

Host Immune Responses to Pathogenic Infections: A Review

Mayada Hussain Ali

Institute of Genetic Engineering and Biotechnology for Postgraduate Studies, University of Baghdad, Iraq.

ABSTRACT	ARTICLE DETAILS
Pathogens, including bacteria, viruses, parasites and fungi, continuously adapt to evade host immune defenses. To counteract these threats, the host orchestrates a complex immune response, deploying specialized cellular network and chemicals that collaboratively identify and eradicate the intruders. The innate immune response functions as the body's primary line of defense, employing pattern recognition receptors to identify infections and activate swift response mechanisms. Subsequent to this primary response, an adaptive response facilitates precise and prolonged eradication of infections through T cells, B cells, and antibodies. This review elucidates the mechanism of the adaptive immune response and delineates the role of distinct immune system components in conferring immunity to infections. Simultaneous precise management of the immune system is more advantageous in combating immunological-related disorders. KEYWORDS: Adaptive immune response, Pathogenic infections, CD4⁺ helper T cells, CD8⁺ cytotoxic T cells and B Lymphocytes.	Published On: 1 September 2026 Available on: https://ijmir.com

1. INTRODUCTION

Immunity denotes the comprehensive protection against diseases, particularly infectious ones. Immune-mediated resistance mechanisms that eradicate, contain, or annihilate pathogens are accountable for this [1,2]. The immune system exhibits a remarkable capacity for dynamic adaptation to physiological challenge through the synergistic interplay of innate and adaptive immune mechanisms, forming a complex cellular network that maintains the homeostasis and functions of the body tissues[3,4]. Adaptive immune responses serve a critical function in augmenting and supporting broad-spectrum host immunity [5,6]. The immune cells initiate a highly coordinated response to pathogens, whereas the innate immunity delivers an immediate yet non-specific primary defense. The adaptive immunity confers a high specificity and enduring protection. T and B lymphocytes serve as the principle cellular mediators of the adaptive immune response, undergo antigen-driven activation and clonal differentiation, culminating in the generation of antibodies[7,8]. Upon re-exposure to the same virus, the host's immunological memory facilitates a more robust and rapid immune response[9,10]. The functions of host immune responses to pathogenic infections are highlighted in this overview. This review aims to elucidate intricate relationship between the host immune system and infectious pathogens with particular emphasis on the underlying mechanisms of action that drive adaptive immune response.

2. ADAPTIVE IMMUNE RESPONSE TO PATHOGENIC INFECTIONS

The adaptive immune response provides a more tailored response to invading infections through its cells. Adaptive immunity is composed of two types, cell-mediated and humoral immunity (Figure 1), which include T cells, derived from the thymus and referred to as "T lymphocytes," and B cells, originating in the bone marrow, so designated as "B lymphocytes" [11,12]. Conventional T cells are functionally divided into CD4⁺ helper T cells and CD8⁺ cytotoxic T cells. CD4⁺ T cells exhibit functional diversity, mediating immune responses via both soluble mediators and direct cell-to-cell interactions. In contrast, CD8⁺ T cells predominantly function by clearing certain target cells. Concurrently, B cells are responsible for production and secretion of antibodies as soluble effector molecules, while, also serving as antigen-presenting cells (APCs), to facilitate targeted antigen presentation to T cells[13,14]. Through high-affinity interactions with target antigens, antibodies effectively neutralize various pathogenic and disrupt their underlying mechanisms, including inhibiting the adhesion of pathogens to host cells and tissue substrates [15,16]. The CD4⁺ T cells population comprises numerous subsets, most notably T-helper 1 (Th1), Th2, Th17, follicular helper (Tfh) and regulatory T cells (Tregs), which interact to regulate infection responses[17,18]. The Th1 cell response is recognized for its protective function against *Mycobacterium tuberculosis* and viral infections, predominantly mediated by the secretion of pro-inflammatory cytokines specifically TNF- α and IFN- γ , which drive recruitment and activation of innate effector cells, including granulocytes and monocytes.

