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**Abstract**

*For a long time, people with peanut allergies have had to carefully read labels, carry around emergency epinephrine injections, and live in fear of accidentally consuming an otherwise benign food that could potentially kill them. Thankfully, researchers have been working on ways to alleviate the harmful effects of these allergies and perhaps even find a cure. In the Learning Early About Peanut allergy (LEAP) study performed in 2015, researchers examined whether the early introduction of peanut consumption could be used to prevent peanut allergies. According to the study, peanuts can be introduced orally to high-risk infants who are sensitized, as well as to non-sensitized infants in the early stages of development (Du Toit et al., 2015). Current research has increased our understanding of peanut allergies and has led to the development of treatments and preventions for this condition. Additionally, the mechanism of peanut allergies and how it differs from other food-borne allergies has been studied in detail, which has helped to revolutionize our understanding of this condition. This knowledge is being used to develop new ways to prevent and possibly cure peanut allergies.*

## Introduction

In the United States, 32 million people suffer from allergies related to food (Gupta et al., 2019). Approximately 9 million of them suffer from allergies to peanuts (Wang, 2021). Peanuts are found in many foods people regularly consume, in many instances, only trace amounts are present. This can be due to using peanut oil or even producing benign foods in a factory that also produces peanut-containing foods. Studies show that an estimated 0.85% of all emergency room visits in the United States are related to allergic reactions, underscoring the high morbidity and possibly mortality (Carrillo-Martin et al., 2020).

Not all people who have peanut allergies will have identical reactions. Some will only have a mild allergic reaction with pruritic hives, while in the most severe cases, the consumption of the allergen can result in anaphylactic shock, which can lead to death if not treated promptly. It is estimated that between 0.7%-2% of cases of anaphylactic shock result in death (Bock, 2021).

The focus of this paper is to explain the pathophysiology of peanut allergies as well as discuss possible preventions and treatments for this allergy.

## Methods

Data was found using Touro University's online library, specifically ProQuest and PubMed databases. Supplemental information was obtained using UpToDate. The main keywords used were peanut allergy, Ara h 2 and 6, Bamba, and LEAP.

## Discussion

### Pathophysiology of Allergic Reactions

An allergic reaction falls into one of the four categories of Gell and Coombs' classical division of immune responses. The type of hypersensitivity is classified based on the mechanism used. Hypersensitivity type I is known as immunoglobulin E (IgE)-mediated. The mechanism involves the release of IgE antibodies against soluble antigens and is also known as an "immediate reaction." When the host is exposed to an antigen, two levels of response occur, sensitization and effect. During sensitization, the host is exposed asymptomatically to the antigen. Following reintroduction, anaphylactic or atopic responses are produced. There is a possibility that a mild reaction can occur upon first exposure to an antigen. However, most reactions will not happen unless it is exposed to an antigen a second time. Hypersensitivity type II engages IgG and IgM antibodies, activating the complement system and cell lysis. A type III hypersensitivity is also called an Immune Complex Reaction. It occurs when IgG, IgM, and sometimes IgA antibodies are involved. These antibodies bind with the antigen and form a large complex that can trigger a more significant immune response and form large complexes that can cause tissue damage, especially in areas of narrower vasculature. T-cell-mediated reactions are involved in type IV hypersensitivity, also called delayed hypersensitivity. T-cells or macrophages are activated by cytokine release, causing tissue damage (Warrington et al., 2011). The prevalence of type I allergies is 48%, followed by type IV allergies at 18%, type III allergies at 10%, and type II allergies at 6% (Żukiewicz-Sobczak et al., 2013).

It is the focus of this article to examine type I hypersensitivity as it relates specifically to peanuts.

### Peanut Allergy Pathophysiology

Peanut allergies are classified as type I reactions or immediate hypersensitivity reactions. An individual with a peanut allergy experiences a range of symptoms when they consume peanuts or come into contact with peanut protein. Whenever a peanut allergy sufferer consumes peanuts or encounters peanut protein, the immune system perceives peanut proteins as harmful invaders and mounts an immune response. This immune response is mediated by mast cells, which are found throughout the body, particularly in tissues that have direct contact with the outside environment, including the skin, respiratory tract, and digestive tract. Histamine and leukotrienes are released by mast cells in the presence of peanut allergens, which cause inflammation and allergic symptoms (Al-Muhsen et al., 2003).

