEDEEKQRSEERKNGLEETICSAKIRENIADAAGADLYN
PRAGRIRTANSLTLPVLRYLRLSAEYVRLYRNGIYAPHWNINANSLLYVIRGEGRVIRVNFQGDVFDNKVRKQLVVVPQNFVVAEQAGEEEGLEYY
VVFKTNDRAAVSHVQVLRATPAEVLANAFGLRQRQVTELKLSGNGRGPLVHPQSQSQSH

>Leg3_3

MSKPFLLSFLSLSLLLFASACLATHSEFDRNLNQCQLDNINALEPDHRVESEAGLTETWNPNNPELKCTGVSLIRRTIDPGLHLPSFSPSPQLIFIIQ
GKGVGLGLSLPGCPETYEPRSSQSRQGSRQPGDSHQKIRRFKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIAQLDSTPRVFYLGGNPETE
FPETQEEQQGRHRQKHSYPVGRRSBGHHQQEESEEQNEGNSVLSGFSSEFLAQTFNTEEDTAKRLRSPRDRSQIVRVEGGLRIINPKGKEEEEEKEQ
EQSHSHREEEEEEEEKEQSRERRKNGLEETICSAKIRENIADAARADLYNPRAGRISTANSLTLPVLRYLRLSAEMVYMLHTGTINANSLLYVIRGEG
RVRIVNCQNTVFDNKVRKQLVVVPQNFVVAEQAGEEEGLEYYVCSRQMTTELLLATYNRCLGPLLQRFQMLLVFVNASHGVKAQWKPWPSGSPSVS
ISISLR

>Leg3_4

MSKPSLSLSFLSLSLLLFASACLATRSEFDRNLNQCQLDNINALEPDHRVESEAGLTETWNPNNPELKCAGVSLIRRTIDPGLHLPSFSPSPQLIFIIQ
GKGVGLGLSLPGCPETYEPRSSQSKQGSRQQQGDSDHQKIRFRKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIAQLDSTPRVFYLGGNPETE
FPETQEEQQGRHRQKHSYPVGRRSBGHHQQEESEEQNEAGRAHRSQIVRVEGGLRIINPKGKEEEEEKEQSHSHSHREEEEEEEEDEEKQRSEERK
NGLEETICSAKIRENIADAARADLYNPRAGRISTANSLTLPVLRYLRLSAEYVRLYRNGIYAPHWNINANSLLYVIRGEGRVIRVNCQGDVFDNKV
RKQLVVVPQNFVVAEQAGEEEGLEYYVVFKTNDRAAEEGLEYVVFKTNDRAAVSHVQVLRATPAEVLANAFGLRQRQVTELKLSGNGRGPLVHPQSQ
SQSH

>Leg3_5

MSKPSLSLSFLSLSLLLFASACLATRSEFDRNLNQCQLDNINALEPDHRVESEAGLTETWNPNNPELKCAGVSLIRRTIDPGLHLPSFSPSPQLIFIIQ
GKGVGLGLSLPGCPETYEPRSSQSRQGSRQQQGDSDHQKIRRF

>Leg3_6

MSKPFLLSLLSLSLLLFASACLATSEFDRNLNQCQLDSINALEPDHRVESEAGLTETWNPNHPELKCAGVSLIRRTIDPGLHLPSFSPSPQLIFIIQ
GKGVGLGLSFPGPCPETYEPRSSQSRQESRQQQGDSDHQKIRRFKGDIIAIPSGIPYWTYNHGDEPLVAISLLDTSNIAQLDSTPRVFYLGGNPETE
FPETQEEQQGRHRQKHSYPVGRRSBGHHQQEESEEQNEGNSVLSGFSSEFLAQTFNTEEDTAKRLRSPRDRSQIVRVEGGLRIINPKGKEEEEEKEQ
SHSHSHREEKEEXLWSRSWMWTSLIFFP

