

Environmental Factors Contribute to the Onset of Food Allergies

Erin Nicole Benton¹ and Christie Maria Sayes^{2*}

¹Department of Health, Human Performance and Recreation, Baylor University, Waco, Texas, USA

²Department of Environmental Science, Baylor University, Waco, Texas, USA

***Corresponding Author:** Christie Maria Sayes, Environmental Science Department, Baylor University, One Bear Place 97266, Waco, TX 76798-7266; Tel: 254 7103469; Fax: 254 7103409; E-mail: Christie_Sayes@baylor.edu

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Abstract

Background: Approximately 50 million Americans experience a food allergy. A food allergy is defined as an immune reaction after an ingested, inhaled, or dermal exposure to a certain food.

Objectives: The objective of this paper is to define the role of the environment as it relates to food allergies. If environmental factors contribute to the onset of food allergies, then this epidemic could be labeled as an emerging public health issue.

Methods: After reviewing articles from the peer-reviewed literature, information was compiled in graphical and tabular form. Literature search included manuscripts published between 1990 to 2017 using PubMed, Scopus, and Web of Science. Search terms focused on “food allergy”, “food sensitivity”, “food intolerance”, and “environment*” studies. Findings from these studies were evaluated by determining relationships between environmental factors and food allergies.

Discussion: Food allergies diagnosed often appear in children under the age of three. People diagnosed are shown to have the following similarities: manifest symptom(s) at age < 20 years old, reside in industrialized environments, inflicted with predisposing health sensitivities, and originating from developed countries. This review focused on discerning the details within the individual’s environment.

Conclusions: We found that increased urbanization contribute to the environment-food allergy nexus. The most cited adverse human health outcomes include multiple allergies, psychological effects, and death. By identifying causes of food allergies, recommendations can be offered to improve the quality of life of those inflicted.

Keywords: Food allergy; Food sensitivity; Food intolerance; Environment; 10 Essential services

1. Introduction

Approximately 50 million Americans experience a food allergy. Food allergies affect up to six percent (6%) of children and four percent (4%) of adults (ACAAI 2016). Food allergies can develop at any age, but typically appear first during infancy or childhood (ACAAI 2016). However, in some occasions, an individual can develop an allergy, and subsequent adverse effect, to a food they have previously eaten with no negative symptoms (ACAAI 2016). In a recent study released by the Center for Disease Control (2013), it was reported that between the years of 1997 and 2011, food allergies among children increased 50% (CDC 2013). The number of food allergies is increasing, but the cause is unknown. The rate of anaphylaxis reactions after exposure to food is increasing, as well [1]. Anaphylactic reactions can be deadly if not immediately treated; key signs are facial swelling and difficulty breathing cause is unknown [1].

Little data is available that postulates the causes of food allergies. However, some hypotheses have emerged over the past 10 years. For instance, factors such as race, ethnicity, and genetics contribute to allergy development (ACAAI 2016). More recently, research efforts have shifted from genetic-centric to synergistic reasoning incorporating environmental factors. Another striking statistic emerging in the literature over the past 5 years is the overwhelmingly high rates of food allergy development among individuals residing in first world countries, as compared to individuals who live in third world countries [2]. It has been postulated that the highly variable environmental factors in an industrialized nation contributes to the increase in the onset of food allergy [3].

Food allergy conditions are a complex diagnosis; each individual is affected differently. It is also a difficult area of epidemiological, toxicological, or medicinal research because many food allergies are self-reported without qualifying or quantifying metrics (such as pathology, symptom, or biomarker identification). To complicate the subject further, a food allergy can exist along a continuum (or spectrum). Figure 1 describes the spectrum of food disorder; an Individual can have ‘no sensitivity’, food ‘sensitivity’, and/or a food ‘allergy’ to a food product. A food allergy is generally regarded as the more severe diseased state and induces an exaggerated immune response. Lastly, the allergic reaction to a food can vary among inflicted individuals. Example conditions arising from a food allergy could range from itching skin to urticarial outbreak to gastrointestinal dysfunction to anaphylaxis (CDC 2013).