### Sensitization and Effect

Allergic reactions involve a two-step process: sensitization and effect. During the sensitization phase of Type I hypersensitivity reactions, allergens (or antigens) are presented to T-cells which is a type of white blood cell whose job is to help recognize and eliminate pathogen by presenting the pathogen to an antigen-presenting cells (APCs). T-cells then stimulate B-cells, another type of white blood cell, to produce IgE antibodies, which bind to the Fc receptors on mast cells and basophils. When the free antigen causes the crosslinking of these bound IgE antibodies on mast cells and basophils, it leads to the degranulation of the cells and the release of histamine, proteolytic enzymes, and other mediators such as prostaglandin, cytokines, leukotrienes, platelet-activating factors, macrophage inflammatory proteins, and tryptase. This results in increased vascular permeability, peripheral vasodilation, and smooth muscle contraction, which can cause symptoms such as increased mucous secretions, bronchospasm, abdominal cramping, rhinitis, and potentially hypovolemia or hypoxia. Pulmonary angioedema or general angioedema can also occur due to fluid shifting into interstitial space. Individuals may experience pruritus and local responses, such as is the case with asthma, or an individual can experience a whole-body response which can include diffuse hives and anaphylaxis (Abbas et al., 2022).

Peanuts contain several proteins that cause allergic reactions, including Arachis hypogaea 1 (Ara h 1), Ara h 2, Ara h 3, and Ara h 6. These proteins are found in the seed coats of peanuts. They are resistant to digestion, which allows them to provoke an immune response when they encounter the immune system. The proteins belong to the 2S albumin protein family, a group of proteins found in many plants. Plants use these proteins to combat pests and diseases. The immune systems of individuals with peanut allergies mistake these proteins for harmful invaders and mount an immune response when detected. Studies have shown that Ara h 2 and Ara h 6 are the most allergenic proteins in peanuts, meaning that they are most likely to trigger an allergic reaction. Ara h 6 is very similar to Ara h 2 in terms of sequence identity, secondary and tertiary structure, and allergenic activity. Ara h 2 and Ara h 6 have about 59% sequence identity and a similar overall structure. While Ara h 2 is well-known as a strong allergen, it has recently been discovered that Ara h 6 is also highly allergenic. Based on their similarities in both physical and immunological properties, it is likely that Ara h 2 and Ara h 6 should be considered as closely related allergens. Other proteins in peanuts, such as Ara h 1 and Ara h 3, are also allergens, but they are not as potent as Ara h 2 and Ara h 6. Therefore, treatments for peanut allergies often focus on these two proteins (Mueller et al., 2014).

In severe cases, an allergic reaction can trigger anaphylaxis. This life-threatening allergic reaction can cause symptoms such as diffuse angioedema, a drastic drop in blood pressure, and respiratory distress due to airway constriction. Anaphylaxis can be treated with medications such as epinephrine, but it requires immediate medical attention and can be fatal if not treated promptly. One of the most common causes of food-induced anaphylaxis is peanuts. The average peanut contains 200 mg of protein. For most people with peanut allergies, symptoms begin after consuming less than 1 peanut, and for highly allergic individuals, even trace amounts can cause symptoms. Based on a study designed to determine the minimum dose of peanut protein that will elicit a reaction in highly sensitized individuals, subjective symptoms have been reported even with doses as low as 100 µg, while objective signs have been observed at 2 mg (Al-Muhsen et al., 2003).

### Initial Exposure Phenomenon

Approximately 70% of children with peanut allergies reported symptoms at their first known exposure. Considering that symptomatic IgE-mediated allergic reactions occur following initial exposure to an allergen, a prior unnoticed exposure is likely to have occurred. Sensitization may occur because of fetal exposure to allergens in breast milk that may arise after the mother consumes peanuts (Al-Muhsen et al., 2003).

