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Immunological Pathway and Therapeutic Strategy to Allergic Inflammation

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Abstract: Allergies create complicated immune responses, inducing inflammation in various organs with most critical impacts on the intestine and skin. This research examines the complex immunological mechanisms underlying allergic inflammation in such tissues. The underlying theme here is imbalance in cytokines, overproduction of some cytokines like interleukin-4 (IL-4) and interleukin-13 (IL-13) leading to inflammation in Th2-biased responses. Activation of immune cells, with T-helper cells, mast cells, and eosinophils playing a critical role, is also part of orchestrating allergic responses. The research is able to successfully synthesize information from preclinical research that illuminates basic biological mechanisms with information from clinical research, which provide an overview of disease and therapy in the context of daily life. Key mechanisms become evident when diseases such as allergic dermatitis and inflammatory bowel disease are examined. Intensity and nature of immune response depend on Th1/Th2 imbalance, with Th2-biased responses most commonly involved in allergic inflammation. Immunoglobulin E (IgE)-dependent hypersensitivity is also involved in allergic reactions with mast cell degranulation and release of inflammatory mediators. Interaction among mesenchymal and epithelial tissues is also involved in ongoing inflammation and remodeling. This research highlights that it is critical to manage allergic and inflammatory diseases by taking a multimodal approach.

Keywords: allergic inflammation, immune cell activation, epithelial barrier, gut-skin axis, therapeutic strategies

1. Introduction

More than 1 billion people worldwide have allergic diseases, with an inappropriate immune response toward innocuous substances. Allergy brings on a misguided reaction toward antigens by inducing constant inflammation in tissues such as intestine and skin despite the immune system otherwise protecting against infection. Such tissues, as initial points for exposure to the outside environment, have a reliance on epithelial barriers in maintaining them in equilibrium. When such barriers are disrupted, antigens have an opportunity to penetrate deeper, invoking immunological responses resulting in inflammation such as in autoimmune diseases [1]. For purposes of immune cell activation, dysfuction in epithelial tissue, and therapeutic potential, it explains how allergic reactions lead to inflammation in intestine and skin.

Occludin, claudins, and zonula occludens (ZO-1) are part of tight junction (TJ) proteins that have control over intestinal epithelium as an absolute barrier. In allergic scenarios, there is augmented permeability with invasion by pathogen, luminal antigens, and byproducts of microbes into the lamina

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propria and activation of immune responses [2]. For instance, diet antigens such as cow's milk proteins or peanuts' proteins may get through an injured gut in food allergy, stimulating dendritic cells (DCs) with induction of Th2 polarisation, with characteristics such as secretion by interleukin (IL)-4, IL-5, and IL-13. Invasion by eosinophils and tissue injury are with augmented cytorefractoriness and reduced expression by proteins such as claudin-1 involved in tight junctions in studies on patients with eosinophilic esophagitis (EoE). In dextran sulfate sodium (DSS) induced allergic colitis, injury by mucosae results in bacterial translocation with activation by TLR4 and NLRP3 inflammasomes and secretion by pro-inflammatory cytokines. The epidermal barrier provided by the skin's stratum corneum, tight junctions, and keratinocytes prevents invasion by allergens. In atopic dermatitis (AD), genetic injury by proteins such as proteins in filaggrin (FLG) impairs barrier function, with invasion by house dust mites (Der p 1).