In contrast, Th17 cells are induced following bacterial or viral infections [19,20]. The secretion of IL-4, IL-5 and IL-13 is primarily driven by Th2 cells, acting alongside other soluble mediator to promote the proliferation and activation of various immune cell subsets, while also stimulating B cells to produce antibodies[21–23]. Treg cells are crucial for sustaining immunological tolerance and averting autoimmune disorders by inhibiting overactive immune responses. During viral infections, they decrease the proliferation and infiltration of infected cells while also facilitating memory formation through antigen persistence. Memory T (TM) cells develop following initial antigen exposure, mediating a swift and potent secondary response following re-encounter with their cognate antigen, thereby conferring long-term immunity[24–26]. Activation of mature T cells is initiated upon engagement of their T cell receptors (TCRs) with peptidic antigens presented to major histocompatibility complex (MHC) molecules. CD8+ T cells engage peptide- MHC class I complexes displayed by almost nucleated cells, these peptides are primarily endogenous antigens originated from proteins produced within the cell, whether encoded by the host genome or by intracellularly replicating pathogens such as viruses. Conversely, CD4+ T cells restrict their TCR recognition to peptide- MHC class II complexes, which are selectively presented by specialized antigen-presenting cell (APC), including, macrophage, B cells and dendritic cells [27,28]. T-cell activation is initiated upon the specific recognition of a peptide-MHC complex on an APC by the TCR complex. This event induces aggregation of downstream signaling molecules at the intercellular interface, thereby establishing the immunologic synapse[29]. The humoral immune pathway commences when the B- cell receptor identifies and engages with the antigen in its natural conformation. Helper T cells secrete specific cytokines that promote B cell expansion and determine the particular antibody isotype to be produced. The released antibodies bind to surface antigens to pathogen, opsonizing them for destruction through complement activation, phagocytosis, and effector cells-mediated elimination. Following pathogen eradication, the immune complexes are removed via the complement cascade. B cells synthesize five principal isotypes of antibodies: IgG, IgE, IgA, IgM and IgD [30]. During viral infections, adaptive immune response triggers B cells antibody production and the clearance of infected host cells by cytotoxic T cells, under the regulation of helper T cells. The T lymphocyte subsets that confer immunological production comprise CD8+ cells, various subsets of CD4+ T cells, and follicular T helper cells[31]. Additionally, CD8+ T robustly pro-inflammatory cytokines, particularly TNF and IFN- γ , during respiratory viral infection, which can facilitate the apoptosis of infected cells. Pro-inflammatory cytokines induce to IL-10 production[32]. Releasing by CD8+ T and Treg cells, IL-10 acts as an immunoregulatory cytokine to control the inflammatory response [33,34]. Th17 lymphocytes are implicated in COVID-19 by releasing IL-17, acts a pivotal cytokine that exacerbates the cytokine storm by secretion of pro-inflammatory mediators (TNF α , IL-1 and IL-6) and promotes the activation of neutrophils, monocytes, macrophages and dendritic cells [35–37]. The contribution of local tissue immunity, sustained by innate and adaptive immune responses, is also noteworthy [38–40]. B cells are pivotal in producing IgM antibodies during the initial stages of bacterial infections and IgG antibodies in the later stages. These antibodies are generated in response to several bacterial structures, including lipopolysaccharides. These antibodies may facilitate bacterial phagocytosis via Fc receptor-mediated endocytosis and enhance the host's bactericidal efficacy. B cells not only produce antibodies but also significantly drive the development of protective T cell responses, as they are proficient antigen-presenting cells (APCs)[41]. Immunoglobulin A (IgA) is a pivotal bioactive component of breast milk that modulate neonatal immune activation via the neutralization microbial antigens. secretory IgA synthesized within the intestinal tract remains crucial for maintaining mucosal homeostasis throughout adulthood, underscoring the role of host immune components in regulating mature microbiota development [42,43]. The immunological defense against fungal infections necessitates relies on cooperation innate and adaptive immune responses, wherein macrophage and dendritic cells, which recognize fungal pathogens to prime T lymphocytes [44]. Subsequently, the adaptive immunity driving the recruitment of helper, cytotoxic, regulatory T cells, and B cells, to coordinate inflammatory cascade[45,46]. Furthermore, dendritic cells, macrophages and neutrophils, and mediated phagocytosis, executing fungal clearance via NADPH oxidative-dependent oxidase burst activity[47]. In murine models, that *H. polygyrus* infection triggers antibody-mediated macrophages, which traps and immobilizes infective larvae to prevent host pathology. This defense mechanism is typically accompanied by an elevation in IgE and eosinophils infiltration are strong indicative of adaptive type 2 immune activity against helminth [48,49]. Immunological memory, mediated via the generation of antigen- specific memory B and T cells, provides long-term production against recurrent infection [50,51].

