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Decision theory for immune ligand recognition

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Variability in the chemical composition of the extra-cellular environment can significantly degrade the ability of cells to detect rare cognate ligands. Using concepts from statistical detection theory, we formalize the generic problem of detection of small concentrations of ligands in a fluctuating background of biochemically similar ligands binding to the same receptors. We discover that in contrast to expectations arising from considerations of signal amplification, inhibitory interactions between receptors can improve detection performance in the presence of substantial environmental variability, providing an adaptive interpretation to the phenomenon of ligand antagonism. Our results suggest that the structure of signalling pathways responsible for chemodetection in fluctuating and heterogeneous environments might be optimized with respect to the statistics and dynamics of environmental composition. Our formalism stresses the importance of characterizing non-specific interactions to understand function in signalling pathways.