Activated keratinocytes also release thymic stromal lymphopoietin (TSLP), augmenting dendritic cell activation for induction of Th2 reactions with secretion of IgE and recruitment of eosinophils. As in the intestine, occludin and claudin-1 skin-tight junction proteins reduce with severity of AD. On disruption of skin barrier by direct contact with an allergen like nickel or perfumes, pro-inflammatory cytokines like IL-1β and TNF-α are secreted in greater quantities, and activation is initiated in protein kinase C (PKC) pathways. This study is focused on inflammation in skin and intestinal tissues by allergy. There are over a billion people with allergy and this triggers unwanted immune responses. The epithelial barriers in these tissues play an important part in functioning by way of entry of allergens and thus cytokine imbalance and activation of immune cells. The gut-skin axis illustrates how gut microbiota controls allergic reactions. The dynamics behind imbalance in Th1/Th2 as well as IgE-mediated responses are reviewed with reference to such conditions as inflammatory bowel disease as well as allergic dermatitis. Immunomodulating biologics, barrier stabilizing therapy, as well as microbiota alteration therapeutics are some among a range of therapy approaches. Safety risk with therapy as well as patients' heterogeneity make translational studies difficult. With allergic diseases on a rise globally, recent advances bring hope for more personalized and efficient therapies.

2. Activation of immune cells and cytokine networks

2.1. Intestinal immune responses in allergic enteropathy

The innate immune cells such as macrophages, DCs, and innate lymphoid cells (ILCs) comprise the first line of protection offered by the intestinal immune system. Resident lamina propria macrophages have reduced levels of pro-inflammatory cytokines such as TNF-α and elevated anti-inflammatory compounds such as IL-10 production, thereby maintaining tolerance towards commensal microbiota [1]. In allergic disorders, an antigen-bound IgE activates receptors FcεRI on mucosal mast cells, inducing degranulation and release of preformed mediators (tryptase, histamine) as well as lipid mediators de novo synthesized. These agents induce diarrhea as well as abdominal pain by stimulating sensory nerves, enhancing vascular permeability, as well as inducing recruitment to the site by eosinophils [2]. Activated ILC2s also release IL-5 involved in differentiation and survival as well as survival of eosinophils and also release IL-13, with augmented goblet cell production or overproduction of mucin. In a mouse model system used in studies on food allergy, ILC2s were removed and there was sudden drop in intestinal eosinophils as well as damage to epithelium, thereby pointing to their role as a pathogen. Type 2 ILCs (ILC2s) are key players in regulation of allergic inflammation in intestine. These cells are positioned near epithelium and get activated by cytokines produced by epithelium such as IL-25, IL-33, and TSLP induced by exposure to an allergen or barrier injury [3].

The Th2 cell polarization is most representative of allergic enteropathy's adaptive immune response, induced by utilization by DCs of trans-epithelial dendrites to engulf lumen antigens [4].

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The differentiation of Th2 cells is promoted by cytokines (e.g., IL-4 and IL-13) and by signals for co-stimulation (e.g., CD80/CD86), whilst antigen processing and presentation by DCs to naive T cells is by utilization of MHC class II molecules. Switching to IgE is induced by activated Th2 cells interacting with B cells in mesenteric lymph nodes, involving STAT6 transcription factor and cytokine IL-4 [5]. The amplification of IgE production, B cell proliferation and antibodies is supported by Tfh cells, positive for CD40 ligand and secreting IL-21.

The Th2 cytokines IL-4 and IL-13 exert several actions on the intestinal epithelium through STAT6-mediated pathways such as down-regulating occludin and claudin-1 tight junction proteins. IL-13 can be used to cause extensive swelling of goblet cells and mucin secretion, destabilizing mucin layer composition in the intestine and promoting increased bacterial adhesion on the epithelium. In line with this, eosinophils induced by IL-5 secrete cytotoxic granules that destroy epithelial cells and cause global disruption to barrier function [6].

2.2. Immune responses in allergic inflammations

Keratinocytes are immune and structural cells of the skin. Upon invasion by an allergen, keratinocytes release danger-associated molecular patterns such as ATP and uric acid that activate PRRs on local immune cells [7]. Keratinocytes and dermal dermal dendritic cells also have Toll-like receptors 2 (TLR2) and 4 that recognize microbe components in allergic lesions and cause inflammation. Staphylococcus aureus lipoteichoic acid acts on keratinocyte TLR2 to release IL-1β and IL-6 that attract neutrophils and cause inflammation in the skin.

