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Comparative immunology of vertebrate hosts facing parasitic challenges.

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Introduction

Parasitism is one of the oldest and most pervasive ecological interactions, influencing host evolution, physiology, and immunity. Vertebrate hosts—ranging from fish and amphibians to birds and mammals—exhibit diverse immune strategies tailored to counter parasitic invasions. While vertebrate immune systems share conserved frameworks, their responses vary due to differences in phylogeny, environmental pressures, and parasite diversity. Exploring comparative immunology across vertebrate taxa reveals how these systems adapt and evolve in the face of parasitic threats, offering insights into disease resistance and potential therapeutic targets [1].

Amphibian model for adaptive immunity and host-pathogen interactions. Key for avian immune development and vaccine studies. Gold standard for mammalian parasitology and immune manipulation. These models enable understanding of conserved and divergent mechanisms under parasitic pressure. Despite their diversity, vertebrates possess two overarching immune arms: Rapid, non-specific response involving pattern recognition receptors (PRRs), phagocytic cells, and inflammation. Specific and memory-based responses driven by lymphocytes (T and B cells), antibodies, and antigen presentation. The balance and specialization of these components vary significantly among vertebrate classes, influencing their response to parasitic challenges [2].

Ability to tailor Th1/Th2/Th17 responses based on parasite type ensures adaptive flexibility. TLR genes show lineage-specific expansion in fish and mammals, correlating with parasite exposure. Host-parasite co-evolution fosters polymorphism in MHC genes, especially in birds and mammals. Some taxa prioritize parasite tolerance over elimination, minimizing immunopathology. Amphibians and fish often display this strategy under chronic infection. Popular for innate immunity studies due to transparent larvae and genetic tools. Teleost fish rely heavily on PRRs such as TLRs and complement proteins to counter protozoans and helminths. While fish possess immunoglobulins (IgM, IgD, IgT), their memory responses are weaker and shorter-lived compared to mammals. The skin, gills, and gut play essential roles, with mucosal IgT protecting against ectoparasites. Skin-based antimicrobial peptides (AMPs) provide frontline defense against parasites like chytrid fungi [3].

Amphibians have functional lymphoid organs and mount humoral and cellular responses, although less complex than mammals. Immune function in amphibians is tightly linked to temperature and environmental conditions, affecting susceptibility. A specialized lymphoid organ for B-cell development, absent in other vertebrates [4].

Birds generate strong antibody responses and exhibit immune memory akin to mammals, aiding defense against blood parasites like *Plasmodium*. Despite strong responses, many avian species possess simplified MHC loci, influencing antigen presentation. Mammals boast the most sophisticated immune architecture among vertebrates: Dendritic cells, NK cells, and diverse T-cell subsets coordinate intricate responses. Memory B and T cells provide lasting protection, essential for resisting chronic parasites like *Trypanosoma* and *Leishmania* [5].

Conclusion

Ectotherms like fish and amphibians exhibit immune suppression under cold conditions,

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influencing parasite success. Hosts in parasite-rich environments tend to evolve enhanced innate defenses or behavioral avoidance strategies. Human-induced stressors compromise immune function, increasing vulnerability across vertebrate classes. Understanding species-specific responses aids creation of effective vaccines for aquaculture, livestock, and wildlife. Knowing how different vertebrates handle parasitic infections informs zoonosis risk and public health surveillance. Immune profiling assists in conservation strategies for parasite-threatened species.

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