

Clinical Characteristics and Pattern of Skin Test Reactivities in Shellfish Allergy Patients in Hong Kong

Adrian Y. Wu, M.D.,* and Gray A. Williams, Ph.D.# (China)

ABSTRACT

Allergens from crustaceans and mollusks exhibit extensive cross-reactivity in vitro. However, the degree and pattern of cross-reactivity between different shellfish species in vivo is still unclear. The objective of this study was to determine the clinical characteristics of shellfish allergic patients in Hong Kong and the pattern of skin test reactivities to the different species. This cohort study involves patients attending the allergy clinic of a large teaching hospital for suspected shellfish allergy. Each subject underwent skin-prick tests to eight species of shellfish and house-dust mites. Eighty-four consecutive patients were tested. Twenty-eight patients reported a history of severe anaphylaxis. Fourteen patients had no positive shellfish skin test and were excluded. There were 183 positive shellfish skin tests, with an average of 2.61 positive tests per subject. Ninety percent of subjects also had positive skin tests to house-dust mites. Overall, 65.7% of subjects had more than one positive skin test to shellfish. There were strong statistical associations between species belonging to the same order but also between some mollusks and crustaceans. We found a high degree of skin test cross-reactivity between different species of shellfish and between shellfish and house-dust mites. Therefore, patients

with a history of shellfish allergy should be cautious with all types of shellfish. (Allergy and Asthma Proc 25:237–242, 2004)

Hong Kong has one of the highest per capita consumption of shellfish in the world, estimated at 14 kg of live, chilled, or frozen shellfish in 1997.¹ Consequently, shellfish allergy is the most common food allergy seen among adults. Tropomyosin has been identified as a panallergen with significant sequence homologies among crustaceans and mollusks, as well as insects such as the fruit fly and house-dust mites.² It is the general impression that there is extensive cross-reactivity between shellfish allergens, but there are few clinical studies addressing this issue. It is unclear whether certain species are more likely to cross-react with each other and whether some species are more likely to elicit serious allergic reactions. In addition, it is unclear to what extent shellfish cross-react with other important invertebrate allergens such as house-dust mites. In this study, we attempt to define the extent and pattern of skin test cross-reactivity between the shellfish species in a cohort of subjects.

METHODS

Patients attending the allergy clinic at Queen Mary Hospital between April 2000 and February 2003 for suspected shellfish allergy were recruited after verbal consent was given. The presentation of previous shellfish reactions, the types of shellfish the patients suspected they were allergic to, and the history of other allergic disorders were recorded. All patients underwent a standard panel of shellfish skin-prick tests including shrimp (*Penaeus* sp.), crab (*Callinectes sapidus*), lobster (*Homarus americanus*), clam (*Mercenaria mercenaria*), scallop (*Pecten magellanicus*), oyster (*Crassostrea virginica*), abalone (*Haliotis* sp.), and “limpet.” The house-dust mites *Dermatophagoides farinae*

From the Departments of *Medicine and #Ecology and Biodiversity, The Swire Institute of Marine Science, The University of Hong Kong, Hong Kong, China

Supported by The University of Hong Kong and a generous donation from Mr. Simon To

Address correspondence and reprint requests to Adrian Wu, M.D., Department of Medicine, Queen Mary Hospital, 102 Pokfulam Road, Hong Kong, China

Copyright © 2004, OceanSide Publications, Inc., U.S.A.

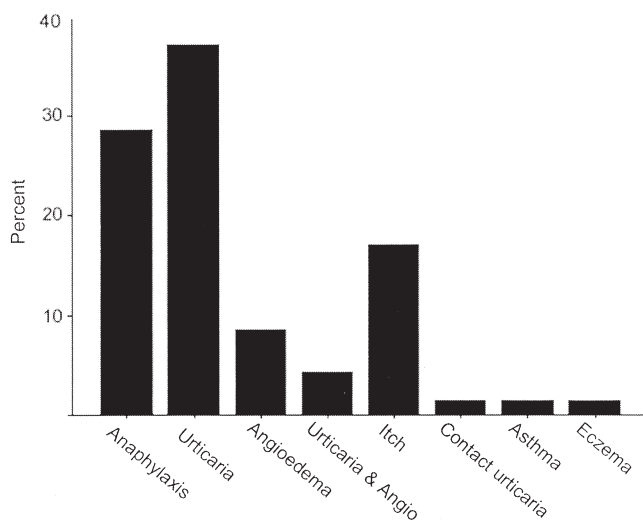


Figure 1. This chart shows the distribution of the presenting symptoms of shellfish allergy.

and *Dermatophagoides pteronyssinus*, together with positive and negative controls, were included also. This study has been approved by the Institutional Review Board of the University of Hong Kong.