The two major skin-resident dendritic cell populations are dermal dendritic cells (dDCs) in the papillary dermis and Langerhans cells (LCs) in the epidermal layer. After successful antigen capture from the epiderm, LCs move to lymph nodes where they activate Th2 cells by producing OX40L and IL-4 [8]. Dermal DCs, on the other hand, are implicated in remoulding tissues by inducing Th1 or Th17 responses involving chronic allergic inflammation. Th1 polarized responses are by dDCs secreting IL-12 in contact hypersensitivity, while LCs secreting TSLP educate T cells into Th2 and Th22 lineages with IL-22-secreting Th22 cells inducing keratinocyte hyperproliferation [9].

Mast cells play a central role in allergic cutaneous inflammation and are concentrated at the dermal-epidermal junction. On cell-surface IgE attachment to an allergen, mast cells degranulate within minutes to release histamine, heparin, and proteases to cause the immediate-phase reaction with vasodilation, swelling, and pruritus [10]. The late-phase reaction (after 6–24 hours) involves mast cells releasing cytokines (e.g., TNF-α and IL-6) and chemokines (e.g., CCL2 and CCL5) to recruit T cells, neutrophils, and eosinophils to the area and cause chronic inflammation [11].

2.3. Cross-talk between innate and adaptive immunity

While communication between innate and adaptive cells is a key element of allergic inflammation. TSLP from keratinocytes in skin triggers activation of DCs to prime Th2 responses, and resident ILC2s within gut initiate early cytokine signals (IL-13 and IL-5) that activate DCs for Th2 polarisation [12]. Microbial metabolites contribute to this communication as well. SCFAs from commensal microbiota regulate Treg cell function by suppressing hyperactive Th2 responses, and dysbiosis decreases levels of SCFA and promotes pro-inflammatory Th17 polarisation.

3. The gut-skin axis: Intertissue communication mechanisms

The low gut microbiota diversity and overgrowth of pathogenic Enterobacteriaceae lead to intestinal ecological imbalance by making intestinal permeability greater and facilitating components such as flagellin and LPS to reach the bloodstream. Upon reaching distal locations such as the skin, these substances activate TLR4 and TLR5, inducing dermal macrophages and keratinocytes to release pro-

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inflammatory cytokines. Oral/dietary exposure to LPS in a mouse model of atopic dermatitis promoted skin inflammation by inducing augmented expression of TSLP in the epidermal layer, with an emphasis on how “leaky gut” is implicated in systemic immune activation.

The cytokines produced due to inflammation in gut or skin also act as humoral messengers, with a role in modulating immune responses in other tissues. For example, increased levels of IL-1β and IL-6, as in AD and allergic colitis, stimulate hepatic acute-phase proteins as well as activate the hypothalamic-pituitary-adrenal (HPA) axis with a resultant release of cortisol that regulates immune cell functioning [13]. Intestinal Th2 cell-derived IL-13 is reported in studies as inhibiting expression by keratinocytes of filaggrin, affecting barrier function and adding to sensitization to allergens. For atopic march, studies have shown that gut inflammation caused by cow’s milk protein allergy (CMPA) is linked with raised levels of serum IgE against food as well as environmental allergens, thus making infants with CMPA susceptible to developing AD early [14]. Patients with Crohn's disease or ulcerative colitis have a 2-3 times higher risk of developing psoriasis caused by genetic factors in common (e.g., polymorphisms in IL-23R) as well as by Th17-driven inflammation [15]. For dermatitis herpetiformis and gluten sensitivity, celiac disease is strongly associated with dermatitis herpetiformis, a bullous dermatitis characterized by dermal deposits of IgA consequent on gluten-induced inflammation in the intestine.