>Leg3_7

STPRVFYLGGNPETEFPETQEEQQGRHRQKHSYPVG

>Leg4_1

MANPNSYCFSLLSVLLLFTSACSARQLPRQPSELYECQLDTHAREPDNRYDSEAGFTETWDSTRPDLRCAGVSVLKRTINPNGNLNPSYVAYPELH
FVEQGMGVLGMAIPGCAETYEEPQWERRGRPQLQQDRHQKVRYVKQGDIAIPPGVPYWTYNYGNTPLVIVSLLDTSNKNQLDQVPRRFYLGGNPE
VEHSVKQSGRKHGDEDTNNMFSGFDSRFLGEVLKVKESTIRKLQSPEDGQGKHQIIHVKGGLSLIRPPEIRSEEEKTRRKREEKVVEEEEEVV
EDEPGKREHREWRKETRKQKEGESEGEAEVVKETKTKEHRRHHGERESSRHGERRQEEEEEDVKEEKQTRTTTKEREGQKGNFLEETVCTLK
LHEDLAGSSQADVFNPRAGRITSVNSLTLPVLKLLHLSAQWVKLYKDGIFMPHWNMNANSVMYVTRGRGRVQVNVNSEGKSVFNGEVRRGKLLVVPQN
FAVAEQAGNEGLEYVVFKTNDRAEMNTLVGRDSAISATPAEVLGHVFGLSPEVNELNKNNRNEGVLATPDSRIQDDFIEMV
>Leg4_2
FLEETVCTLKLHEDLAGSSQADVFNPRAGRITSVNSLTLPVLKLLHLSAQWVKLYKNGIFMPHWNLNANS
>Leg4_3
RQLPRQPSELYECQLDTHAREPDNRYDSEAGFTETWDXTXPDLRCAGVSVLKLTINP
>Piss3_1*
MARSMKLACVALVICMVVIAPMAEAAALSCGTVSADMAPCVTYLQAPNNASPPPPCCAGVKLLAAATTPDRQAACNCLKSAAGSI PKLNTNNAAAL
PGKCGVSIPYKISTSTNCNTVRF
>Piss3_2
MARSMKLACVVLAMCMLVAPMAEAAAFSCATVMTDLRPLCTYLEAANNASPPPPCCAGVKNLQAAAPT VADRQAACNCLKSTAGAISNLNANNAAALP
GKCGVNIPYKISASTNCNTI
>Piss3_3
MARSMKLACVVLVICMVVIAPMAEAAALSCGAVTGD LAPCVTYLQAPNNASPPPPCCAGVKLLGAATTPDRQAACNCLKSAAGSISKLNTNNVAAL
PGNCGVSIPYKISTSTNCNTYVLLLLCFCHGSH
>Piss3_4
MCCFGDVHGSIYAYAEAAALSCGAVTGD LAPCLTYLQAPNNASPPPPCCAGVKLLGAATTPDRQAACNCLKSAAGSISKLNTNNAAALPGKCGVSI
PYKISTSTNCNTVKF
>Piss3_5
MARSMKLACVVLVICMVVIAPMAEAAALSCGTVSADMAPCVTYLQAPNNASPPPPCCAGVKLLAAATTPDRQAACNCLKSAAGSI PKLNTNNAAAL
PGKCGVSIPYKISTSTNCNTVRF
>Piss3_6
MARSMKLACVVLVICMVVIAPTAEEAALSCGTVSGDLAPCLTYLEAPNNASPPPSCCAGVKLLGAATTPDRQAACNCLKSAAGSISKLNTNNAAAL
PGKCGVSIPYKISTSTNCNTIKF
>Piss3_7
MAEAAALSCGTVSGDLAPCLTYLQAPNNASPPPPCCAGVKLLAAATTPDRQAACNCLKSAAGSISR LNTNNAAALPGKCGVSIPYKISTSTNCNTV
RF
>Piss3_8
MAEAAALSCGTVSGDLAPCLTYLQAPNNASPPPPCCAGVKLLGAATTPDRQAACNCLKSAAGSISR LNTNNAAALPGKCGVSIPYKISTSTNCNTI
KF