Studies show that peanut allergens can be found in breast milk after consumption. One such study was done in 2014 that showed that the Ara h 6 protein from peanuts was evident in human breast milk just 10 minutes after being fed 30 g of roasted peanuts (Bernard et al., 2014).

### Diagnosis of Peanut Pllergies through Clinical Testing

Peanut allergies can be detected by IgE testing to individual peanut protein components in the suspected individual's blood rather than the entire peanut protein. Compared to crude peanut-specific IgE, IgE against Ara h 2 has shown to have better discrimination than that against other peanut-specific IgE. The diagnostic uncertainty will, however, persist in 5% of cases even when using component-resolved diagnostics, so food challenges will be necessary to clarify the diagnosis. In addition, peanut allergy component testing has only a small diagnostic advantage over skin prick tests (SPT) (Hemmings et al., 2020).

While skin prick tests and high levels of peanut specific IgE can indicate sensitization to peanuts, an oral food challenge (OFC) test is often necessary to confirm a diagnosis of peanut allergy. However, OFC tests can be risky and time-consuming, and may not always be performed.

In addition to its use for seasonal allergies, a conjunctival provocation test can also be used to diagnose peanut allergies in children. During the test, an allergen is applied to the conjunctiva, the membrane that covers the white of the eye. It is then observed if there are any allergic reactions (Lindvik et al., 2017).

**Outgrowing Peanut Allergies**

It was previously believed that peanut allergy is unlikely to be outgrown, but recent studies have shown that this may not always be the case. One study found that around 21.5% of patients with peanut allergies were able to outgrow their allergies (Skolnick et al., 2001). In another study, children with intermediate levels of peanut-specific IgE had a 55% chance of outgrowing their allergy, while those with lower peanut-specific IgE levels had a 63% chance, and those with an undetectable peanut-specific IgE had a 73% chance of successfully passing an oral challenge with peanut (Fleischer et al., 2003). The data suggests that patients with a peanut specific IgE level of 5 or less may have at least a 50% chance of outgrowing their allergy. However, it is crucial to note that peanut allergy can sometimes reappear after a negative skin test or challenge, especially if peanuts are not regularly consumed (Al-Ahmed et al., 2008).

**Studies Aimed at Preventing Peanut Allergies**

A clinical trial was conducted in 2013 to evaluate the safety and effectiveness of a candidate vaccine called EMP-123 for the treatment of peanut allergies. EMP-123 is a mix of recombinant hypoallergenic variants of the peanut allergens Ara h 1, 2, and 3, encapsulated in inactivated E. coli cells and administered rectally as an adjuvant. Inactivated E. coli can serve as a carrier for vaccine components, expressing specific antigens from the target pathogen. However, the trial was unsuccessful as 5 out of the 10 enrolled patients experienced adverse reactions and had to drop out. It is possible that the adverse reactions experienced by the patients were due to incomplete removal of the IgE-binding epitopes from the allergens (Wood et al., 2013).

In 2015, researchers conducted the Learning Early About Peanut Allergy (LEAP) study. It was discovered that Jewish children in the United Kingdom were 10 times more likely to develop a peanut allergy than Israeli children of similar ancestry. A study of infants in the United Kingdom found that peanut-based foods are usually not consumed during the first year of life. In Israel, peanut-based foods are usually introduced when infants are approximately 7 months old. The goal of the study was to determine whether introducing peanuts to infants at high risk of peanut allergy early could prevent peanut allergy development. A total of 640 infants aged 4 to 11 months were enrolled in the study. There was a high risk that these infants would develop a peanut allergy due to their severe eczema, egg allergy, or both. Two groups of infants were assigned randomly: one group received peanuts as snacks at least three times a week, and the other group avoided peanuts altogether. By using a food challenge test, the study assessed whether children developed peanut allergies at age 5. Peanut allergy rates were significantly lower in the intervention group (1.9%) than in the control group (13.7%). This is evidence that the early introduction of peanuts to infants at high risk of peanut allergy can effectively prevent the occurrence of peanut allergies later in life (Du Toit et al., 2015).