4. Pathological effects: cellular and molecular mechanisms

4.1. Intestinal disorders: acute to chronic inflammation

Clinical presentations of eosinophilic gastroenteritis (EGE), involving infiltration by eosinophils in stomach, intestine, or colon, may range from nausea to enteropathy with loss of proteins. Regarding history, it is clear that proteins in the granules secreted as a result of infiltration by the eosinophils in the submucosa cause damage to cells in the epithelium as well as subepithelial fibrosis. Th2 cytokines lead to proliferation of oesophageal epithelial cells with EoE, and eventually, strictures and dysphagia are formed. The pathogenesis of EoE is recognized to have one fundamental contributor in epithelial hypoxia-inducible factor-1α (HIF-1α), that recruits eosinophils by means of CCL26 and leads to expression of claudin-1. Casein and whey proteins lead to mast cell degranulation in intestinal mucosa in cow's milk protein allergy (CMPA). This leads to release of tryptase, degradation of TJ proteins such as occludin, and increased intestinal permeability [16]. This compromise leads to bacterial translocation, macrophage NLRP3 inflammasome activation, release of IL-1β and IL-18, and further compromise in epithelial function. Therapeutic interest in targeting NLRP3 is also provided by mouse model studies, where genetic deletion of the protein is able to prevent food allergy-induced gut inflammation.

4.2. Dermatologic disorders: the molecular basis for lesional formation

The “triangle” consisting of dysbalanced microbiota, overactivity of Th2/Th22, and defective barrier function is involved in the pathogenesis of AD. The most powerful genetic risk factor for AD is Filaggrin (FLG) gene mutations that confers dryness to skin and augmented transepidermal water loss by inhibiting formation of natural moisturising factor such as free amino acids and urocanic acid. This leaves an opportunity for Staphylococcus aureus colonisation and its superantigens like toxic shock syndrome toxin-1 to engage T cells to release polyclonally IL-17 and IL-22, inducing keratinocyte proliferation and expression induction of the antimicrobial peptide LL-37, paradoxically supporting bacterial survival. Chronic spontaneous urticaria (CSU) is defined by whealing on at least a daily basis for more than 6 weeks due to FcεRI or IgE autoantibodies (autoimmune urticaria). The mast cell degranulation is initiated by the autoantibodies with release of histamine that binds to endothelial H1 receptors, resulting in dermal oedema and increased vascular permeability. Sensory

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nerves are stimulated by physical triggers to release neuropeptides (e.g., substance P) in physical urticaria (e.g., dermatographism), directly stimulating mast cells without evading mechanisms involving IgE [11].

5. Therapeutic strategies: targeting a specific pathway

For probiotics and postbiotics, postbiotics like microbial metabolites like butyrate enhances TJ integrity by activating HDAC function, while live microbial strains like Bifidobacterium lactis BB-12 stimulates mucosynthesis by TLR2 pathway activation of the MUC2 gene. For supplementation with glutamine, with no human evidence for allergic enteropathy, glutamine, an energy substrate utilized by enterocytes, activates ZO-1 expression and reduces dextran sulfate sodium (DSS) induced colitis in mouse models [17]. For ceramide emollients, topical therapy with ceramides 1, 3, and 6-II restores lipid bilayer in the entire stratum corneum in patients with AD, helpful for minimizing transepidermal water loss and improving expression of the FLG gene. For retinoids topical, there is the limitation due to sensitivity of the skin, though a third-generation retinoid, adapalene, is reported to promote keratinocyte differentiation and expression of tight junction proteins (claudin-1 and occludin) in acne and AD [18]. For tralokinumab, by targeting IL-13 only, tralokinumab inhibits epithelial remoulding and overproduction of mucus with efficacy in severe asthma with ongoing research in EoE. For dupilumab, this humanised monoclonal anti-IL-4Rα antibody inhibits both IL-4 and IL-13 signalling with reduced Th2-mediated inflammation in AD, asthma, and EoE.