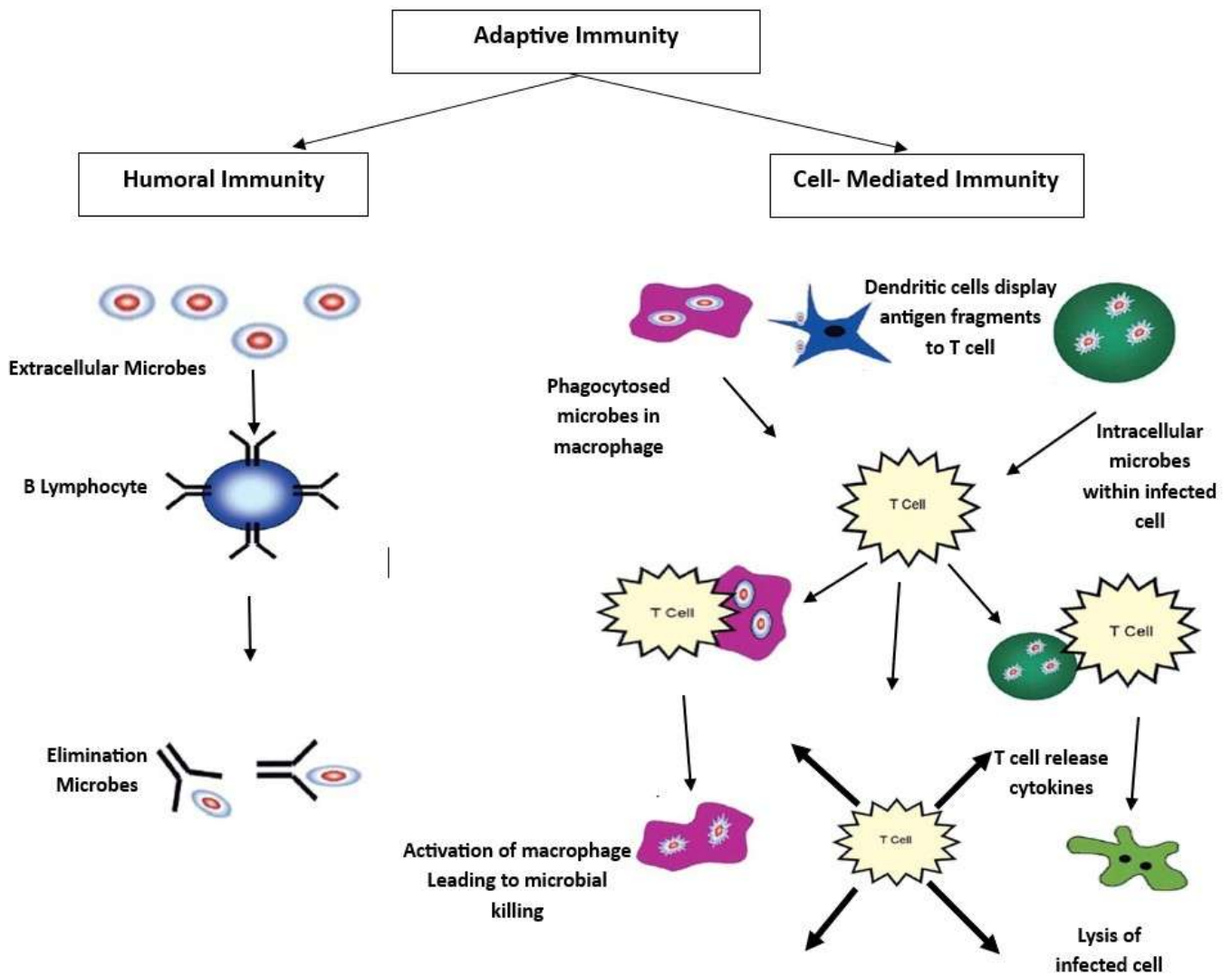


Figure 1. Humoral and cell-mediated immunity components [11].

3. CONCLUSION

While recent literature has shed light on host -pathogen dynamics and immune persistence, extensive research remains vital. Investigating adaptive immune mechanisms presents an available framework for deciphering complex immune functions and formulating sophisticated immunotherapeutic interventions. Coupled with cutting-edge technologies and an evolving understanding of immune network complexities, future breakthroughs are anticipated. Cultivating deeper insights into these processes remains imperative for advancing disease diagnostics, therapeutic modalities and vaccine development.