Follow-up research (LEAP-On) also showed that the consumption group maintained peanut allergy reductions 12 months after allergen avoidance (Palladino, Breiteneder, 2018).

Interestingly, Bamba, a popular Israeli snack containing approximately 50% peanut protein, was chosen as the preferred peanut snack in the LEAP study. Among the children aged 4 to 16 who consumed peanuts in the LEAP trial, 70% ate Bamba as their primary peanut food during the first 12 months (Hindley et al., 2018).

The LEAP study's use of Bamba to reduce the prevalence of peanut allergy has raised questions about its allergen composition and the levels of specific peanut allergens that may be associated with tolerance to peanuts. A study was done to measure the levels of the major allergens Ara h 1, Ara h 2, and Ara h 6 in Bamba and compare them to those in other peanut-containing foods, as well as estimate the doses of these allergens that may be tolerable in individuals who regularly consume Bamba. The allergen levels in Bamba were measured by an enzyme-linked immunoassay. Bamba's allergen levels were measured at Ara h 1, 2388 µg; Ara h 2, 1988 µg; and Ara h 6, 2341 µg. Thus, the weekly doses of allergens consumed by children in the LEAP study were calculated to be 83 mg Ara h 1, 120 mg Ara h 2, and 127 mg Ara h 6 (total 330 mg/wk). As opposed to other peanut products, Bamba has relatively similar levels of the three major allergens. Previous research has shown that peanut butter usually contains 2-4 times more Ara h 1 than Ara h 2 or Ara h 6, while peanut flour can have up to 20 times more Ara h 2 and Ara h 6 than Ara h 1. Peanut flour used in clinical trials of oral immunotherapy (IOT) also tends to have 2-10 times more Ara h 2 than Ara h 1. According to these findings, consuming around 330 mg of specific peanut allergens per week may help to prevent peanut allergy and induce tolerance to peanuts. (Hindley et al., 2018).

An additional clinical trial, published in 2016, included 40 children with suspected or known peanut allergies aged 9 to 36 months who were treated with early intervention OIT (E-OIT) to evaluate its safety and effectiveness. The children were randomly assigned to receive E-OIT at doses of 300 or 3000 mg/day in a double-blinded fashion. The primary endpoint was sustained unresponsiveness at 4 weeks after stopping E-OIT, was assessed by a double-blinded, placebo-controlled food challenge. The outcomes were compared with those of 154 matched standard-care controls. The results showed that 78% of the children in the intent-to-treat analysis and 91% in the per-protocol analysis achieved unresponsiveness over a median of 29 months. Peanut-specific IgE levels significantly declined in the E-OIT-treated children, who were 19 times more likely to successfully consume dietary peanuts than the matched standard-care controls. Allergic side effects during E-OIT were common but mild to moderate in severity. These findings suggest that E-OIT has an acceptable safety profile and is highly effective in rapidly suppressing allergic immune responses and achieving safe dietary reintroduction of peanuts in children (Vickery et al., 2017).

A phase II clinical trial was conducted at 8 centers in the US to evaluate the safety and efficacy of AR101 (Palforzia), a novel oral biologic drug for the treatment of peanut allergies. The study enrolled 55 peanut-sensitized individuals between the ages of 4 and 26 years, all of whom had symptoms triggered by less than 143 mg/day of peanut protein as assessed by a double-blind, placebo-controlled food challenge. The patients were given daily doses of Palforzia or placebo, with the dosage gradually increased from 0.5 mg to 300 mg/day. The results showed that Palforzia generally improved the patient's symptoms and tolerated 18-fold higher amounts of peanut protein after treatment (Bird et al., 2018).

**Treatments**

Though many OITs are being researched and developed, Palforzia is the only current FDA-approved treatment to help expose children and teenagers to peanut proteins in controlled amounts in a medical facility. Treatment with Palforzia is typically initiated in a healthcare setting, where the patient can be monitored for signs of allergic reactions. Once the maintenance dose is reached, treatment can be continued at home (Erlich, 2022).