Various cytokines that play a role in allergic inflammation, such as IL-4, IL-6, IL-22, and IFN-γ, activate through JAK kinases (JAK1, JAK2, and TYK2). Tofacitinib, a drug used to manage rheumatoid arthritis and AD, reduces inflammation and pruritus by inhibiting JAK1, an IL-4 and an IL-13 signal mediator. Care should, nonetheless, be exercised in selecting patients because of potential opportunistic infection and cardiovascular complications. The expanded ex vivo Tregs transfer has in mouse models been used to explore food allergy, and has shown therapeutic value through inhibition of Th2 responses by secreting TGF-β and IL-10 [19]. Vitamin D3 and rapamycin are now under clinical trial to enhance levels of functional Tregs in allergic rhinitis.

Healthy donor FMT was also shown in a landmark study to be related with higher Bifidobacterium and Lactobacillus species, reduced intestinal permeability and Th2 cytokine levels in a food allergy mouse model. While standardized protocols and long-term safety data are required, human case series in cow's milk protein allergy (CMPA) in children have shown resolution of skin and gastro-intestinal symptoms with FMT. By stimulating Bifidobacteria growth, inulin-type fructans enhance production of SCFAs such as propionate and butyrate, which then act on G-protein coupled receptors (GPR43, GPR109A) of immune system cells to inhibit proliferation in Th2 cells and promote Treg differentiation. Synbiotic therapy, consisting both prebiotics and probiotics, may exert a synergistic action on treating microbial-immune imbalance.

6. The emerging frontiers in allergic inflammation research

Recent scnra-seq studies have revealed novel cell types in inflamed guts and skin for single-cell RNA sequencing (scRNA-seq) in organ-specific immunity. For instance, “inflammatory keratinocytes” in AD secrete TSLP and IL-33, and “reactive epithelial cells” in 6EoE contain high chemokines (CCL26) [20]. These findings give us tools to develop CCL26 antagonists to target EoE with precise cell subset targeting. During sensitization to allergy, immune cell expression is regulated by epigenetic mechanisms such as DNA methylation and histone acetylation as well as protein restriction (Figure 1). For example, such a condition is reversed by inhibition by employing histone deacetylase inhibitors (HDACi) and promotes regeneration of immune tolerance, and hypomethylation within the promoter region of IL-4 in allergic dermatitis patients’ Th2 cells enhances prolonged cytokine

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secretion. NPs possess an advantage of drug targeting to inflamed tissues because they can penetrate barriers such as skin's stratum corneum and stomach mucosa. Chitosan-based nanoparticles encapsulated anti-IgE antibodies penetrated more effectively in preclinical tests, and this reduced mast cell degranulation in allergic contact dermatitis.