REFERENCES

- 1) Soares MP, Teixeira L, Moita LF. Disease tolerance and immunity in host protection against infection. *Nat Rev Immunol* 2017;17:83–96. <https://doi.org/10.1038/nri.2016.136>.
- 2) Franjić S. Innate Immune Systems Provide Strong Defense Against Infections. *Biomed J Sci Tech Res* 2022;46:37422–7. <https://doi.org/10.26717/bjstr.2022.46.007350>.
- 3) Sun L, Wang X, Saredy J, Yuan Z, Yang X, Wang H. Innate-adaptive immunity interplay and redox regulation in immune response. *Redox Biol* 2020;37:101759. <https://doi.org/10.1016/j.redox.2020.101759>.
- 4) Zhang Y, Qin Y, Cheng Z. Innate immune regulation of adaptive immunity: mechanisms, implications, and bias. *Front Immunol* 2026;Volume 17. <https://doi.org/10.3389/fimmu.2026.1847470>.
- 5) Carpenter S, O'Neill LAJ. From periphery to center stage: 50 years of advancements in innate immunity. *Cell* 2024;187:2030–51. <https://doi.org/10.1016/j.cell.2024.03.036>.
- 6) Belkaid Y, Hand TW. Role of the microbiota in immunity and inflammation. *Cell* 2014;157:121–41. <https://doi.org/10.1016/j.cell.2014.03.011>.