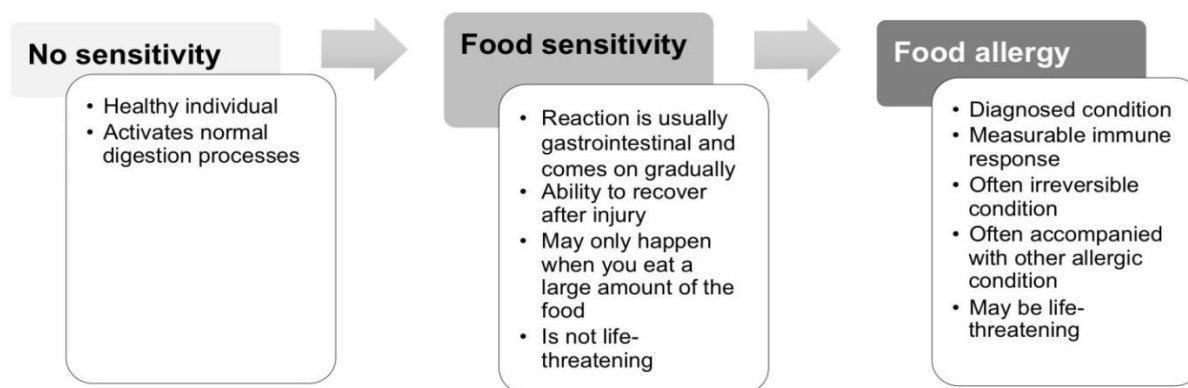


Figure 1: The progression of food allergy diagnosis. This figure shows the possible interactions a body can have to an allergen. The three stages are: no sensitivity to the food, food sensitivity, and food allergy.

Literature presents the possible correlation between the environment and an increase in allergies. While no literature has yet to prove causation, a few articles have proposed possible correlations. Within the environmental construct of food and food delivery, the individual's culture often promotes specific allergic reactions; if a food is not eaten in the population, then tolerance to the food is never developed, thus can result in a food allergy. A few significant research studies published in the literature have postulated that environmental factors influence the onset of food allergies, but very few have collected empirical data suggesting causation. Without causations and known ways to prevent food allergies, the epidemic will continue to grow and continue to adversely affect millions of people. A country's food system can present itself as a cause to an allergen being present in the country or not. The dual-allergen-exposure hypothesis hypothesizes that in countries where a food is not consumed, there is no environmental exposure, an allergy to that food will not occur [4]. An example of this occurred in the United Kingdom. Prior to 1970, kiwis had never been present or eaten in the UK. Since the 1970's when the kiwi was introduced to the UK, the rate of kiwi allergies has grown significantly [4].

Another possible hypothesis could be in countries where they avoid a certain food i.e. peanuts, the rates of peanut allergies tend to be higher. There's a misunderstanding that by completely avoiding and not introducing an infant/child to the item, they won't develop an allergy. However, we've seen in America that this proves the opposite. Consequently, countries such as in Africa and some Asian countries where peanuts are widely eaten and avoided, there are very low rates of peanut allergies [4]. Researchers know that the environment plays a role in the development of food allergies, but few have studies have found concrete evidence to support the role that the environment plays. Some possible roles the environment contributes to food allergies include: traffic pollution, animal exposure, farm environment, smoking, and air pollution. One study reviewed found that long-term exposure to traffic pollutions can increase allergy sensitization [3]. The study looked at children. One possibility of this correlation could be the knowledge that exposure to traffic and air pollution can increase rates of asthma which therefore can increase the rates of food allergies. Another study looked at the effects of dog ownership on the development of atopy among infants. It found that households that had a dog, the infants residing in these houses, were less likely to develop atopic dermatitis. This could appear in the form of eczema. It found that these results only proved true with dogs though, cats were evaluated as well but found to have no effect on the development of atopy [5].

Two studies indicated evidence that early exposure to a farm environment could lower the risk of a child developing atopy in the future. One study found that living on a farm in the early years helped to raise rates of genotype CD14. Low CD14 levels are associated with an increased risk of developing atopic sensitization. This study showed that the farm environment contributed to higher rates of CD14 among infants therefore, the infants had a lower risk of developing atopy [6]. Another study on farm environment found that a farm environment was successful in preventing allergic rhinitis (hay fever) and allergic conjunctivitis (itching eyes), but not allergic dermatitis (eczema) [7]. Allergic rhinitis and allergic conjunctivitis do not lead to the development of food allergies. More research needs to be done on the protective factors of a farm environment and the development of food allergies.