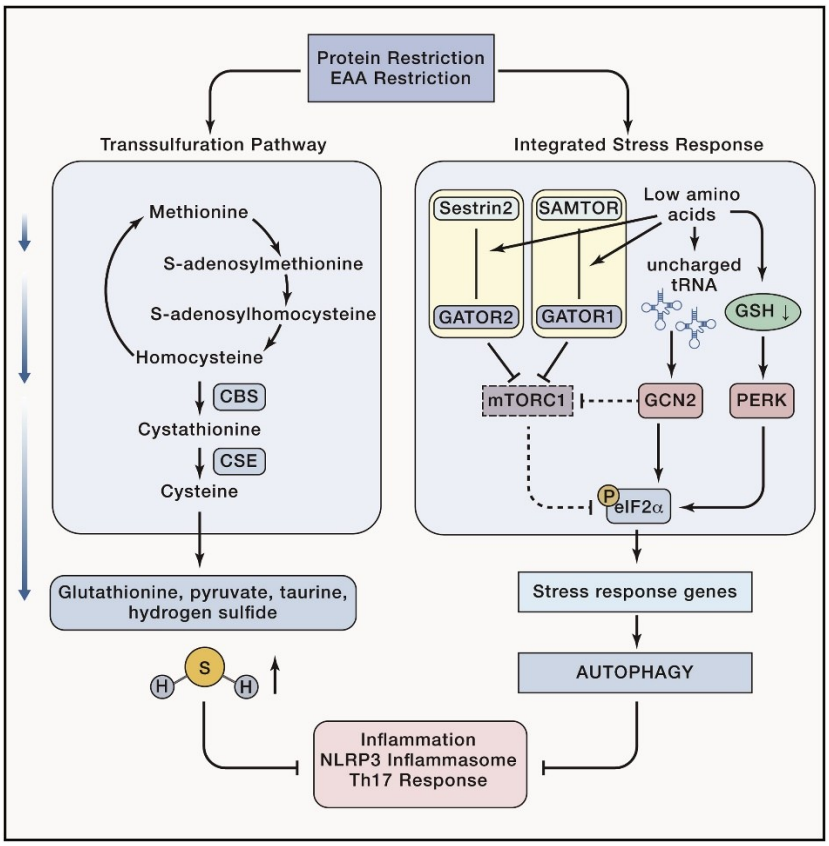


Figure 1: Immune response based on protein restriction [20]

7. Challenges in translational research

Due to genetic (mutations in FLG compared with TLR polymorphisms), microbiological (S. aureus compared with Clostridium spp. colonisation), and environmental (urban compared with rural) exposures, allergic inflammation is highly heterogeneous in patients. Identifying proper personalised healthcare strategies, e.g., genetic risk-based choice of biologics or microbial profile-based probiotic therapy, is a key challenge. Based on recent findings on augmented herpes simplex virus infection rates among patients with AD, treatments against Th2 immunity (e.g., dupilumab) can expose the patient to helminth infection or respiratory tract virus infection. It is therefore essential to design treatments that induce tolerance without impairing host defence. Safety concerns of malignancy risk (e.g., lymphoma with long-term JAK inhibitor therapy) and cardiovascular events should be elucidated by post-marketing surveillance and real-world evidence research. For instance, tofacitinib has a black-box warning for thrombosis, which warrants close cardiovascular risk observation.

8. Conclusion

The inflammation replicated by autoimmune diseases in allergic skin and intestinal illnesses is primarily a result of a complicated interplay among immune cell dysregulation, host-microbe associations, and disruption in epithelial barrier. The commensal gut microbota composition may get

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disrupted by an impaired host-microbiota interaction, referred to as a dysbiotic state. For instance, hyper-permeability of gut may ensue with an overgrowth of pathobionts like an imbalance with loss of symbiotic microbes like Bifidobacterium and Lactobacillus. This causes translocation of allergens and components of microbes, thus stimulating immune cells. In a similar manner, atopic dermatitis caused by a dysbiotic state with an increase in Staphylococcus aureus levels may exacerbate inflammation in skin by stimulating immune cells with the production of toxins.

The inflammation is complicated by immune cell dysregulation, such as that involving T-helper cells, eosinophils, and mast cells. The inflammation is underpinned by overproduction by these cells of disproportionate cytokines like IL-4 and IL-13, impairing epithelial barrier function through an imbalance in Th1/Th2 response, with Th2 cells becoming dominant in allergic disease. The epithelial barrier is critical as an initial line of protection in skin and gut. When this barrier is breached, as in atopic dermatitis in skin or in eosinophilic esophagitis in gut, an allergen passes through and sets off an immune cascade. Recent single-cell immunology has transformed our view on immune cell heterogeneity to a degree that has enabled us to come up with novel therapeutic targets. How one organ's inflammation affects others is now shown to have made novel therapeutic options available for the gut-skin axis. The studies on mechanisms of epigenetics enabled us to realize how regulation of gene expression occurs with allergic diseases. Subsequent to these advances, interest has now shifted from immunosuppression in broad terms to more specific therapies such as drugs maintaining epithelial barrier function or biologics affecting cytokine pathways selectively.