- 7) Marshall JS, Warrington R, Watson W, Kim HL. An introduction to immunology and immunopathology. *Allergy, Asthma and Clinical Immunology* 2018;14:1–10. <https://doi.org/10.1186/s13223-018-0278-1>.
- 8) Bonham E. The Role of Immune Responses in Host-pathogen Interactions: Implications for Infectious Disease Management. *Clin Infect Dis* 2023;7:237.
- 9) He P, Zhou Y, Feng Y, Zhou T, Li F, Mi Y, et al. Perspectives on the Development of Immune Memory Associated with Vaccination. *Vaccines (Basel)* 2026;14. <https://doi.org/10.3390/vaccines14050420>.
- 10) Takeuchi O, Akira S. Pattern recognition receptors and inflammation. *Cell* 2010;140:805–20. <https://doi.org/10.1016/j.cell.2010.01.022>.
- 11) Rabb H. The T cell as a bridge between innate and adaptive immune systems: implications for the kidney. *Kidney Int* 2002;61:1935–46. <https://doi.org/10.1046/j.1523-1755.2002.00378.x>.
- 12) Navas P. Focus on cellular biochemistry. *Protoplasma* 2000;213:vii–vii. <https://doi.org/10.1007/BF01282149>.
- 13) Iwasaki A, Medzhitov R. Control of adaptive immunity by the innate immune system. *Nat Immunol* 2015;16:343–53. <https://doi.org/10.1038/ni.3123>.
- 14) Akira S. Innate immunity and adjuvants. *Philosophical Transactions of the Royal Society B: Biological Sciences* 2011;366:2748–55. <https://doi.org/10.1098/rstb.2011.0106>.
- 15) Chi H, Pepper M, Thomas PG. Principles and therapeutic applications of adaptive immunity. *Cell* 2024;187:2052–78. <https://doi.org/10.1016/j.cell.2024.03.037>.
- 16) Sehrawat S, Rouse BT. Immunity to Infections. *Encyclopedia of Life Sciences*, John Wiley & Sons, Ltd; 2017, p. 1–12. <https://doi.org/https://doi.org/10.1002/9780470015902.a0000478.pub3>.
- 17) Andrew Kiboneka. Principals of innate and adaptive immunity. *Immunity to microbes & fundamental concepts in immunology*. *World Journal of Advanced Research and Reviews* 2021;10:188–97. <https://doi.org/10.30574/wjarr.2021.10.3.0271>.
- 18) Turvey SE, Broide DH. Innate immunity. *Journal of Allergy and Clinical Immunology* 2010;125. <https://doi.org/10.1016/j.jaci.2009.07.016>.
- 19) Xu J, Xie L. Advances in immune response to pulmonary infection: Nonspecificity, specificity and memory. *Chronic Dis Transl Med* 2023;9:71–81. <https://doi.org/10.1002/cdt3.71>.
- 20) Thakur A, Mikkelsen H, Jungersen G. Intracellular pathogens: Host immunity and microbial persistence strategies. *J Immunol Res* 2019;2019. <https://doi.org/10.1155/2019/1356540>.
- 21) Egholm C, Heeb LEM, Impellizzieri D, Boyman O. The regulatory effects of interleukin-4 receptor signaling on neutrophils in type 2 immune responses. *Front Immunol* 2019;10:1–14. <https://doi.org/10.3389/fimmu.2019.02507>.
- 22) Hillion S, Arleevskaya MI, Blanco P, Bordron A, Brooks WH, Cesbron JY, et al. The Innate Part of the Adaptive Immune System. *Clin Rev Allergy Immunol* 2020;58:151–4. <https://doi.org/10.1007/s12016-019-08740-1>.
- 23) Duque GA, Descoteaux A. Macrophage cytokines: Involvement in immunity and infectious diseases. *Front Immunol* 2014;5:1–12. <https://doi.org/10.3389/fimmu.2014.00491>.
- 24) Schroeter CB, Huntemann N, Bock S, Nelke C, Kremer D, Pfeiffer K, et al. Crosstalk of Microorganisms and Immune Responses in Autoimmune Neuroinflammation: A Focus on Regulatory T Cells. *Front Immunol* 2021;12:1–29. <https://doi.org/10.3389/fimmu.2021.747143>.
- 25) Wang R, Lan C, Benlagha K, Camara NOS, Miller H, Kubo M, et al. The interaction of innate immune and adaptive immune system. *MedComm (Beijing)* 2024;5:1–37. <https://doi.org/10.1002/mco2.714>.
- 26) Netea MG, Domínguez-Andrés J, Barreiro LB, Chavakis T, Divangahi M, Fuchs E, et al. Defining trained immunity and its role in health and disease. *Nat Rev Immunol* 2020;20:375–88. <https://doi.org/10.1038/s41577-020-0285-6>.
- 27) Neefjes J, Jongsma MLM, Paul P, Bakke O. Towards a systems understanding of MHC class I and MHC class II antigen presentation. *Nat Rev Immunol* 2011;11:823–36. <https://doi.org/10.1038/nri3084>.
- 28) Foti M, Granucci F, Pelizzola M, Beretta O, Ricciardi-Castagnoli P. Dendritic cells in pathogen recognition and induction of immune responses: a functional genomics approach. *J Leukoc Biol* 2006;79:913–6. <https://doi.org/10.1189/jlb.1005547>.
- 29) Bonilla FA, Oettgen HC. Adaptive immunity. *J Allergy Clin Immunol* 2010;125:S33–40. <https://doi.org/10.1016/j.jaci.2009.09.017>.
- 30) Nardy AF, Freire-de-Lima GG, Morrot A. Immune responses to infectious pathogens. *Innovative Immunology* 2015:1–11.
- 31) Lee C, Lee H, Park JC, Im SH. Microbial Components and Effector Molecules in T Helper Cell Differentiation and Function. *Immune Netw* 2023;23:1–27. <https://doi.org/10.4110/in.2023.23.e7>.
- 32) Peñaloza HF, Noguera LP, Riedel CA, Bueno SM. Expanding the current knowledge about the role of interleukin-10 to major concerning bacteria. *Front Microbiol* 2018;9:1–8. <https://doi.org/10.3389/fmicb.2018.02047>.
- 33) Gambadauro A, Galletta F, Li Pomi A, Manti S, Piedimonte G. Immune Response to Respiratory Viral Infections. *Int J Mol Sci* 2024;25:1–19. <https://doi.org/10.3390/ijms25116178>.