Frozen abalone was purchased from a local market and cooked by boiling in distilled water for 10 minutes. Canned "limpets" were purchased from a food supplier (Goodview Seafood International, Ensenada, Mexico) that supplied the same shellfish to the largest local restaurant chain. This shellfish is used extensively in Chinese dim sum (dumplings), fried rice, noodles, and soup. Several of our cases involved ingestion of this shellfish in restaurants and fast-food stalls. Abalone and "limpet" extracts were prepared by cold extraction of the cooked shellfish at 4°C in sterile phosphate-buffered saline overnight. The extracts were centrifuged at 50,000 × g, and the supernatants were concentrated using Centricon YM-3 filter units (Millipore, Bedford, MA). The total protein content was determined using the DC protein assay (Bio-Rad Laboratories, Hercules, CA) and the concentration was adjusted to 20 mg/mL. Before use, the extracts were sterile filtered and diluted 1:1 with sterile glycerin. The other extracts were purchased from Greer Laboratories (Lenoir, NC). Prick tests were performed using the ALK lancets (ALK-Abello, Horsholm, Denmark), and the average of the largest diameter of the wheal and its perpendicular diameter was determined. Skin test reactions with a diameter of at least 3 mm greater than the negative control reaction were deemed positive. The χ^2 tests, using 2 × 2 contingency tables, were used to determine association between the skin test results of different shellfish species, with $p < 0.05$ being significant.

RESULTS

Eighty-four (34 Male) consecutive patients with valid skin test results were recruited. The average age was 33.8 years (range, 7–71 years). Twenty-eight (33.3%) pa-

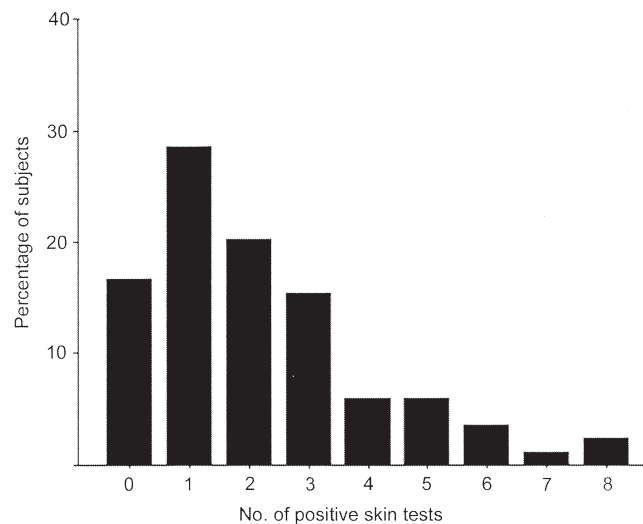


Figure 2. This chart shows the distribution of the number of positive skin tests per subject.

tients reported a history of severe anaphylaxis that required emergency medical treatment after shellfish ingestion. Two patients had worsening of their asthma only, 1 patient had contact urticaria only, and the other 53 patients complained of cutaneous symptoms only after shellfish ingestion. The distribution of symptoms is shown in Fig. 1. Thirty-four patients (40.5%) had a history of asthma, 55 patients (65.5%) had allergic rhinitis, and 21 patients (25%) had atopic dermatitis. Twenty patients (23.8%) had no history of other allergic diseases.

Fourteen patients (16.7%) did not have any positive shellfish skin test. Seven of these patients presented with anaphylaxis after shellfish ingestion. Two of these 14 patients claimed they reacted to shrimp only, 2 to crab only, 1 to oyster only, 4 to both crab and shrimp, 1 to crab and clam, 1 to abalone, and 1 to an unidentified bivalve. These patients were excluded from further analysis. Overall, 43 patients claimed they had reactions to shrimp, 37 to crab, 11 to lobster, 1 to scallop, 6 to limpet, 5 to abalone, 3 to snail, 1 to mussel, and 1 to clam. Figure 2 shows the distribution of the number of positive shellfish skin tests per patient. Overall, there were 183 positive shellfish skin tests with an average of 2.61 positive reactions per patient. Sixty-five percent of subjects had more than one positive skin test to shellfish. The proportion of patients with skin test sensitivity to each species is shown in Fig. 3. Ninety percent of subjects also had positive skin tests to house-dust mites.