Air pollution can be another cause of developing food allergies. A study found that passive or active smoking could play a role in the sensitization to food allergens. Passive smoking is inhalation of second-hand smoke and active smoking is a person who smokes. The same study found that exposure to aeroallergens or air pollutants can cause higher rates of respiratory infections which in turn might play an important role in the sensitization to food allergens as well [8].

The purpose of this review is to examine environmental factors as a cause of food allergies. First, we attempted to identify environmental factors that contribute to the increasing prevalence of food allergies in the past two decades. Second, we summarized the role that physiological factors (such as genetics, gender, and age) have played in the development of food allergies. Third, we evaluated the importance of the 10 Essential Services of Public Health in food allergy causation. The objective of this paper is to define the role of the environment as it relates to food allergies. If environmental factors contribute to the onset of food allergies, then this epidemic could be labeled as an emerging public health issue.

2. Methods

We performed a structured literature search focused on identifying all relevant human studies related to environmental factors and food allergies. Multiple databases were queried between November 2016 and May 2017. PubMed, Scopus, and Web of Science search engines were utilized with keyword searches. Papers were included if they were tagged with at least one search term from Group A and the term “environment*” from Group term B (Table 1). Further literature research narrowed the field to pediatric relevance. The most common themes identified from the original Group B term included: environmental factors, farm environment, smoking, and air pollution. Resultant papers written in English, found in the keyword search, and peer-reviewed were included in the analysis. Searches included both research and review articles on humans, but excluded articles using animal or cell-based models. Other inclusion criteria include specific environmental factors noted in abstract and cohorts of children or young adults.

Databases	Group A terms	Group B terms	Number of papers returned
PubMed	food allergy	environment*	212
	food sensitivity		1
	food intolerance		9
Scopus	food allergy	environment*	569
	food sensitivity		4
	food intolerance		23
Web of Science	food allergy	environment*	247
	food sensitivity		1
	food intolerance		10

Table 1: Search terms for literature review. * indicates end-truncated search term. Terms entered into database with quotation marks returned results with exact matches. Data includes both research and review articles.

3. Results

Using this search strategy, we identified a total of 569 unique articles in English, while carefully eliminating any frequencies in search results among and between the search engines employed. After other exclusion criteria were accounted for, 11 articles remained for review. The bibliographies of these 11 papers were also examined for additional relevant articles, but relevant cited articles were already captured in the initial analyses. These articles are limited to research studies with experimental designs and are summarized in Table 2. Our analysis is outlined as follows: first, brief overviews of Individual allergens, their prevalence and diagnoses; historical perspectives (Current era vs. past eras), discussion of Allergy vs. intolerance/sensitivity, and Known causes and pre-existing health conditions are discussed. Second, the five working hypotheses in this field of study are explained. Third, the environmental factors contributing to the onset of food allergies are proposed.

Paper Reference	Brief Study Design	Environmental Factor Measure	Human Health Measure	Result
Gern et al. [5]	Pet exposure in the home compared against cytokine secretion in infants	Dogs	Indicators of atopy	Having a dog in infancy is associated with higher cytokine secretion profiles and reduced allergic sensitization
Kilpelainen et al. [7]	Self-reported wheezing from Finnish students (18-24 yr.) collected via questionnaire	Childhood farm environment	Food allergy, allergic rhinitis and/or allergic conjunctivitis	The childhood farm environment independently reduced the risk for physician-diagnosed allergies
Liu et al. [8]	Sensitization measured by skin prick on Chinese twin pairs (12-28 yr.)	Living conditions, environment, and genetics	Peanut and shellfish food sensitization	Sensitivity to common food allergens is influenced by genetic and environmental factors
Leynaert et al. [6]	Questionnaire on farm exposure in childhood in 2 French centers	Childhood farm environment & D14 C-159T polymorphism	Atopic sensitization	CD14 C-159T and farm childhood environment exposure may modify the development of atopy
Simpson et al. [9]	Population-based birth cohort study	Endotoxin in house dust	Allergic sensitization and eczema	Increasing endotoxin exposure is associated with reduced risk of allergic sensitization
Melén et al. [3]	Birth cohort study	Air pollution from local traffic	Allergic disease and inflammatory response	Long term exposure to traffic pollutions can increase allergy sensitization
Lawlis et al. [10]	Online survey of principals on school	School environment	Food-induced allergic reactions	Detailed awareness and management guidelines are