Palforzia is not intended to cure peanut allergies rather it is meant to lessen the severity of future reactions. Thus, patients receiving Palforzia are strongly advised to always carry injectable epinephrine just in case they experience a severe allergic reaction (Heo, 2021).

In the hope of curing peanut allergies in adults, a clinical trial was performed to test the use of a monoclonal antibody injection used to target the cytokine interleukin-33 (IL-33) in peanut-allergic individuals (Chinthrajah et al., 2019). IL-33 is a protein involved in the immune system and is thought to play a role in the development of allergic reactions. In peanut-allergic individuals, IL-33 has been found to be elevated in the blood and the skin. IL-33 may stimulate the production of other cytokines, and immune cells that contribute to the allergic reaction. Blocking IL-33 has been shown to reduce the severity of allergic reactions in animal models (Ding et al., 2018).

The trial included a small group of 20 participants and found that a single dose of the antibody, called Etokimab, significantly improved desensitization to peanuts as determined by standardized food challenges and SPTs. There was also a trend towards reducing atopy-related events (such as asthma, eczema, food allergy, and allergic rhinitis) in the group receiving Etokimab compared to the placebo group. The results showed that the group receiving treatment with Etokimab showed a 73% and 57% increase in the amount of peanut protein they could tolerate on days 15 and 45, respectively, while the placebo group saw no improvement on either day. Additionally, the group receiving the placebo reported more instances of atopy-related conditions such as asthma, eczema, food allergy, and allergic rhinitis compared to the group receiving the treatment (60% vs. 7%, respectively). These results suggest that IL-33 blockade may effectively inhibit allergic responses throughout the human body. Further studies are needed to understand the mechanisms behind these effects and to determine the potential of anti-IL-33 therapy for the treatment of peanut allergies (Chinthrajah et al., 2019).

**Quality of Life**

In peanut-allergic patients, increased stress and anxiety levels can negatively impact their quality of life (QoL) due to the burden of avoiding peanuts strictly and fearing anaphylaxis (Heo, 2021).

In a study to determine QoL in children with severe peanut allergies, researchers studied 20 children with severe peanut allergies, as well as a group of 20 children diagnosed with insulin-dependent diabetes mellitus. A comparison between the two groups was chosen because both conditions need to be monitored daily and can potentially result in adverse effects if they are not managed properly. The study evaluated the children using two disease-specific QoL questionnaires while also having them photograph their facial experiences over a 24-hour period. Results showed that the QoL of children with peanut allergies was worse than that of those with

insulin-dependent diabetes mellitus, with peanut-allergic children experiencing more fear of adverse events, anxiety about eating and feeling more restricted by their allergies in physical activities. However, they also reported feeling safer when carrying epinephrine kits and were not anxious about eating at familiar restaurants. The difference between the two groups appears to be related to higher anxiety levels in the peanut allergy group, particularly in situations outside of the home or school. While this anxiety may help promote adherence to strict allergen avoidance measures, it can also lead to mental health problems if the restrictions are unrealistic or unfounded. Children with peanut allergy must constantly be aware of allergen hazards in their environment and carry an injection to save their life in case of accidental exposure (Avery et al., 2003).

**Conclusion**

Unfortunately for those living with peanut allergies, there is currently no approved cure for adults suffering from peanut allergies. Until recently, it has been one of the few allergies that people would not grow out of over time. However, there are now several OITs, including one that is FDA-approved, that help wean children and teenagers who have peanut allergies so that they no longer have a severe immune response to the allergen. Further research is currently underway aiming to cure peanut allergies once and for all. Until then, it is important to continue practicing diligence, such as carrying an epinephrine injector and closely adhering to FDA reporting on trace amounts of peanuts in food products.