We did not find a significant association between a history of anaphylaxis and a history of asthma ($\chi^2 = 0.29$). We also did not find significant associations between a history of anaphylaxis and sensitivity to scallop ($\chi^2 = 0.20$), oyster ($\chi^2 = 0.69$), crab ($\chi^2 = 0.58$), shrimp ($\chi^2 = 0.87$), or lobster ($\chi^2 = 0.57$). Anaphylaxis was positively associated with limpet ($\chi^2 = 7.35$, $p < 0.01$) and abalone ($\chi^2 = 4.5$, $p < 0.05$) sensitivity and negatively associated with clam sensitivity ($\chi^2 = 5.22$, $p < 0.05$).

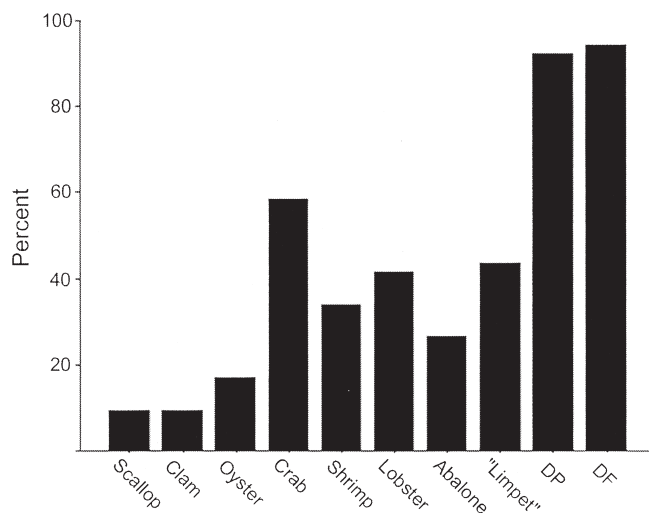


Figure 3. This chart shows the proportion of subjects having a positive skin test reaction to each species. DP, *Dermatophagoides pteronyssinus*; DF, *Dermatophagoides farinae*.

Table I shows the probability of a patient having sensitivity to a shellfish species if he/she has a positive or negative skin test to another shellfish species. For example, if a shellfish-allergic patient has a positive skin test to clam, his/her probability of having a positive skin test to scallop was 0.55, whereas if his/her skin test to clam was negative, the probability of sensitivity to scallop was only 0.05. Table II shows the results of the χ^2 values between skin test results of two species. Sensitivity to the bivalve mollusks, scallop, clam, and oyster is significantly interdependent, and so is the sensitivity between the crustaceans shrimp and lobster, and the sensitivity between limpet and abalone. There is also a significant association between shrimp and the bivalves, crab and limpet, scallop and limpet, and scallop and abalone. Overall, of the 70 patients with positive shellfish skin tests, 25 (35.7%) patients were sensitive to crustaceans only, 18 (25.7%) patients were sensitive to mollusks only, and 27 (38.6%) patients were sensitive to both crustaceans and mollusks.

DISCUSSION

Shellfish is one of the most common causes of food allergy among adults in Hong Kong. This probably is caused by the ubiquity of shellfish in the local diet. It is a common belief among the lay public that people allergic to one shellfish species are at high risk of reactions to other shellfish species. Although there is some serological evidence to support this hypothesis, the degree of clinical cross-reactivity is still unknown. The aim of this study was to define the pattern of skin test reactivities to different shellfish species of crustaceans and mollusks in a cohort of patients.

We selected subjects for this study based on clinical history. Fourteen out of the 84 patients did not have positive skin tests to the eight species tested, although every patient

claimed to have experienced clear-cut allergic reactions after ingesting some sort of shellfish. One possible reason is that although cross-reactivity is prevalent among shellfish species, some patients have been found only to react to a specific species of shellfish,³ which our skin test panel might have missed. Often, it is difficult for a layperson to identify different species of shellfish, especially when Chinese cooking frequently renders the ingredients unidentifiable. In addition, other hidden ingredients in the meal might have been responsible for the allergic reaction.