	allergy awareness		(i.e. anaphylaxis) from milk, eggs, peanuts, & seafood	integral for schools to adequately manage food-induced allergic reactions, in the school environment
Makhija et al. [11]	Questionnaires on home demographics of mothers and fathers of food allergic children	Home environment and demographic characteristics	Eczema, atopic diseases, & food allergies	Parents of food allergic children found higher rates of sensitization to foods and aeroallergens compared with the general population
Majowicz et al. [12]	Conceptual model	Built and natural environment	Foodborne illness, food insecurity, obesity, & food allergy	Health practitioners should consider how targeted public health actions produce positive or negative population health impacts
Ben-Shoshan et al. [13]	Telephone survey of individuals with probable self-reported food allergies	Personal/family history of atopy, sociodemographics, & lifestyle habits	Food allergy (i.e. milk, egg, peanut, tree nut, shellfish, fish, wheat, soy, or sesame)	Development of eczema in the first 2 years of life is consistently associated with food allergies
Bedolla-Barajas et al. [14]	Questionnaire to parents of children (6-14 yr.) needing allergy treatment	Demographic and clinical data history	Oral allergy syndrome (OAS)	OAS is not uncommon in our environment; pineapple was the main food related. <i>Quercus</i> sp. was the pollen associated
Xu et al. [15]	Questionnaire to parents of Chinese children (3-6 yr.) with atopic dermatitis	Home environment	Atopic dermatitis	Home renovation/redecoration, new furniture, indoor mold, urban residency, heredity disposition and food allergy can be risk factors for childhood allergy development

Table 2: Summary of the research articles from the peer-reviewed literature that relates an environmental factor to the onset of an allergic reaction, sensitization, or disease.

4. Discussion

4.1 Individual allergens, their prevalence and diagnoses

A relatively small amount of foods are referred to as major food allergens, i.e. foods known to elicit an allergic reaction in humans. These foods include milk, egg, tree nuts, peanuts, seafood, shellfish, soy, and wheat [16]. People can exhibit intolerance to other foods, such as lactose or sulfites; but the adverse reaction to humans after exposure is not described as life threatening.

Nut allergies (peanut and tree nut) are the leading cause of anaphylaxis, either fatal or nonfatal, in the United States and the United Kingdom [16]. Unlike other food allergens, peanuts are linked to a genetic susceptibility. The environmental and physiological precursors to the development of a peanut allergy include early onset of a soy allergy and eczema as an infant, respectively [17]. In some studies, maternal diet plays a role in the development of a peanut allergy, but other studies have proven this relation false [17]. A peanut allergy is unique in that the reaction is chronic and sustained throughout an individual's life [17].

According to several studies, the prevalence of food allergies are significantly lower in developing countries than those in developed countries [18]. However, individuals from developing countries who immigrate to modernized countries lose their protection to certain allergens [18]. The difference between the rates of food allergy onset between developed versus developing countries could be due to factors in the local environmental construct.

It is difficult to pinpoint the rates of allergy prevalence due to the common practice of self- diagnosis, rather than practitioner diagnosis. Allergies can range from a less complex intolerance or sensitivity to more complex anaphylaxis. Few studies have been able to accurately report the prevalence of certain food allergens [19]; and accurate diagnosis is directly related to prevalence. The most widely accepted method to qualitatively diagnose an allergy is through either a skin test or blood test. Skin allergy testing is a method for medical diagnosis of allergies designed to inflame a controlled irritation response [20]. Blood allergy tests measure the upregulation of immunoglobulin E (IgE, the antibody that triggers food allergy symptoms) to specific foods [21]. In an ideal setting, the test would also include a double-blind, placebo-controlled food challenge (DBPCFC) [22]. More accurate prevalence rates for food allergies can be gained with more DBPCFC reported studies.