**References**

Abbas, M., Moussa, M., & Akel, H. (2022, July 18). Type I Hypersensitivity Reaction. Nih.gov; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK560561

Al-Ahmed, N., Alsowaidi, S., & Vadas, P. (2008). Peanut Allergy: An Overview. Allergy, Asthma & Clinical Immunology, 4(4). https://doi.org/10.1186/1710-1492-4-4-139

Al-Muhsen, S., Clarke, A. E., & Kagan, R. S. (2003). Peanut allergy: an overview. CMAJ : Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne, 168(10), 1279–1285.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC154188/

Avery, N. J., King, R. M., Knight, S., & Hourihane, J. O'B. (2003). Assessment of quality of life in children with peanut allergy. Pediatric Allergy and Immunology, 14(5), 378–382. https://doi.org/10.1034/j.1399-3038.2003.00072.x

Bernard, H., Ah-Leung, S., Drumare, M.-F. ., Feraudet-Tarisse, C., Verhasselt, V., Wal, J.-M. ., Créminon, C., & Adel-Patient, K. (2014). Peanut allergens are rapidly transferred in human breast milk and can prevent sensitization in mice. Allergy, 69(7), 888–897. https://doi.org/10.1111/all.12411

Bird, J. A., Spergel, J. M., Jones, S. M., Rachid, R., Assa'ad, A. H., Wang, J., Leonard, S. A., Laubach, S. S., Kim, E. H., Vickery, B. P., Davis, B. P., Heimall, J., Cianferoni, A., MacGinnitie, A. J., Crestani, E., & Burks, A. W. (2018). Efficacy and Safety of AR101 in Oral Immunotherapy for Peanut Allergy: Results of ARC001, a Randomized, Double-Blind, Placebo-Controlled Phase 2 Clinical Trial. The Journal of Allergy and Clinical Immunology: In Practice, 6(2), 476-485.e3. https://doi.org/10.1016/j.jaip.2017.09.016

Bock, S. A. (2021, May 28). Fatal anaphylaxis. Uptodate.com. https://www.uptodate.com/contents/fatal-anaphylaxis

Carrillo-Martin, I., Gonzalez-Estrada, A., Funni, S. A., Jeffery, M. M., Inselman, J. W., & Campbell, R. L. (2020). Increasing Allergy-Related Emergency Department Visits in the United States, 2007 to 2015. The Journal of Allergy and Clinical Immunology: In Practice, 8(9), 2983–2988. https://doi.org/10.1016/j.jaip.2020.05.056

Chinthrajah, S., Cao, S., Liu, C., Lyu, S.-C., Sindher, S. B., Long, A., Sampath, V., Petroni, D., Londei, M., & Nadeau, K. C. (2019, November 14). Phase 2a randomized, placebo-controlled study of anti–IL-33 in peanut allergy. Jci.org; American Society for Clinical Investigation. https://insight.jci.org/articles/view/131347

Ding, W., Zou, G.-L., Zhang, W., Lai, X.-N., Chen, H.-W., & Xiong, L.-X. (2018). Interleukin-33: Its Emerging Role in Allergic Diseases. Molecules, 23(7), 1665. https://doi.org/10.3390/molecules23071665

Du Toit, G., Roberts, G., Sayre, P. H., Bahnson, H. T., Radulovic, S., Santos, A. F., Brough, H. A., Phippard, D., Basting, M., Feeney, M., Turcanu, V., Sever, M. L., Gomez Lorenzo, M., Plaut, M., & Lack, G. (2015). Randomized Trial of Peanut Consumption in Infants at Risk for Peanut Allergy. New England Journal of Medicine, 372(9), 803–813. https://doi.org/10.1056/nejmoa1414850

Erlich, D. (2022, January 1). Peanut Allergen Powder (Palforzia) for Peanut - ProQuest. https://www.proquest.com/scholarly-journals/peanut-allergen-powder-palforzia-allergy/docview/2631931335/se-2

Fleischer, D. M., Conover-Walker, M. K., Christie, L.,

Burks, A. Wesley., & Wood, R. A. (2003). The natural progression of peanut allergy: Resolution and the possibility of recurrence. Journal of Allergy and Clinical Immunology, 112(1), 183–189. https://doi.org/10.1067/mai.2003.1517

Gupta, R. S., Warren, C. M., Smith, B. M., Jiang, J., Blumenstock, J. A., Davis, M. M., Schleimer, R. P., & Nadeau, K. C. (2019). Prevalence and Severity of Food Allergies Among US Adults. JAMA Network Open, 2(1), e185630. https://doi.org/10.1001/jamanetworkopen.2018.5630