By history, more patients claimed that they were allergic to shrimp or crab than other species. This might be because shrimp and crab are the most easily identifiable shellfish species on the dining table and the most frequently consumed. In our experience, clinical history often is inaccurate because species identification by patients is unreliable. In Chinese, "shrimp" might mean shrimp, prawn, and even scampi. Patients might also be misled by restaurants that mislabel cheap food ingredients as more expensive ones. One common practice is to substitute abalone with limpet. Many patients avoided eating all shellfish after their first allergic reaction, making it difficult to ascertain whether they might be allergic to other species. However, even with avoidance, almost all of our subjects had experienced unintentional exposure. Hidden seafood allergens often are present in Chinese dim sum, soup, and rice porridge.

Symptoms of shellfish allergy can range from trivial to life threatening. In our cohort, one-third of the subjects experienced anaphylaxis after shellfish ingestion. It is our impression that shellfish is a common cause of anaphylaxis in the adult population of Hong Kong, but this figure might be an overestimation because patients with milder symptoms are less likely to be referred for specialist consultation. We did not find an increased risk of anaphylaxis in those subjects with asthma, but the efficacy of modern controller medications might have negated this tendency. We could find only an association between limpet and abalone sensitivity and the risk of anaphylaxis. This is consistent with the general perception among the lay public that these shellfish are more likely to cause severe allergic reactions.

Our results indicate a high incidence of cross-reactivity between different shellfish species on skin testing. Sixty-five percent of subjects had more than one positive shellfish skin test, which is consistent with previously published reports, with each subject reacting to an average of 33% of all species tested.

Shrimp (genera *Penaeus* and *Metapenaeus*) allergens are the most thoroughly studied shellfish allergens. The major heat-stable allergen of shrimp was first identified by Hoffman⁴ to be a 38-kDa glycoprotein and called shrimp antigen II. Subsequently, a similar allergen from *Penaeus aztecus* that reacted with sera from 82% of shrimp-allergic subjects was identified by other investigators⁵ and called Pen a 1. Pen a 1 is responsible for most of the allergenicity of shrimp; it inhibited 85% of the radioallergosorbent test (RAST) reactivity to whole body shrimp extract.⁶ The

TABLE I

Probability of Having a Positive Skin Test to the Shellfish Listed at the Top Depending on Whether the Skin Test to the Shellfish Listed in the Left Column is Either Positive or Negative

	Scallop	Clam	Oyster	Crab	Shrimp	Lobster	Abalone	Limpet
Positive Skin Test								
Overall	0.13	0.16	0.21	0.57	0.39	0.47	0.32	0.45
Scallop		0.67	0.56	0.67	0.78	0.67	0.63	0.88
Clam	0.55		0.46	0.64	0.91	0.82	0.44	0.63
Oyster	0.33	0.33		0.67	0.73	0.60	0.42	0.46
Crab	0.15	0.18	0.25		0.48	0.58	0.25	0.31
Shrimp	0.26	0.37	0.41	0.70		0.78	0.39	0.41
Lobster	0.18	0.27	0.27	0.70	0.64		0.30	0.38
Abalone	0.25	0.20	0.25	0.45	0.45	0.45		0.79
Limpet	0.25	0.18	0.18	0.39	0.32	0.39	0.54	
Negative Skin Test								
Overall	0.13	0.16	0.21	0.57	0.39	0.47	0.32	0.45
Scallop		0.08	0.16	0.56	0.33	0.44	0.27	0.39
Clam	0.05		0.17	0.56	0.29	0.41	0.30	0.43
Oyster	0.07	0.11		0.55	0.29	0.44	0.29	0.45
Crab	0.10	0.13	0.17		0.27	0.43	0.41	0.63
Shrimp	0.05	0.02	0.09	0.49		0.28	0.28	0.48
Lobster	0.08	0.05	0.16	0.46	0.16		0.33	0.52
Abalone	0.07	0.12	0.16	0.63	0.33	0.49		0.30
Limpet	0.03	0.09	0.18	0.70	0.38	0.53	0.12	

The first row of data is the overall rate of sensitization to the shellfish listed at the top.

