

Journal club



ADAPTIVE IMMUNITY BY CONVERGENT EVOLUTION

In a series of three extraordinary papers published between 2004 and 2013, Max D. Cooper and colleagues discovered a new type of adaptive immunity in jawless vertebrates. This revolutionary discovery demonstrated three examples of convergent evolution between jawed and jawless vertebrates: first, in the development of adaptive immunity (an expression that was coined by Cooper's mentor Robert Good); second, in the concomitant development of two main arms of adaptive immunity, with some cells recognizing intracellular antigens ($\alpha\beta$ T cells and VLRA cells) and other cells recognizing extracellular antigens (B cells and VLRB cells); and third, in the concomitant development of two types of T cell recognizing distinct antigens, with the VLRC cells discovered in jawless vertebrates found to resemble $\gamma\delta$ T cells in jawed

“ the greatest discovery in the history of modern immunology ”

vertebrates. I can think of no other example of convergent evolution determining the development of such a central feature of any physiological system in vertebrates.

Convergent evolution provides much stronger evidence of the relationship between evolutionary pressure and physiological necessity than does evolutionary conservation. Conservation is common; indeed, it is not surprising, as evolution arises from a common ancestor. Convergent evolution is much more remarkable. In that context, the nature of Cooper's discovery extends beyond vertebrates; none of the many examples of convergent evolution in living organisms reaches the magnitude of the example provided by adaptive immunity in jawed and jawless vertebrates, which shows convergent evolution at the molecular, cellular and physiological levels.

Remarkably, these three papers built on Cooper's earlier seminal contribution to our understanding of the dichotomy of B cells and T cells, with his and Good's discovery of B cells

in the 1960s, combined with Jacques Miller's description of T cells. Nearly 50 years later, Cooper extended this observation to another branch of the animal kingdom — from jawed to jawless vertebrates. This is far more than a mere replication, however, as it documents convergent evolution, in turn proving that innate immunity alone is not sufficient to ensure the survival of higher organisms. I view Max Cooper's discovery of the evolutionary necessity of adaptive immunity — a requirement so great as to generate convergent evolution — as the greatest discovery in the history of modern immunology.

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ORIGINAL ARTICLES Pancer, Z. *et al.* Somatic diversification of variable lymphocyte receptors in the agnathan sea lamprey. *Nature* **430**, 174–180 (2004) | Guo, P. *et al.* Dual nature of the adaptive immune system in lampreys. *Nature* **459**, 796–801 (2009) | Hirano, M. *et al.* Evolutionary implications of a third lymphocyte lineage in lampreys. *Nature* **501**, 435–438 (2013)