4.2 Commonality among children

The onset of food allergies diagnosed among children in the United States have risen 50% since 1997 [23]. Not only have the rates of allergies increased in the past two decades, but the rates of morbidity associated with allergies have risen, as well. Jackson et al. [23] concludes that there is no clear understanding of the reasons for the rising incidence rates; however, the nature of the interaction between genetic and environmental factors requires more research [23].

4.3 Allergy vs. Sensitivity

Any allergy has the potential to trigger a life threatening immune response. A sensitivity (also referred to as an intolerance) is generally not life threatening, but does result from the inability to metabolize or digest a food completely [22, 25]. The majority of studies that focus on food allergies tend to avoid the more mild and less complex food intolerances or sensitivities [26]. There is evidence to suggest, however, that some food sensitivities can lead to food allergies over time [27] (Figure 2). Most food intolerances and sensitivities are associated with abdominal symptoms such as nausea, bloating, and pain [28]. However, they can also be associated with symptoms such as neurological dysfunction, psychological disturbances, fibromyalgia, and skin rash [29].

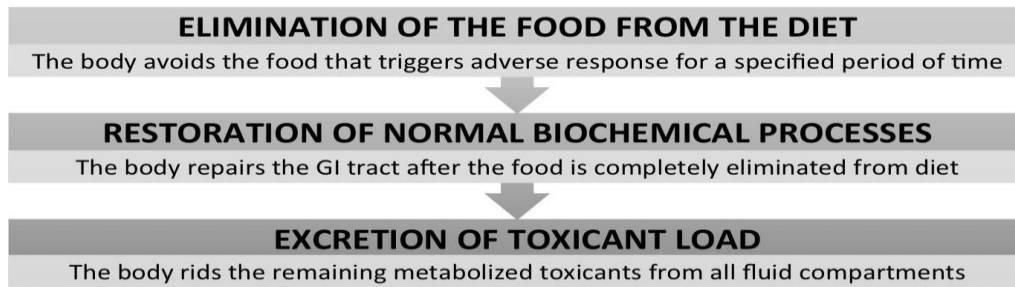


Figure 2: Steps to overcome sensitivity related illness.

Although there are currently no proven methods to overcome a diagnosed food allergy, there are known ways to overcome a sensitivity related food illness. The first step includes completely eliminating the food from the diet, avoidance of the trigger response. The second step includes biochemical restoration. This is the body repairing itself since it is no longer experiencing illness. The third and final step is elimination of bioaccumulated toxicant load. Since the body is no longer experiencing the food item, it is able to complete rid itself of the toxicants. In some cases, the food at this point can start to be reintroduced to the diet in small amounts.

The most common food sensitivities include complex carbohydrates, histamines, and lactase. In carbohydrate intolerance, an essential enzyme is missing from the digestion processes, which causes the incomplete metabolism of fermentable carbohydrates (i.e. sugars and starches). In histamine intolerance, foods with large amount of the chemical histamine (i.e. alcohol, bananas, avocados, or eggplants) cause itchy eyes or tongue, runny nose, or congestion due to a lack of the enzyme diamine oxidase (DAO). In lactose intolerance, the enzyme lactase, responsible for breaking down lactose or milk sugar, is missing and causes diarrhea, nausea, vomiting, abdominal cramps, and bloating [25].

4.4 Known causes and pre-existing health conditions

There is limited information on the known causes of food allergies. There have been many correlations found but only a few studies have proven causation. Asthma and eczema are known pre-existing health conditions that often lead to the development of food allergies [30, 31]. Generally accepted correlations are listed below:

- Children tend to have more than one food allergy present at a time [17].
- Eczema in infants is an early indicator to the presence of a food allergy [32].
- Individuals with asthma tend to have a food allergy [16].
- Genetic history of food allergies can increase the risk for developing a food allergy tenfold [16, 21].

A few relationships between environmental factors and food allergies that have been studied but are inconclusive and often debated:

- A higher body mass index (BMI) is associated with an increased risk of allergies in children; however, the association varies depending on gender, age, and type of allergen [33].
- Some foods prepared and eaten raw (uncooked) induce adverse allergic reactions; however, some of the same foods prepared and eaten cooked also induce the same reaction [34].
- Antibiotic use in children, as well as lack of healthy commensal bacteria has shown to be a risk factor for developing food allergies; but, the trends in observed data are not general [35].