TABLE II

The χ^2 Value Between Two Shellfish Skin Tests Determined by Using 2×2 Contingency Tables

	Clam	Oyster	Crab	Shrimp	Lobster	Abalone	Limpet
Scallop	20.24*****	7.14***	0.38	6.70***	1.58	4.00*	6.65***
Clam		4.47*	0.23	15.09*****	6.30**	0.78	1.12
Oyster			0.71	9.74*****	1.27	0.67	0
Crab				3.14	4.02*	1.76	6.12**
Shrimp					16.55*****	0.91	0.25
Lobster						0.08	0.28
Abalone							12.63*****

* $p < 0.05$, ** $p < 0.025$, *** $p < 0.01$, **** $p < 0.005$, ***** $p < 0.001$.

amino acid sequence of Pen a 1 showed significant homology with tropomyosins from various other species.⁷ The major heat-stable allergen from *Penaeus indicus* (Pen i 1)⁸ and *Metapenaeus ensis* (Met e 1)⁹ also have been sequenced and found to be tropomyosins. Subsequently, major allergens from other crustacean species including the common crab *Charybdis feriatus* (Cha f 1),¹⁰ spiny lobster *Panulirus stimpsoni* (Pan s 1),¹¹ and American lobster *Homarus americanus* (Hom a 1)^{11,12} have been sequenced and also found to be tropomyosins. The major allergens from the various crustacean species show a high degree of amino acid sequence homology (reviewed by Reese *et al.*²), in most cases >90%. Cross-inhibition studies between Cha f 1 and Met e¹⁰ and between Hom a 1, Pan a 1, and Met e 1⁹⁻¹¹ indicated a high degree of immunoglobulin E

(IgE) cross-reactivity between these species as well. Clinically, it has been reported that patients with shrimp sensitivity often complain of reactions to other crustacean species.¹³ Our data also support these findings. For example, a shellfish-allergic subject with a positive skin test to shrimp has a 70 and 78% chance of having reactivity to crab and lobster, respectively. If the shrimp skin test is negative, the chance of positive reactions to crab and lobster is reduced to 49 and 28%.

The most commonly eaten mollusks belong to the classes Bivalvia (clam, scallop, oyster, and mussel), Gastropoda (abalone, limpet, and whelk), and Cephalopoda (squid and octopus), although species belonging to the classes Polyplacophora (chitons) and Scaphopoda (tusk shells) are sometimes eaten also. Indeed, almost any shellfish, as long as it

is not poisonous, can be found on the table of Hong Kong restaurants! Major allergens from several mollusks, including the oyster *Crassostrea gigas* (Cra g 1),^{14,15} spiny top shell *Turbo cornutus* (Tur c 1),¹⁶ abalone *Haliotis midae* (Hal m 1),¹⁷ Pacific squid *Todarodes pacificus* (Tod p 1),¹⁸ and the brown garden snail *Helix aspersa* (Hel as 1)¹⁹ have been identified. These were all found to be tropomyosins with significant sequence homology between the different species.

Cross-reactivity between mollusk species and between mollusks and crustaceans is not well defined. An early study showed significant RAST and skin-prick test reactivity to oyster in shrimp-allergic subjects.²⁰ In another study, IgE reactivity against different Gastropoda, Bivalvia, and Cephalopoda species was found in nine out of nine sera from shrimp-allergic subjects.²¹ Our findings suggest significant cross-reactivity between the bivalves and between abalone and limpet. We are not able to confirm the identity of the limpet, because processing before canning removes most of the features that can be used for identification. However, the morphology of what remains suggests that it might be a chiton, which belongs to the class Polyplacophora, rather than a limpet, which is a gastropod. IgE immunoblots against a panel of limpet and chiton extracts, using sera from subjects sensitized to this shellfish but not to abalone, seem to confirm this hypothesis (Wu AY and Williams GA, unpublished data). Nevertheless, there is strong association between this shellfish and abalone. Clinical cross-reactivity between different species of gastropods probably is common; one of our patients, a university student known to be allergic to abalone, suffered fatal anaphylaxis recently after ingesting three snails. Our data also suggested that cross-reactivity between mollusks and crustaceans is common; 39% of subjects with positive shellfish skin tests were sensitive to both mollusks and crustaceans. Whether these associations are clinically meaningful requires additional investigation, because a previous study failed to show any correlation between oyster and shrimp cross-reactivity during RAST inhibition studies and clinical sensitivity.²¹ However, a recent report showed significant cross-reactivity between scallop and shrimp by immunoblot inhibition in a seafood worker with occupational asthma.²² The subject reacted to inhalation challenges with both scallop and shrimp.