There are several key challenges still to be overcome. One concerns high diversity among patients on environmental, microbiological, and genetic parameters. Another concerns immune function in allergic inflammation without over-suppression, or patients become vulnerable to infection. Another priority is long-term safety with new drugs, including new biologics and immunosuppressive agents. These requirements emphasize the necessity for interdisciplinary science with translational science, microbiology, and immunology. While allergic diseases are on an upward trend worldwide for prevalence, such rapid advances in these areas are enabling provision of successful therapy with achievement of homoeostasis at the tissue level and better health in patients.

References

[1] *Macpherson, A. J., & Harris, N. L. (2004). Interactions between commensal intestinal bacteria and the immune system. Nature Reviews Immunology, 4(6), 478-485.*

[2] *Galli, S. J., et al. (2008). Mast cells in allergy and inflammation. Journal of Internal Medicine, 264(6), 478-487.*

[3] *Neill, D. R., et al. (2010). Nuocytes are a new type of innate effector leukocyte that mediate type 2 immunity. Nature, 464(7293), 1377-1381.*

[4] *Jabri, B., & Brown, J. A. (2012). Intraepithelial lymphocytes and intestinal epithelial cells: Partners in defence and disease. Nature Reviews Immunology, 12(9), 639-650.*

[5] *Kleinjan, A., et al. (2013). The many ways to make Ige. Immunological Reviews, 252(1), 165-182.*

[6] *Rothenberg, M. E., & Hogan, S. P. (2006). The eosinophil as a therapeutic target. Nature Reviews Immunology, 6(9), 688-698.*

[7] *Schmidt, S., et al. (2012). Keratinocytes: Key performers in skin immune surveillance. Trends in Immunology, 33(11), 559-568.*

[8] *Banchereau, J., & Steinman, R. M. (1998). Dendritic cells and the control of immunity. Nature, 392(6673), 245-252.*

[9] *Novak, N., et al. (2003). TSLP is a cytokine that induces dendritic cell-mediated Ige class switching and allergic inflammation. Journal of Experimental Medicine, 197(10), 1351-1356.*

[10] *Galli, S. J., et al. (2005). Mast cells as "tunable"ors of immune responses. Nature Reviews Immunology, 5(9), 699-710.*

[11] *Lawrence, C. B., et al. (2013). The immunopathogenesis of chronic urticaria. Journal of Allergy and Clinical Immunology, 132(2), 265-276.*

[12] *Salimi, M., et al. (2016). Innate lymphoid cells in mucosal immunity and inflammation. Nature Reviews Immunology, 16(1), 14-28.*

DOI: 10.54254/2753-8818/2025.AU24052

[13] Dinarello, C. A. (2018). Interleukin-1β, interleukin-1 receptors, and interleukin-1 receptor antagonist. Immunity, 48(4), 675-689.

[14] Spergel, J. M., et al. (2005). Atopic dermatitis and food hypersensitivity in infants: Clinical and immunologic relationships. Journal of Allergy and Clinical Immunology, 115(1), 126-132.

[15] Kavanaugh, A., et al. (2015). The bidirectional relationship between psoriasis and inflammatory bowel disease. Journal of the American Academy of Dermatology, 73(5), 773-780.

[16] Nigrovic, P. A., et al. (2009). Tryptase activates protease-activated receptor-2 and disrupts tight junctions in intestinal epithelial cells. Gastroenterology, 136(2), 607-615.

[17] Wischmeyer, P. E. (2008). Glutamine in critical illness: Current evidence and controversies. Current Opinion in Clinical Nutrition and Metabolic Care, 11(1), 61-66.

[18] Thiboutot, D., et al. (2018). Clinical efficacy and safety review: Adapalene 0.1% aqueous gel for acne vulgaris. Journal of Dermatology Treatment, 17(10), 1087-1091.

[19] Blair, P. J., et al. (2019). Regulatory T cells in allergic disease. Journal of Allergy and Clinical Immunology, 143(2), 469-480.

[20] Grimbacher, B., et al. (2020). Single-cell analysis of human atopic dermatitis identifies a unique epithelial cell type associated with disease severity. Immunity, 53(3), 616-630.e6.