4.5 The food allergy hypotheses

Through the review of the scientific literature, several hypotheses were presented, tested, and either proven true or inconclusive. These hypotheses aim to explain some of possible reasons behind the current allergy epidemic and offer recommendations to prevent allergies from developing in otherwise healthy individuals. These five (5) hypotheses include:

1. Dietary fat intake hypothesis
2. Antioxidant production hypothesis
3. Vitamin D exposure hypothesis
4. Hygiene hypothesis
5. Dual-allergen exposure hypothesis

4.5.1 Dietary fat intake hypothesis (H1): The dietary fat intake hypothesis offers the idea that reduction in consumption of animal fats and increase in margarine and vegetable oils use has led to the decrease in common food allergies [4, 36]. Individuals use margarine and vegetable oil in their diets in an increasing rate due to the conception that these oils are a healthier alternative to animal fats. Some literature presents a possible correlation in a decrease in animal fats and a positive correlation with an increase in food allergies [4]. Through literature search, 114 papers were found to pertain to this hypothesis (Figure 3).

4.5.2 Antioxidant production hypothesis (H2): The antioxidant hypothesis argues that the decrease in consumption of fresh fruit and vegetables accounts for food allergies and the adverse outcome of asthma [4, 37]. Fruits and vegetables contain vital nutrients and antioxidants. These nutrients and antioxidants play important roles in maintaining health and fighting infection. With decreased fruit and vegetable intake, individuals do not get necessary essential elements needed for building sufficient immune system. Through a search of the literature, 462 articles included the antioxidant hypothesis (Figure 3).

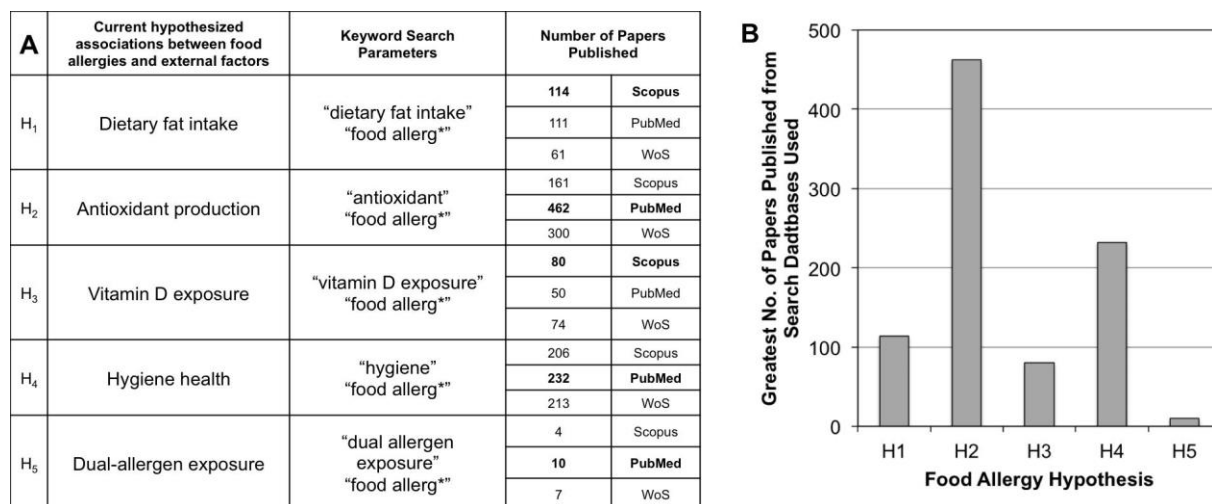


Figure 3: (A) Current hypothesized associations between food allergies and external factors and articles associated with them. (B) Greatest number of papers published from search databases used versus the food allergy hypothesis number.