Because crustaceans belong to the phylum Arthropoda, several studies have addressed the issue of cross-reactivity between crustaceans and other arthropod classes such as insects and arachnids. The tropomyosin allergen Der P 10 from *Dermatophagoides pteronyssinus* shares >65% sequence homology with other invertebrate tropomyosins and reacted to shrimp anti-tropomyosin antibodies.²³ Serum from shrimp-allergic subjects identified 7/8 Pen a 1-homologous epitopes in Der p 10/Der f 10, suggesting that these homologous epitopes are responsible for the cross-reactivity seen between shrimp and house-dust mites.²⁴ Ninety percent of our subjects had positive skin-prick tests to *D.*

pteronyssinus and/or *D. farinae*. This might simply reflect the highly atopic nature of our subjects, because house-dust mites are the most common aeroallergens in Hong Kong. For comparison, a recent study showed that 77.5% of 227 adult asthma patients attending our clinic had positive skin tests to *D. pteronyssinus* and/or *D. farinae*. In a separate study, we interviewed and performed shellfish skin tests on 111 adult patients before starting dust-mite immunotherapy for allergic rhinitis at our ear, nose, and throat department. All of these patients had positive skin test and nasal challenge responses to *D. pteronyssinus* and/or *D. farinae*. Twenty-nine (26%) of these patients had skin test reactivity to a shellfish mix extract (ALK-Abello), but only 6 of these subjects reported previous reactions to shellfish (Wu AY and Williams GA, unpublished data). Therefore, cross-reacting antibodies to shellfish might be common in dust-mite-allergic subjects but clinical reactions are much less so. However, cross-reactivity between house-dust mites and shellfish can be clinically important. Van Ree *et al.* reported that 2 of 17 patients undergoing mite immunotherapy developed snail sensitivity, and the novel IgE antibodies cross-reacted with mites.²⁵ One of our subjects, an 8-year-old girl with anaphylactic sensitivity to shrimp, suffered an episode of anaphylaxis after heavy exposure to house-dust mites while playing with an old rag doll.

Skin test positivity to several shellfish species does not in itself prove cross-reactivity, because this also might be caused by cosensitization in highly atopic individuals. IgE cross-inhibition assays will be required to confirm cross-sensitization. This study also is limited by the lack of data regarding clinical sensitivity. Skin test reactivity does not automatically infer clinical sensitivity, and challenge studies are needed for confirmation. However, it is difficult to perform challenge tests in clinical practice, especially when there is a risk of anaphylaxis. Most practicing allergists would rely on skin test findings for diagnosis and management, and few patients will consent to challenge testing, especially if they have experienced severe symptoms in the past. Therefore, additional studies that include double-blind placebo-controlled food challenges are required to document the clinical cross-sensitivity between shellfish species.

REFERENCES

1. Pawiro S. Hong Kong: Recent trends in the seafood trade. INFOFISH Int 98:22–26, 1998.
2. Reese G, Ayuso R, and Lehrer SB. Tropomyosin: An invertebrate pan-allergen. Int Arch Allergy Immunol 119:247–258, 1999.
3. Morgan JE, O'Neil CE, Daul CB, et al. Species-specific shrimp allergens: RAST and RAST-inhibition studies. J Allergy Clin Immunol 83:1112–1117, 1989.
4. Hoffman DR, Day ED, and Miller JS. The major heat stable allergen of shrimp. Ann Allergy 47:17–22, 1981.
5. Daul CB, Slattey M, Reese G, et al. Identification of the major brown shrimp (*Penaeus aztecus*) as the muscle protein tropomyosin. Int Arch Allergy Clin Immunol 105:49–55, 1994.