- 34) Maciel-Fiuza MF, Muller GC, Campos DMS, do Socorro Silva Costa P, Peruzzo J, Bonamigo RR, et al. Role of gut microbiota in infectious and inflammatory diseases. *Front Microbiol* 2023;14. <https://doi.org/10.3389/fmicb.2023.1098386>.
- 35) Gallo PM, Gallucci S. The dendritic cell response to classic, emerging, and homeostatic danger signals. Implications for autoimmunity. *Front Immunol* 2013;4:1–18. <https://doi.org/10.3389/fimmu.2013.00138>.
- 36) Soto JA, Gálvez NMS, Andrade CA, Pacheco GA, Bohmwald K, Berrios R V., et al. The Role of Dendritic Cells During Infections Caused by Highly Prevalent Viruses. *Front Immunol* 2020;11:1–22. <https://doi.org/10.3389/fimmu.2020.01513>.
- 37) Darif D, Hammi I, Kihel A, El Idrissi Saik I, Guessous F, Akarid K. The pro-inflammatory cytokines in COVID-19 pathogenesis: What goes wrong? *Microb Pathog* 2021;153:104799. <https://doi.org/10.1016/j.micpath.2021.104799>.
- 38) Tirelli C, De Amici M, Albrici C, Mira S, Nalesso G, Re B, et al. Exploring the Role of Immune System and Inflammatory Cytokines in SARS-CoV-2 Induced Lung Disease: A Narrative Review. *Biology (Basel)* 2023;12:1–20. <https://doi.org/10.3390/biology12020177>.
- 39) Al-Qahtani AA, Alhamlan FS, Al-Qahtani AA. Pro-Inflammatory and Anti-Inflammatory Interleukins in Infectious Diseases: A Comprehensive Review. *Trop Med Infect Dis* 2024;9. <https://doi.org/10.3390/tropicalmed9010013>.
- 40) Arora A, Singh A. Exploring the role of neutrophils in infectious and noninfectious pulmonary disorders. *Int Rev Immunol* 2024;43:41–61. <https://doi.org/10.1080/08830185.2023.2222769>.
- 41) García-Gil A, Lopez-Bailon LU, Ortiz-Navarrete V. Beyond the antibody: B cells as a target for bacterial infection. *J Leukoc Biol* 2019;105:905–13. <https://doi.org/10.1002/JLB.MR0618-225R>.
- 42) Tomkovich S, Jobin C. Microbiota and host immune responses: A love-hate relationship. *Immunology* 2016;147:1–10. <https://doi.org/10.1111/imm.12538>.
- 43) Zhou X, Wu Y, Zhu Z, Lu C, Zhang C, Zeng L, et al. Mucosal immune response in biology, disease prevention and treatment. *Signal Transduct Target Ther* 2025;10:7. <https://doi.org/10.1038/s41392-024-02043-4>.
- 44) Nami S, Mohtasham MH, Pourmahmoud S, Baradari S, Zamani A. A Review on Antifungal Innate and Adaptive Immune Responses. *Biomedical Research Bulletin* 2025;3:83–8. <https://doi.org/10.34172/biomedrb.9076>.
- 45) Harvanová G, Duranková S, Bernasovská J. The role of cytokines and chemokines in the inflammatory response. *Alergologia Polska - Polish Journal of Allergology* 2023;10:210–9. <https://doi.org/10.5114/pja.2023.131708>.
- 46) Heidari M, Maleki Vareki S, Yaghobi R, Karimi MH. Microbiota activation and regulation of adaptive immunity. *Front Immunol* 2024;15:1–13. <https://doi.org/10.3389/fimmu.2024.1429436>.
- 47) Cifaldi C, Ursu GM, D’Alba I, Paccoud O, Danion F, Lanternier F, et al. Main human inborn errors of immunity leading to fungal infections. *Clinical Microbiology and Infection* 2022;28:1435–40. <https://doi.org/10.1016/j.cmi.2022.06.031>.
- 48) Allen JE, Sutherland TE. Host protective roles of type 2 immunity: Parasite killing and tissue repair, flip sides of the same coin. *Semin Immunol* 2014;26:329–40. <https://doi.org/10.1016/j.smim.2014.06.003>.
- 49) Obata-Ninomiya K, Domeier PP, Ziegler SF. Basophils and Eosinophils in Nematode Infections. *Front Immunol* 2020;11:1–12. <https://doi.org/10.3389/fimmu.2020.583824>.
- 50) Kogut MH, Lee A, Santin E. Microbiome and pathogen interaction with the immune system. *Poult Sci* 2020;99:1906–13. <https://doi.org/10.1016/j.psj.2019.12.011>.
- 51) Akkaya M, Kwak K, Pierce SK. B cell memory: building two walls of protection against pathogens. *Nat Rev Immunol* 2020;20:229–38. <https://doi.org/10.1038/s41577-019-0244-2>.