4.5.3 Vitamin D exposure hypothesis (H3): The vitamin D hypothesis has been postulated in two different (i.e. opposing) forms. The first form argues that increases of vitamin D levels have led to increased food allergies; while the second form argues that decreases of vitamin D levels have led to increased food allergies [4, 38]. The first form argues that because of an increased consumption of Vitamin D from sources such as dairy products, more children experience an increase in food allergies [39]. The second form presents the idea that a lack of Vitamin D, mainly in the form of sunlight, leads to an increased risk of food allergies [40]. Several studies have been conducted comparing epinephrine injection (a.k.a. EpiPen®) usage rates in northern United States to southern United States [41-44]. States in the northern region had higher rates of food allergies as well as less exposure to sunlight. The Vitamin D exposure hypothesis has been frequently evaluated. A literature search revealed 80 papers on the topic (Figure 3).

4.5.4 Hygiene hypothesis (H4): Studies testing the hygiene hypothesis have rarely focused on food allergies, as the adverse outcome, alone. However, the hypothesis examines the role of commensal gut flora in the development of food allergies [4, 45, 46]. Studies focused on the effects of protecting children from microorganism exposure and the chances of food allergy development [47]. Exposing children to microorganisms has been shown to strengthen the immune system [48, 49]. The hygiene hypothesis is the most commonly studied food allergy hypothesis. A review of the literature presented 232 papers on the topic (Figure 3). This also was the most researched hypothesis through clinical experiments presenting with quantitative findings.

4.5.5 Dual-allergen exposure hypothesis (H5): The last food allergy hypothesis involves dual- allergen exposure and argues that if a food allergy only occurs if the allergen is presented to an individual [4, 50, 51]. More specifically, if a certain food is not exposed to a culture or community, there should be no risk of developing an allergy to that food item. This was evident in Northern Europe in the 1980's [52]. The dual-allergen exposure hypothesis is the least researched hypothesis. A literature search presented only 10 papers on the topic (Figure 3). The papers that were found all consisted of review articles. This hypothesis has a lot of room for growth and research.

4.6 Human health outcomes

The long-term human health outcomes that could occur from food allergies include increased allergic reactions (to more than one allergen), chronic psychological effects, and decreased life expectancy. It is common among people with one food allergy to develop additional allergies and those allergens result in an anaphylactic reaction [1, 4, 53]. For some food allergies, children have a high probability of outgrowing the allergic reaction by the time they grow to adulthood; however, a peanut or tree nut allergy, which have the highest rates of anaphylaxis, are rarely outgrown [2, 27, 54]. Food allergies can also affect quality of life and can even cause psychological distress [55-58]. Food allergies developed in adulthood can cause a significant adjustment, which has shown to be difficult for people. If a person has several food allergies, as well as asthma, s/he develop aversions to food, lack in socialization, and difficulty breathing [19, 59, 60]. Specifically, eliminating certain foods in the diet results in missing nutrients. Although rare, death can occur as a result of an allergic reaction [61]. This usually occurs in people who have

anaphylactic reactions if treatment is not timely or if the reaction is not noticed. Public health policies from the 10 essential public health services provide a suitable framework to develop best practices for individuals, healthcare practitioners, charities, recreation organizations, schools, and community services to follow. Public health systems (i.e. the network of all public, private, and voluntary entities in a community) deliver essential public health services. Briefly, the 10 essential services include monitoring health, diagnosing problems and identifying hazards, informing people, mobilizing partnerships, developing policies, enforcing regulations, linking people to services, assuring competencies in workforce, evaluating effectiveness, and researching innovative solutions [62].

Essential Service	Interface with Food Allergies and the Environment
1 Monitor Health	<ul style="list-style-type: none"> • Be aware of common allergies and incidence rates • Evaluate the health status of their individuals
2 Diagnose and Investigate	<ul style="list-style-type: none"> • Identify and investigate health threats in a timely manner • Create action plan to address emerging health related threats
3 Inform, Educate, Empower	<ul style="list-style-type: none"> • Prevent health emergencies through education • Inform school communities through the use of signage
4 Mobilize Community Partnerships	<ul style="list-style-type: none"> • Establish relationships between the school, the community, the parents, and the local physicians • Ensure roles and responsibilities in case of an emergency • Form a local coalition to promote allergy friendly food establishments, schools, and other public places
5 Develop Policies	<ul style="list-style-type: none"> • Ban certain allergens from the location • Protect the health of the most vulnerable populations
6 Enforce Laws	<ul style="list-style-type: none"> • Utilize and enforce food allergy regulations • Provide alternative allergen-friendly food options
7 Link to Care	<ul style="list-style-type: none"> • Provide constant management and surveillance • Hire practitioners who can diagnose and treat those with food allergies • Provide safe spaces in schools for children with food allergies to go • Provide grocery stores with allergy friendly food • Provide allergy friendly and safe food establishments • Ensure resources provided are affordable and available to all people regardless of race and/or culture
8 Assure Competent Workforce	<ul style="list-style-type: none"> • Employ practitioners that up to date on the most current research in the field of food allergies • Educate healthcare workers, teachers, and food service handlers
9 Evaluate	<ul style="list-style-type: none"> • Ensure that the policies, professionals, and regulations in place are working • Evaluate efficacy of policies • Improve upon deficiencies
10 Research	<ul style="list-style-type: none"> • Continue to conduct research in the field of food allergies • Engage efforts for diagnosis, treatment, and cures • Seek prevention strategies and analyze costs versus benefits