6. Morgan JE, Daul CB, Lehrer SB, et al. Characterization of important shrimp allergens by immunoblot analysis. *J Allergy Clin Immunol* 85:170, 1990 (Abs).
7. Daul CB, Slattery M, Morgan JE, et al. Common crustacea allergens: Identification of B cell epitopes with shrimp-specific monoclonal antibodies. In *Molecular Biology and Immunology of Allergens*. Kraft D, and Sehon A (Eds). Boca Raton, FL: CRC Press, 291–294, 1993.
8. Shanti KN, Martin BM, Nagpal S, et al. Identification of tropomyosin as the major shrimp allergen and characterization of its IgE binding epitopes. *J Immunol* 151:5354–5363, 1993.
9. Leung PSC, Chu KH, Chow WK, et al. Cloning, expression, and primary structure of *Metapenaeus ensis* tropomyosin, the major heat-stable shrimp allergen. *J Allergy Clin Immunol* 92:837–845, 1994.
10. Leung PSC, Chen Y, Gershwin MR, et al. Identification and molecular characterization of *Charybdis feriatus* tropomyosin, the major crab allergen. *J Allergy Clin Immunol* 102:847–852, 1998.
11. Leung PS, Chen YC, Mykles DL, et al. Molecular identification of the lobster muscle protein tropomyosin as a seafood allergen. *Mol Mar Biol Biotechnol* 7:12–20, 1998.
12. Mykles DL, Cotton JL, Taniguchi H, et al. Cloning of tropomyosins from lobster (*Homarus americanus*) striated muscles: Fast and slow isoforms may be generated from the same transcript. *J Muscle Res Cell Motil* 19:105–115, 1998.
13. Waring N, Daul C, DeShazo R, et al. Hypersensitivity reactions to ingested crustacea. Clinical evaluation and diagnostic studies in shrimp-sensitive individuals. *J Allergy Clin Immunol* 76:440–445, 1985.
14. Ishikawa M, Ishida M, Shimakura K, et al. Tropomyosin, the major oyster *Crassostrea gigas* allergen and its IgE-binding epitopes. *J Food Sci* 63:44–47, 1998.
15. Leung PS, and Chu KH. cDNA cloning and molecular identification of the major oyster allergen from the Pacific oyster *Crassostrea gigas*. *Clin Exp Allergy* 31:1287–1294, 2001.
16. Ishikawa M, Ishida M, Shimakura K, et al. Purification and IgE-binding epitopes of a major allergen in the gastropod *Turbo cornutus*. *Biosci Biotechnol Biochem* 62:1337–1343, 1998.
17. Lopata AL, Zinn C, and Potter PC. Characteristics of hypersensitivity reactions and identification of a unique 49 kd IgE-binding protein (Hal-m-1) in abalone (*Haliotis midae*). *Allergy Clin Immunol* 100: 642–648, 1997.
18. Miyazawa H, Fukamachi H, Inagaki Y, et al. Identification of the first major allergen of a squid (*Todarodes pacificus*). *J Allergy Clin Immunol* 98:948–953, 1996.
19. Asturias JA, Eraso E, Arilla MC, et al. Cloning, isolation, and IgE-binding properties of *Helix aspersa* (Brown Garden Snail) tropomyosin. *Int Arch Allergy Immunol* 128:90–96, 2002.
20. Lehrer SB, and McCants ML. Reactivity of IgE antibodies with crustacea and oyster allergens. Evidence for common antigenic structures. *J Allergy Clin Immunol* 80:133–139, 1987.
21. Leung PSC, Chow WK, Duffey S, et al. IgE reactivity against a cross-reactive allergen in crustacea and mollusca. Evidence for tropomyosin as the common allergen. *J Allergy Clin Immunol* 98:954–961, 1996.
22. Goetz DA, and Whisman BA. Occupational asthma in a seafood restaurant worker: Cross-reactivity of shrimp and scallops. *Ann Allergy Asthma Immunol* 85:461–466, 2000.
23. Asturias JA, Arilla MC, Gomez-Bayon N, et al. Sequencing and high level expression in *Escherichia coli* of the tropomyosin allergen (Der p 10) from *Dermatophagoides pteronyssinus*. *Biochim Biophys Acta* 1397:27–30, 1998.
24. Ayuso R, Reese G, Leong-Kee S, et al. Molecular basis of arthropod cross-reactivity: IgE-binding cross-reactive epitopes of shrimp, house dust mite, and cockroach tropomyosins. *Int Arch Allergy Immunol* 129:38–48, 2002.
25. Martinez A, Martinez J, Palacios R, et al. Importance of tropomyosin in the allergy to household arthropods. Cross-reactivity with other invertebrate extracts. *Allergol Immunopathol* 25:118–126, 1997. □

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.