H. Lindvik, Carlsen, L., P. Mowinckel, J. Navaratnam, Borres, M. P., K. -H Carlsen, Medicinska fakulteten, och, M., och, & Uppsala universitet. (2017). Conjunctival provocation test in diagnosis of peanut allergy in children. Clinical and Experimental Allergy, 47, 785–794. https://doi.org/10.1111/cea.12899

Hemmings, O., Du Toit, G., Radulovic, S., Lack, G., & Santos, A. F. (2020). Ara h 2 is the dominant peanut allergen despite similarities with Ara h 6. Journal of Allergy and Clinical Immunology, 146(3), 621-630.e5. https://doi.org/10.1016/j.jaci.2020.03.026

Heo, Y.-A. (2021). Peanut (Arachis hypogaea) allergen powder-dnfp (PalforziaTM) in peanut allergy: a profile of its use. Drugs & Therapy Perspectives, 37(11), 495–502. https://doi.org/10.1007/s40267-021-00868-5

Hindley, J. P., Filep, S., Block, D. S., King, E. M., & Chapman, M. D. (2018). Dose of allergens in a peanut snack (Bamba) associated with prevention of peanut allergy. Journal of Allergy and Clinical Immunology, 141, 780. https://doi.org/10.1016/j.jaci.2017.05.050

Moran, T. P., & Kulis, M. D. (2022). A "LEAP" forward in understanding immune mechanisms of oral tolerance to peanut. Journal of Allergy and Clinical Immunology. https://doi.org/10.1016/j.jaci.2022.04.022

Mueller, G. A., Maleki, S. J., & Pedersen, L. C. (2014). The Molecular Basis of Peanut Allergy. Current Allergy and Asthma Reports, 14(5). https://doi.org/10.1007/s11882-014-0429-5

Palladino, C., & Breiteneder, H. (2018). Peanut allergens. Molecular Immunology, 100, 58. https://doi.org/10.1016/j.molimm.2018.04.005

Skolnick, H. S., Conover-Walker, M. K., Koerner, C. B., Sampson, H. A., Burks, W., & Wood, R. A. (2001). The natural history of peanut allergy. Journal of Allergy and Clinical Immunology, 107(2), 367–374. https://doi.org/10.1067/mai.2001.112129

Vickery, B. P., Berglund, J. P., Burk, C. M., Fine, J. P., Kim, E. H., Kim, J. I., Keet, C. A., Kulis, M., Orgel, K. G., Guo, R., Steele, P. H., Virkud, Y. V., Ye, P., Wright, B. L., Wood, R. A., & Burks, A. W. (2017). Early oral immunotherapy in peanut-allergic preschool children is safe and highly effective. Journal of Allergy and Clinical Immunology, 139(1), 173-181.e8. https://doi.org/10.1016/j.jaci.2016.05.027

Wang, J. (2021, November). Peanut, tree nut, and seed allergy: Clinical features. Uptodate.com. https://www.uptodate.com/contents/peanut-tree-nut-and-seed-allergy-clinical-features

Warrington, R., Watson, W., Kim, H. L., & Antonetti, F. R. (2011). An introduction to immunology and immunopathology. Allergy, Asthma & Clinical Immunology, 7(S1). https://doi.org/10.1186/1710-1492-7-s1-s1

Wood, R. A., Sicherer, S. H., Burks, A. W., Grishin, A., Henning, A. K., Lindblad, R., Stablein, D., & Sampson, H. A. (2013). A phase 1 study of heat/phenol-killed, E. coli-encapsulated, recombinant modified peanut proteins Ara h 1, Ara h 2, and Ara h 3 (EMP-123) for the treatment of peanut allergy. Allergy, 68(6), 803–808. https://doi.org/10.1111/all.12158

Żukiewicz-Sobczak, W. A., Wróblewska, P., Adamczuk, P., & Kopczyński, P. (2013). Causes, symptoms, and prevention of food allergy. Advances in Dermatology and Allergology, 2, 113–116. https://doi.org/10.5114/pdia.2013.34162