Table 3: The 10 essential services as they relate to food allergy occurrences.

Table 3 lists the 10 essential services and explains how each relates to food allergy occurrences. Currently, the following components provide active services towards addressing the food allergy epidemic, as it relates to environmental factors, in the United States:

1. Health is monitored. Healthcare practitioners are aware of common allergies and incidence rates in localities and evaluate the health status of individuals.
2. Community partnerships are mobilized. Relationships between schools, the community centers, affected individuals (or parents of individuals), food establishments, and local physicians are established and the roles and responsibilities of each stakeholder are defined.
3. Policies are developed. Certain allergens are banned from specific locations and the most vulnerable populations are protected.
4. Regulations are enforced. Alternative allergen-friendly food options are available.
5. Link to Healthcare is known. Practitioners who can diagnose and treat those with food allergies are trained, hired, and supplied with resources.
6. Workforce is competent. Continuing educations is available for practitioners, healthcare workers, teachers, and food service handlers.
7. The system is evaluated. Policies and regulations are in place and working.

Conversely, a few challenges and data gaps in the field of environmental factors and their contribution to the food allergy epidemic still exist. The following components of the 10 essential services currently provide insufficient resources towards addressing the food allergy epidemic, as it relates to environmental factors, in the United States:

1. Research: Several studies contain contradicting information. Ethnicity plays a role in the risk of some individuals developing a food allergy; however, the conclusions are not uniform across all studies and no trends have been found. Because of this, it is increasingly difficult to establish causation for food allergy development.
2. Prevention: There is a lack of information (i.e. protocols, guidance documents, or educational material) available for individuals to prevent exacerbation of existing allergies or development of new allergies.
3. Diagnosis: Due to the increased prevalence of individuals self-diagnosing, accurate incidence rates are outdated and lack correlations with environmental health, urbanization, food system and accessibility, geography, socioeconomic, or other demographic data.

Recent research efforts have found more success in correlating environment factors and food allergies when more than one variable, such as environmental health, urbanization, food system and accessibility, geography, socioeconomic, or other demographic data. Dempfle et al. [63] suggests that by looking at both genetic and environmental factors together, more conclusive results can be obtained [63]. Simpson et al hypothesizes that precision medicine (a.k.a. personalized medications) is a possible intervention for food and seasonal allergies [9]. Through the use of precision medication, allergens can be directly targeted and unintended drug-induced side effects may be prevented.

The five working hypotheses postulating the sources of food allergies deserve further investigations and possible interventions. In any intervention regarding food allergies, starting young and early exposure is key. Any of the possible interventions such as dermal or oral introduction are most affective if done early on in life. Recommendations for further research include identifying potential combinations of gene, introducing food exposure in early life stage and through a variety of exposure routes, and developing frameworks for designing precision medicines.

5. Conclusion

In conclusion, food allergies are a field that more research needs to be done in. A lot of studies done have found correlations but have failed to prove causation. It is known that asthma can increase the risk of developing food allergies. There is also evidence supporting the environment playing a role but to what extent is still unknown and still being studied. Without causations and known ways to prevent food allergies, the epidemic will continue to grow and continue to affect millions of people.

6. Competing Financial Interests Declaration

Neither ENB nor CMS have any conflicts of interest, financial or otherwise.

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